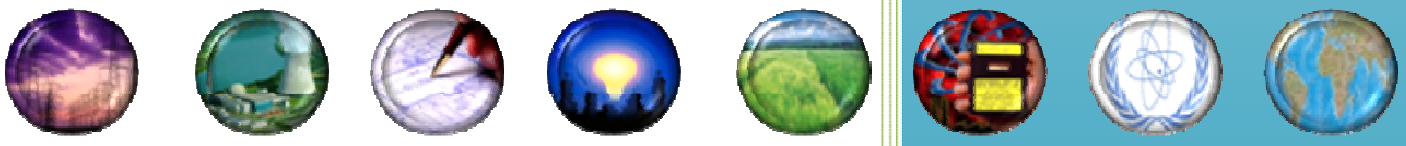
July 2007

Nuclear Energy in Israel: A Concept Study



Artem Kroupenev

Moshe Alexenberg

Eli Cornblit

Eric Cohen

ARGOV Fellows Program in Diplomacy

Table of Contents

Introduction

Our research indicates that in Israel not only will electricity consumption double in twenty years, but electricity production capacity is currently nearing its maximum output level. Moreover, in terms of energy security, considering government policy to shift towards the use of natural gas combined with the imminent depletion of Israel's gas reserves, it is problematic for Israel to be largely dependent on natural gas and those countries that supply it to Israel. In addition, increased global demand for fossil fuels will continue to cause a steep rise in fossil fuel prices, negatively impacting electricity production costs. Renewable energies alone cannot provide a sufficient replacement for fossil fuels or satisfy Israel's electricity diversification efforts. Furthermore, environmental degradation and global warming caused by fossil fuel emissions will continue unless sufficient alternative energy sources are employed. These assumptions demonstrate the necessity of building additional power plants in Israel and adopting alternative energy sources to power those plants.

This paper provides a comprehensive conceptual analysis of the feasibility of building a nuclear power plant in Israel to solve some of Israel's most challenging energy problems. The main issues identified as critical to this analysis are the economic, geo-political, and environmental aspects of constructing and operating a nuclear power plant in Israel. These three aspects provide a framework for exploring the feasibility and necessity of such an undertaking.

A few words about our research

The development of our topic and the guidelines of our research were set in close coordination with Dr. Amit Mor of Eco-Energy Ltd. In our work process, we have interviewed a number of leading experts in the fields of Israel's energy security, environmental sustainability and nuclear policy. We have presented our concept at the Ministry of National Infrastructures and received feedback from government officials. We have also corresponded with international geopolitical and energy experts, nuclear energy development companies and environmental organizations.

Overview

For the purpose of identifying the full range of possible topics involved in constructing a nuclear power plant in Israel, we have separated our research into three distinct categories –economics, geopolitics and the environment. We will begin analyzing the economic realm by introducing Israel's future energy requirements. We will discuss the projected demand and supply scenarios and explain the need for diversifying Israel's electricity production. We will discuss the insufficient ability of renewable energy sources to fulfill Israel's needs of energy diversification and present the development of nuclear energy as an additional and more viable alternative.

Following a brief statistical overview of today's trends of nuclear development around the world, we will discuss the breakdown of the economic costs of nuclear energy. We will continue to analyze the economic sub-topics of nuclear power competitiveness in comparison to other sources of electricity production, sources of funding and possible positive effects that a nuclear plant may have on developing the Negev and creating jobs in southern Israel.

The geopolitical realm will be presented with an overview of recent international and domestic developments that serve as our premises for discussing new opportunities for conducting serious research into the development of nuclear power in Israel.

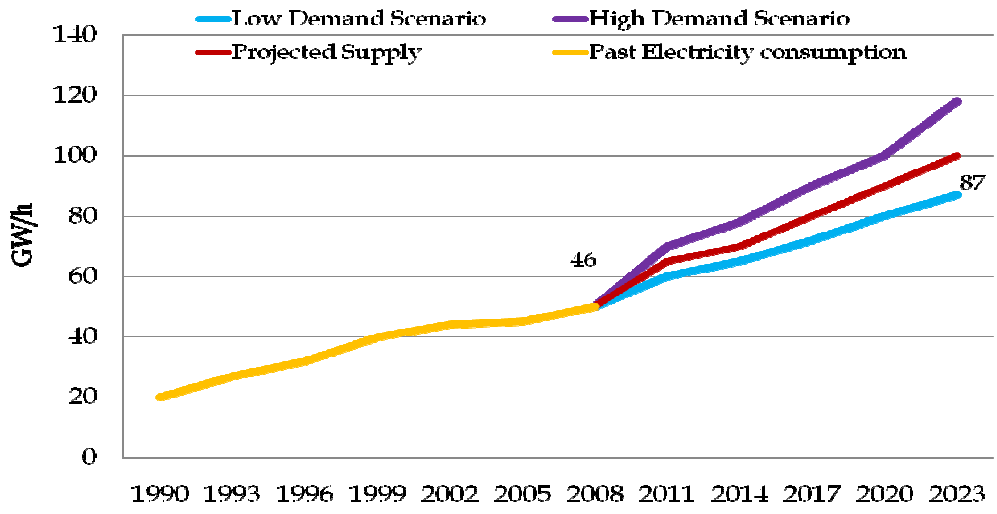
We will then proceed to present our analysis of the environmental aspects of nuclear power and to discuss the sub-topics of historical and current trends in public acceptability, safety, and waste management that would be relevant to introducing nuclear power into Israel's electricity supply sector.

We will conclude the paper with a summary of our findings and we will provide recommendations for government policy and further research regarding this topic.

Economics

Israel has similar per capita electricity demand as other OECD countries. Accordingly, Israel consumes large amounts of electricity, about 46 Gigawatt hours (GW).[1] This demand is growing at an expedient rate and within the next twenty years Israel's electricity demand is estimated to more than double. In order to match this demand with sufficient supply, Israel must begin building power plants to provide between 87 and 118 GW of electricity by the year 2023. 87 GW is a low estimate assuming a small rate of economic growth in Israel of about 4% while 118 GW is a high estimate assuming a high economic growth rate of approximately 5%.[2] The high and low estimates are calculated according to economic growth due to a clear correlation worldwide between economic growth and growth in electricity demand.

Chart 1 – Forecast of electricity demand in Israel



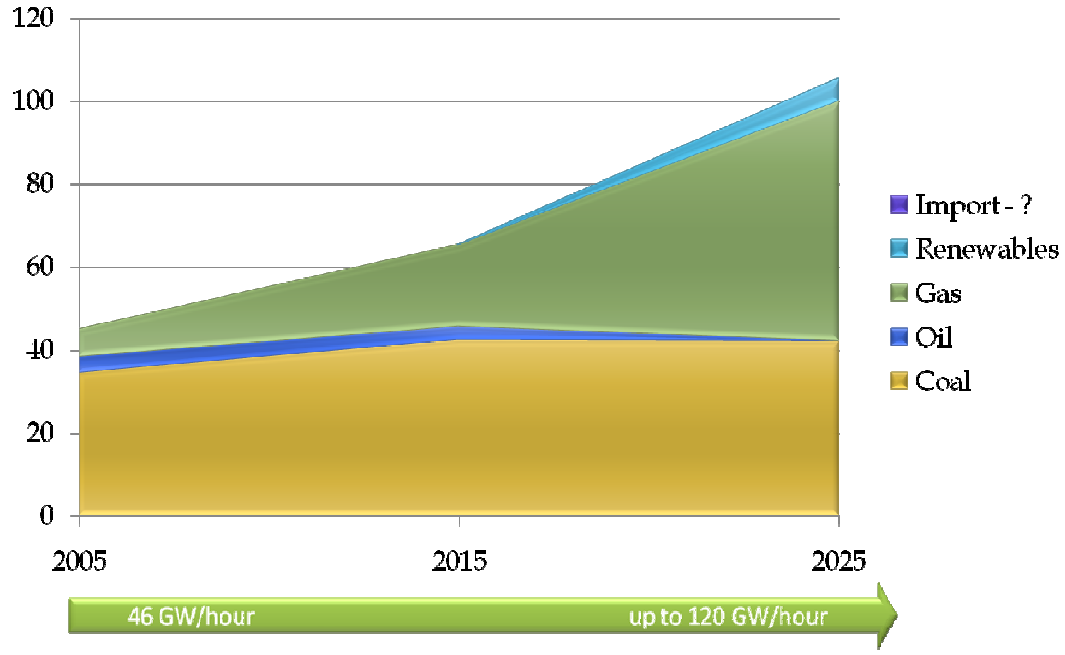
Source: Eco Energy Ltd.

[1] See Chart 1

[2] Mor, A., & Saroussi, S. (2006). *Energy Master Plan for the State of Israel - תוכנית האב למשק האנרגיה- דוח מסכם ותוכנית חומש.* Herzliya, Israel: Eco-Energy M.S.(2001) Ltd.

Currently, the vast majority of Israel's electricity production comes from coal powered plants and from natural gas powered plants. The breakdown of current and projected types of electricity supply in Israel[3] clearly shows a shift from coal power plants to natural gas powered plants.[4] This shift from coal power plants to natural gas is a direct result of the Israeli government's policy to replace much of Israel's coal plants with natural gas and to build more natural gas power plants in the future. "The recent structural change using natural gas is possible following an agreement signed last year between Israel and Egypt that will enable Israel to purchase natural gas from Egypt, to be used by the Israel Electric Corporation (IEC) for a period of 15 years. In addition, natural gas reserves have been discovered off the coast of Israel."[5]

Chart 2 – Forecast of energy production in Israel



Source: Eco Energy Ltd.

[3] Ibid.

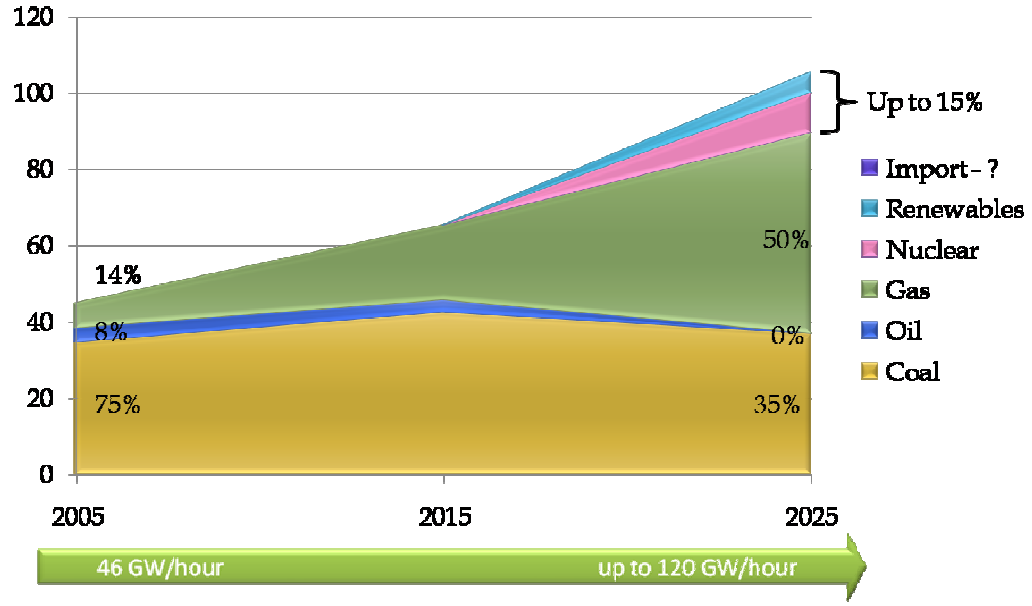
[4] See Chart 2

[5] Israel Ministry of Environmental Protection. (2006, January). *Israel's Experience in Sustainable Energy.* Retrieved from Unep.org: http://www.unep.org/GC/GCSS-IX/DOCUMENTS/Israel-energy3.pdf

This shift towards natural gas, Israel's growing demand for electricity and the fact that Israel's gas reserves are projected to be depleted within two decades[6] will create a dependency on natural gas from another country, namely Egypt. This dependency cannot be offset by renewable energies alone. Another type of energy must be introduced in addition to renewable energies to effectively diversify Israel's electricity supply.

Together with renewable energy, construction of a nuclear power plant in Israel is estimated to provide up to 15% of Israel's electricity production, which would serve as a significant foundation for a policy of diversification of Israel's electricity production.[7]

Chart 3 – Forecast of energy production in Israel



Source: Eco Energy Ltd.

[6] Mor, A., & Saroussi, S. (2006). *Energy Master Plan for the State of Israel - תוכנית האב למשק האנרגיה- דוח מסכם ותוכנית חומש.* Herzliya, Israel: Eco-Energy M.S.(2001) Ltd.

[7] See Chart 3.

Our proposal

An appropriate step towards this diversification would be to construct a 1,200 – 3000 Mw capacity third generation nuclear power plant with a 60 year life span at Shivta in the Negev.[8] In order to realize this endeavor Israel should begin by building one reactor with a capacity of between 1,200 and 1,500 Megawatts reserving the option of building a second reactor alongside the first. By the time the first reactor is built within 20 years it will provide up to 5% of Israel's electricity production. The capital costs of building the first reactor is estimated at $1.5-2 billion dollars or around $1,200 per Kilowatt hour. These figures are based on the average costs to build a nuclear reactor in the rest of the world.

World nuclear trends

Rising electricity demand is not unique to Israel. World electricity demands are growing at a similar rate.[9] To meet this demand worldwide, approximately 31 nuclear power plants are currently under construction. This will add to the 437 existing nuclear plants spread out over 30 countries which together provide 16% of world electricity needs[10] or 371.773 GW.[11] Seventy-four nuclear power plants are planned to be built in the next fifteen years and another one hundred and eighty-two have been proposed for the next three decades[12]. India and China each are rushing to build dozens of reactors. France and Belgium are 78% and 70% respectively reliant on nuclear energy for their electricity supply. The global trend towards nuclear energy is based mainly on the economic competitiveness of nuclear energy and increased concerns of global warming.

[8] The Israeli government has reserved a site at Shivta in 1980 for the purpose of constructing a nuclear power plant. For a brief discussion of prospects of nuclear energy developments in Israel, see: World Nuclear Association. (2007, June). *Emerging Nuclear Energy Countries.* Retrieved from world-nuclear.org: http://www.world-nuclear.org/info/inf102.html

[9] See Appendix 1 – World nuclear energy map.

[10] World Nuclear Association. (2007, May 31). *World Nuclear Power Reactors 2006-07 and Uranium Requirements.* Retrieved from world-nuclear.org: http://www.world-nuclear.org/info/reactors.html

[11] International Atomic Energy Agency. (2007). *LATEST NEWS RELATED TO PRIS AND THE STATUS OF NUCLEAR POWER PLANTS.* Retrieved from iaea.org: http://www.iaea.org/programmes/a2/index.html

[12] op. cit. World Nuclear Association. (2007)

Economic aspects

Five key aspects have been identified by our research that comprises the economic realm of nuclear energy in Israel.

Investment and production costs

The investment and production costs for building a nuclear power plant in Israel include the costs of operating and maintaining the plant and the costs of buying nuclear fuel, uranium. Our research estimates that these costs are highly competitive meaning much lower relative to the costs of operating and maintaining non-nuclear power plants, and the costs of other fuels. In addition to being a cheap fuel source, "uranium has the advantage of being a highly concentrated source of energy which is easily and cheaply transportable. The quantities needed are very much less than for coal or oil. One kilogram of natural uranium will yield about 20,000 times as much energy as the same amount of coal. It is therefore intrinsically a very portable and tradable commodity."[13]

Investment and production costs also include capital costs meaning the costs of actual construction of the power plant (which includes receiving the technology) and the costs of decommissioning and refurbishing the power plant towards the end of its 60 year life span. The capital costs for building a nuclear plant are higher relative to the capital costs of building other types of power plants. However, the overall costs are still lower relative to other types of power plant construction. This is because the operational, maintenance, and fuel costs are so low that they offset the high capital costs.

Moreover, nuclear fuel is a small part of the overall costs of production, construction, and operating a nuclear power plant, only 20% of the costs. Natural gas fuel, for example, comprises 73% of the overall costs of production, construction, and operating a natural gas powered plant. According to the IAEA, this results in a staggering fact that "doubling the cost of nuclear fuel would increase the cost of electricity by only 2% to 4%. Doubling the cost of natural gas would increase the cost of electricity by 60% to 70%." Thus, the nuclear option makes Israel exponentially less dependent on market fluctuations of fossil fuel prices.

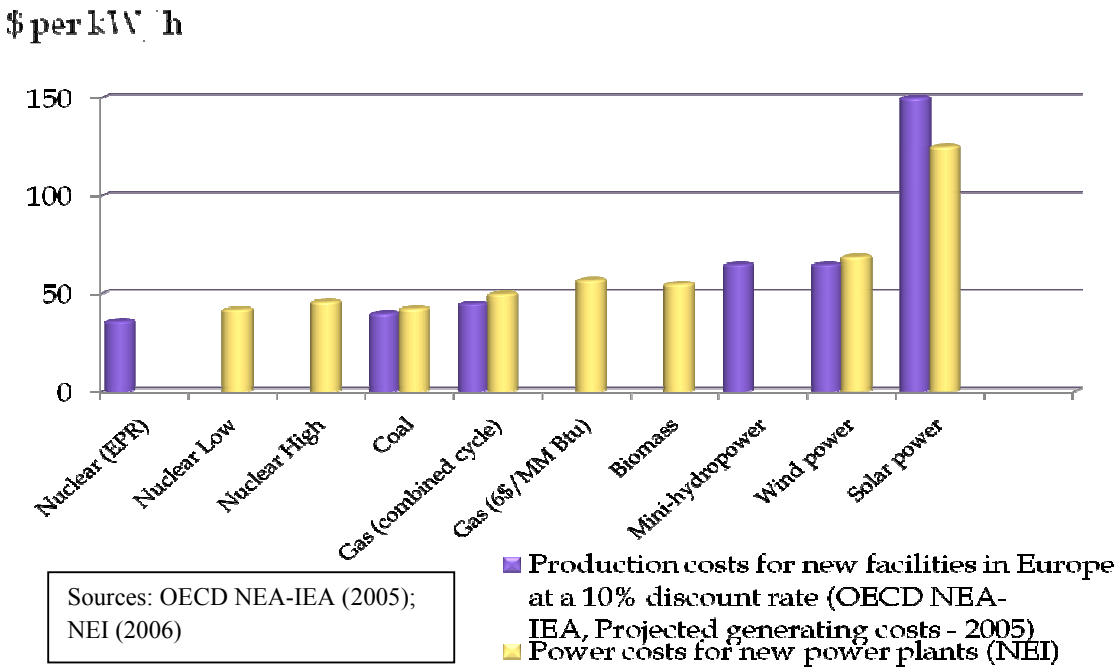
[13] Ibid.

The savings are profound. On average, a megawatt of electricity produced by nuclear energy costs half the amount of a megawatt of electricity produced by natural gas. As the demand for natural gas continues to rise, prices are predicted to rise in the future along with demand making alternative energies namely nuclear energy even more competitive economically.

Competitiveness

According to data that we combined from sources at the OECD and the Nuclear Energy Institute, nuclear energy costs are highly competitive relative to other sources of electricity production. Nuclear power is the most competitive, certainly in terms of the direct costs and reliability of the energy supply. Only hydro-electric power is more competitive. However, this is irrelevant for Israel since no sources exist to produce electricity from hydro-power.[14]

Chart 4 – Net Kilowatt/Hour costs of different methods of electricity production[15]



Sources: OECD NEA-IEA (2005); NEI (2006)

[14] See Appendix 2 - Electricity Production Competitiveness Chart.

[15] Chart data notes: Electricity cost from wind energy does not include wind energy tax credit; $/MM Btu refers to cost of natural gas; $/kW refers to the overnight capital cost of new nuclear plants; Estimates assume 12% cost of equity, 7% cost of debt and a 50/50 debt/equity ratio; Prices are average estimates converted to US $ according to May 2007 rates.

Other renewable energies like wind and solar are uncompetitive economically. To quote one official government assessment, "Plans are now going forth in Israel to establish a 100 MW solar power plant in the northern part of the Negev desert. The technology is available but the cost is still too high to compete with alternatives." [16]

Additionally, Israeli studies show that Israel's capacity for renewable energies is very limited. Even if Israel develops renewable energy to its fullest capacity, it will still provide no more than 5% of Israel's electricity needs by 2023.[17] While renewable energies are important to help Israel diversify electricity production, alone they cannot provide sufficient supply. This is why nuclear energy must be seriously considered as an alternative for diversification.

Emissions regulations

While emissions regulations are not a factor currently in Israel, in the future any increase in emissions standards will make nuclear power even more economically competitive. This is simply because nuclear power plants emit only a tiny amount of CO2 emissions and thus, will not endure any cost associated with higher emissions regulations. With Israel's eye on emulating EU emission standards this may become a significant factor in the future. The savings in electricity costs from building nuclear power plants in European countries are profound. This is mainly due to high EU emissions standards that prove costly for fossil fuel power plants:

"In March 2007, The European Council endorsed the European Commission's Strategic Energy Review and agreed on a unilateral cut of 20% in EU greenhouse gas emissions by 2020, relative to 1990 levels. This will require strengthening and extending carbon trading arrangements as well as deploying low-carbon, or zero-carbon technology."[18]

For Israel, deploying low carbon technology refers to developing nuclear energy, since Israel has limited capacity for developing renewable energies.

[16] Israel Ministry of Environmental Protection. (2006, January). *Israel's Experience in Sustanable Energy.* Retrieved from Unep.org: http://www.unep.org/GC/GCSS-IX/DOCUMENTS/Israel-energy3.pdf

[17] Mor, A., & Saroussi, S. (2006). *Energy Master Plan for the State of Israel - דוח מסכם ותוכנית חומש -תוכנית האב למשק האנרגיה.* Herzliya, Israel: Eco-Energy M.S.(2001) Ltd.

[18] World Nuclear Association. (2007, April). *Policy Responses to Global Warming.* Retrieved from world-nuclear.org: http://www.world-nuclear.org/info/inf105.html

Sources of funding

There are two main options for Israel to receive the necessary investment to build a nuclear power plant. Although we will discuss the separate considerations of Government and Private funding initiatives, a range of combination between the two sources are likely to emerge.

Government funding

Government funding is a possibility. Considering the strategic value and the economic competitiveness of nuclear energy, it would be worthwhile for the Israeli government to invest in such an endeavor. However, due to the large amount of money needed for the initial investment, it will be difficult to organize the money from the existing budget. Moreover, the government run company, Israel Electric Company (IEC) may potentially be a major obstacle. The IEC is highly protective of its workers jobs. Building a nuclear power plant will threaten some of those jobs since building a fossil fuel powered plant would maintain a steady increase in the amount of manpower needed. For this reason, private sector construction of a nuclear power plant would complement government plans for the future privatization of IEC while government funding makes construction vulnerable to IEC foot-dragging.

Nevertheless, the Minister of National Infrastructure, Binyamin Ben Eliezer, has stated that building a nuclear power plant is a national priority.[19] If this endeavor is transformed into official policy, it is possible to organize and allocate funding from the ministry for such a project. Minister Ben Eliezer's recent statements towards constructing a nuclear power plant have re-introduced nuclear power to the political and public agenda.

The main companies that build nuclear reactors are the American companies Westinghouse and General Electric, French company, Areva, and the Russian company Atomstroy. Considering issues regarding the nuclear Non-Proliferation Treaty (NPT) that will be analyzed below, Westinghouse and General Electric are a particularly appealing choice to construct a nuclear power plant in Israel since they are American companies.

[19] Wrobel, S. (2007, February 11). *Israel considers building nuclear plant.* Retrieved from Jerusalem Post: http://www.jpost.com/servlet/Satellite?cid=1170359834179&pagename=JPost%2FJPArticle%2FShowFull

The newest reactors, or third generation reactors, are already in operation in Japan. Third generation reactor suppliers in North America, Japan, Europe, Russia and South Africa have conceived of a dozen new nuclear reactor designs at advanced stages of planning. Economically, these reactors are more viable than traditional models since their standardized design reduces bureaucracy and thus, capital costs and construction time. Moreover, these reactors are considered easier to operate, have a longer life span (60 years), include mechanisms that extend fuel life, reduce waste, and create more advanced safety procedures.[20]

There are several light water reactors with 60-year life spans that may be appropriate for constructing within a nuclear power plant in Israel. General Electric/Hitachi's 1,350 MWe advanced boiling water reactor (ABWR) is already in commercial use in Japan and has met the requirements of both the US and EU. While the capital costs of units built in Japan were $2000 per kilowatt, future units are expected to cost $1,700 per kilowatt. The 1100 MWe Westinghouse AP-1000 is a relevant candidate for construction in Israel with a projected $1,200 per kilowatt and a reduced construction time to 36-month. General Electric's 1,390 MWe ESBWR reactor is also a competitor. Many other kinds of reactors are currently in advanced development stages and several new kinds of reactors are expected to be ready for commercial use within the next four years.[21]

Private Funding

While it is possible for the Israeli government to provide the funding to build a nuclear power plant, it is very likely for funding to come from the private sector. Given the economic competitiveness of nuclear energy private investors, many of them foreign, will be interested in the profitable venture of constructing a nuclear power plant in Israel. However, given the strategic importance of nuclear energy the Israeli government will surely insist on being highly involved and will undoubtedly retain a golden share. This share will provide the Israeli government with the necessary control of this strategic asset.

[20] World Nuclear Association. (2007, May). *Advanced Nuclear Power Reactors.* Retrieved from world-nuclear.org: http://www.world-nuclear.org/info/inf08.html

[21] Ibid.

Another issue with private sector funding is that a nuclear power plant in Israel can be perceived to include high security and political risks. To offset these concerns, the Israeli government would need to provide investment guarantees or subsidize insurance costs for foreign investor companies that build the power plant. These guarantees could be provided through legislation regarding energy security considerations and funded by including these extra costs in the consumer electricity price. This would be modeled after Europe where the majority of costs are covered by the consumer. In their 2006 report,[22] Eco-Energy Ltd. recommends that the Israeli energy market will adopt the EU electricity-cost model within the next twenty years. Indeed, rising energy prices will inevitably bring about a decrease in electricity subsidies in Israel. Rising prices however, also produce the need to increase the efficiency and diversity of methods of production.

Our research shows that building a nuclear plant in Israel is a profitable venture and will attract private investors. Nonetheless, government involvement is necessary. Government involvement will only reduce the profitability of such a venture minimally mainly due to bureaucratic approval hurdles, passing relevant legislation, and gaining government sponsored investment guarantees resulting in a longer than average construction time than it takes to build a nuclear plant in the rest of the world.[23]

Employment creation

In addition to contributing to Israel's strategic interests, the building of a nuclear power plant at the Shivta site can serve as a significant part in government policy to develop the Negev. Nuclear power plants around the world have proven to create a multiplier effect whereby investment is attracted to the area due to growth in businesses loosely associated with building and operating the power plant. This will create jobs in many sectors in addition to attracting highly skilled professionals to work in the nuclear plant.[24]

[22] Mor, A., & Saroussi, S. (2006). *Energy Master Plan for the State of Israel - תוכנית האב למשק האנרגיה -דוח מסכם ותוכנית חומש.* Herzliya, Israel: Eco-Energy M.S.(2001) Ltd.

[23] According to data provided by the IAEA and World Nuclear Institute, the average construction times of new nuclear power plants range from 3.5 to 6 years.

[24] Elaboration on the positive implications of developing the Negev and its national priority status is beyond the scope of this paper.

According to the timelines mentioned earlier in our proposal, the Israeli government would be able to create special training programs for Israeli scientists and engineers in order to encourage local experts to take part in operating a nuclear power plant in Israel. Special research grants and university programs may be provided for this cause.

Geopolitics

Energy security, a ubiquitous buzzword often thrown around by the chattering classes, represents a key precondition for resource-poor Israel's survival and continued economic growth. The strategic importance of diversifying Israel's energy network and enhancing Israel's self-reliance is clearly on the agenda of Israel's decision makers. Recently, Israel Electric Corporation CEO, Uri Ben-Noon asserted that "the possibility of generating electricity from a nuclear power plant in Israel was on the agenda."[25] This statement directly reflects the thinking of Gideon Frank, director of the Atomic Energy Commission. Furthermore, Minister of National Infrastructure, Binyamin Ben-Eliezer, remarked in February 2007 that "the option of generating electricity from nuclear energy was an option to be considered."[26] Although these statements are hardly more than preliminary indications, they display a major shift of perspective regarding Israeli civilian nuclear development and reflect an increase in the domestic favorability of such an endeavor.

Israel's strategy of shifting future electricity production from coal to natural gas, which was discussed in the previous section (economics), will create new geopolitical concerns related to increased dependency on Egyptian gas supplies. In 2005, a contract was signed with Egypt to construct a gas pipeline[27] that would provide Israel with considerable amounts of natural gas, mainly suited for electricity production.[28] Currently, Israel produces its own natural gas that is used for the majority of domestic demand. Israel's domestic production of natural gas is, however, rapidly becoming depleted and, unless measures are taken to diversify suppliers, within 20 years Israel may become reliant solely on Egyptian natural gas.[29] This reliance presents a real

[25] Wrobel, S. (2007, February 11). *Israel considers building nuclear plant.* Retrieved from Jerusalem Post: http://www.jpost.com/servlet/Satellite?cid=1170359834179&pagename=JPost%2FJPArticle%2FShowFull

[26] Ibid.

[27] Blackwell Synergy. (2005, August). Egypt-Israel deal could pave way to wider gas trade. *Oil and Energy Trends Volume 30 Issue 8* , pp. 7-8.

[28] The Associated Press, Reuters. (2005, June 30). *Egypt and Israel sign 15-year natural gas deal.* Retrieved from International Herald Tribune Business Website: http://www.iht.com/articles/2005/06/30/business/gas.php

[29] op. cit. Mor & Saroussi (2006)

geopolitical concern, as Egypt would gain direct strategic control over Israel's future electricity supply. To offset these concerns, Israel must diversify its sources of electricity production. According to our research, building a nuclear power plant would be an appropriate step towards strategic diversification.

Geopolitical issues revolving around nuclear power production in Israel have been the main non-starter until now. While Israel has considered developing nuclear power several times, beginning in 1976, and throughout the 1980's, Israel's policy of ambiguity towards its military nuclear program has halted any serious progress in researching such an endeavor. This security strategy has prevailed over the perceived benefits of introducing nuclear energy into the array of sources of electricity production in Israel.

The key geopolitical issue for constructing a nuclear plant in Israel is international support for the purchase of fissile materials and technology. While, ostensibly, Israel produces an estimated 10 tons of uranium on an annually,[30] it would need to acquire uranium and nuclear technologies on the international market to operate a civilian nuclear program. The international regulatory environment of the Nuclear Nonproliferation Treaty (NPT) has historically constrained support for civilian nuclear programs in non-signatory nations. The Nuclear Suppliers Group (NSG), a coalition of forty-five nuclear states, regulates the legal international market in fissile fuels and nuclear technologies, and has agreed to limit the promotion of civilian programs to signatories of the NPT. To regulate nuclear activity and enforce safety standards, states with nuclear programs must submit to international inspections of the International Atomic Energy Agency (IAEA), which directly contradicts Israel's existing policy of nuclear ambiguity. Therefore, not signing the NPT (and retaining an unfavorable environment for a civilian nuclear program) has so far served as both a central strategic condition and a direct consequence of Israel's ambiguity strategy.[31]

In spite of these apparent geopolitical obstacles, changes both in the domestic and in the international environment have provided new opportunities for civilian-use

[30] Nuclearweaponarchive.org. (1997, December 10). *Israel's Nuclear Weapons Program.* Retrieved from nuclearweaponarchive.org: http://nuclearweaponarchive.org/Israel/index.html

[31] Arad, U. (2007, May 20). Geopolitical feasibility of civilian nuclear power development in Israel. (A. Kroupenev, Interviewer).

nuclear research in Israel. Several recent developments serve as our premises for depicting a more favorable current geopolitical environment that allows Israel to build a nuclear power plant.

Nuclearization trends in the Middle East

A few distinct trends of nuclear progress have recently emerged in the Middle East and its neighborhood. In what can be seen as a reaction to Iranian nuclear development, in late 2006 and in 2007, there has been an unprecedented amount of statements of intention emerging from among Middle East nations to initiate nuclear programs. Although we must take care to analyze each country's intentions separately and not to combine these statements into a hasty Middle East nuclearization scheme, the overall political and economic incentives for initiating a nuclear development are apparent. The reasons behind Middle Eastern nations' desire for nuclear power are many and vary according to country. For some nations it serves as a reactionary deterrence policy in light of Iranian nuclear development, while for others it is for the economic purpose of diversifying energy production sources and maintaining technological development in the oil-rich nations and in pursuit of less dependence on fossil fuels in the struggling resource-poor states. Any combination of these factors serves as a solid premise for Middle Eastern leaders to initiate nuclear programs. Furthermore, Iran's arguable success in countering Western non-proliferation demands under the legal framework of the NPT has shown the benefits of openly pursuing civilian nuclear program from a leadership standpoint. In Iran, President Ahmadinejad's pursuit of nuclear power is publicly portrayed as a legitimate move, which will greatly increase Iran's international standing and prestige, in addition to serving as a guardian of its long-term economic growth. Seeing that this "legitimate" pursuit increased Ahmadinejad's domestic popularity, other Middle Eastern leaders may state intentions to initiate nuclear programs in order to gain support among their own populations.

The sub-trends of regional nuclearization include Saudi Arabia and the Gulf states - Kuwait, Bahrain, the United Arab Emirates, Qatar and Oman - that agreed in February

2007 with the IAEA to conduct a feasibility study for a regional nuclear power and desalination program to be in place by 2009.[32]

Simultaneously, Saudi Arabia is intent on pursuing the nuclear issue[33] and has discussed a separate agreement with Russia to develop both civilian and military nuclear programs.[34]

The new nuclear environment in the Middle East seems to have affected Israel's immediate neighbors - Egypt and Jordan. Egypt has shifted away from its long standing "nuclear free Middle East" policy and announced plans to renew nuclear power development in 2006.[35] King Hussein of Jordan recently asserted that nuclear energy is on his agenda as a component of Jordan's future development.[36] In addition, Libya still retains a civilian nuclear research reactor following the dismantlement of its military nuclear program in 2004.

Within these unique trends, Israel remains a non-signatory to the NPT and maintains a policy of nuclear ambiguity.

US – India nuclear deal

In addition to the developments in the Middle East, there is the peculiar status of India and Pakistan, two nuclear powers that are non-signatories to the NPT and that are in the process of upgrading their civilian nuclear programs. India is of particular interest due to its role in circumventing the international non-proliferation environment. In 2006, India, an NPT non-signatory, signed a deal to purchase uranium fuel and equipment from the United States despite India's ongoing nuclear weapons

[32] BBC News International. (2006, December 10). *Gulf states announce nuclear plan.* Retrieved from BBC News: http://news.bbc.co.uk/2/hi/middle_east/6167041.stm

[33] Dvali, A. (2004, March). *Issue brief: Will Saudi Arabia Acquire Nuclear Weapons?* Retrieved from Nuclear Threat Initiative Website: http://www.nti.org/e_research/e3_40a.html

[34] Karam, S. (2007 , February 12). *Russia could help Saudi in atomic energy-Putin.* Retrieved from Reuters Website: http://www.reuters.com/article/latestCrisis/idUSL1239787

[35] *Egypt Nuclear Overview.* (2006, November). Retrieved from Nuclear Threat Initiative Website: http://www.nti.org/e_research/profiles/Egypt/Nuclear/index_1692.html

[36] Eldar, A. (2007, January 20). *King Abdullah to Haaretz: Jordan aims to develop nuclear power.* Retrieved from Haaretz.com: http://www.haaretz.com/hasen/spages/815304.html

program.[37] This deal is a breach in the traditional NPT regime but may serve as a positive precedent for Israel, should it choose to develop a nuclear program while maintaining its present security strategy of nuclear ambiguity. In light of this deal, Israel may now find it easier to negotiate uranium purchases without having to submit to international inspections at its Dimona nuclear facility. Furthermore, as a major US ally, Israel may be able to capitalize on the US-India nuclear deal in order to gain Washington's support for a civilian nuclear program.

An additional noteworthy event that may indicate a change in Israel's nuclear policy environment is the Israeli Prime Minister Ehud Olmert's remark regarding Israel's nuclear weapons program in December 2006.[38] Although this remark was quickly retracted and framed as an unintentional slip, it was uttered in the context of Israel's political confrontation with Iran over its nuclear program. In this light, Prime Minister Ehud Olmert's statement may indicate that Israel is re-conceptualizing its long-standing policy of nuclear ambiguity[39]. This assumption is supported by a number of international experts in the realm of Israel's nuclear strategy.[40, 41]

Although it is uncertain whether and how these developments will immediately contribute to creating a positive environment for an Israeli civilian-use nuclear power program, the recent changes in the international environment have alleviated a number of previously daunting geopolitical obstacles.[42]

[37] VandeHei, J., & Linzer, D. (2006, March 3). *U.S., India Reach Deal On Nuclear Cooperation.* Retrieved from WashingtonPost.com: http://www.washingtonpost.com/wp-dyn/content/article/2006/03/02/AR2006030200183.html

[38] Verter, Y. (2006 , December 12). *Olmert's nuclear remark spurs damage control bid.* Retrieved from Haaretz.com: http://haaretz.com/hasen/spages/799736.html

[39] Rajiv, S. S. (2006, December 22). *Olmert's 'Nuclear Slip' and Israeli Nuclear Ambiguity.* Retrieved from Institute for Defence Studies and Analyses website: http://www.idsa.in/publications/stratcomments/SamuelRajiv221206.htm

[40] Schiff, Z. (2000, August 24). *How long can nuclear ambiguity last?* Retrieved from GlobalSecurity.org (Ha'aretz): http://www.globalsecurity.org/wmd/library/news/israel/000824-israel.htm

[41] Arad, U. (2007, May 15). Geopolitical feasibility of civilian nuclear power development in Israel. (A. Kroupenev, Interviewer)

[42] Luft, G. (2006, May 15). International acceptability of an Israeli nuclear power program. (A. Kroupenev, Interviewer)

Security

Another issue that requires a geopolitical analysis is Israel's unique security situation. This situation raises legitimate concerns regarding the possibility of an attack against Israel's nuclear installations. Due to these concerns, previous proposals for nuclear power plants in Israel suggested fortified reactor shells and even the construction of the entire nuclear power facility underground. Such protective measures have made the construction cost estimates too high for serious feasibility consideration.

However, the likelihood that Israel's neighbors would attempt a strike against an Israeli civilian nuclear power plant must be considered. The likelihood can be based on two factors, motivation and capability. In terms of motivation, the fact that Israel is a full-fledged, if unofficially declared, nuclear power makes Israel's most dangerous enemies such as Iran and Syria arguably unwilling to target a nuclear facility for fear of similar retaliation. If one subscribes to the opinion that some of Israel's enemies cannot be deterred or that regardless of such calculations, a nuclear facility creates a dangerously vulnerable site for targeting in retaliation by countries like Iran, then the factor of capabilities must be consider concomitantly with motivation. In terms of capabilities, while Israel has continued its military buildup, its regional rivals have not kept up. Aside from Saudi Arabia, no country in the region has an air-force capable of even penetrating Israel's airspace let alone bombing a strategic site. Moreover, Israel's regional neighbors, specifically Iran and Syria (and Hezbollah) have missiles capable of reaching any part of Israel but with little accuracy. Due to basic security standards at nuclear power plants, missiles that are not accurate enough to achieve a direct hit on the reactor are not capable of causing enough damage to be of concern. Thus, regardless of increased or decreased motivation, an air-strike or missile strike from Israel's neighbors is highly unlikely to be capable of damaging a reactor core.

Lesser terrorist threats like those from Gaza such as a Kassam rocket attack does not present more of a threat than it does to any other type of power plant. Contrary to belief, a terrorist attack on a nuclear power plant would not create a nuclear explosion. The strategic threat would be comparable to any other source of electricity production. Israel has an impressive reputation for its ability to secure strategic sites and such threats should not be considered to present any danger of particular significance.

Environment

Public opinion

The majority of scientists in areas connected to nuclear research agree that nuclear energy is one of the better ways to produce electricity in relation to environmental sustainability. However, this view is not shared by people who associate nuclear energy with images of devastation from Hiroshima, scenes of horror from Chernobyl, and science fiction movies that portray nuclear wars and the resulting annihilation.

The media tends to dramatize facts in its pursuit to obtain higher ratings. Public opinion of nuclear energy is also influenced by the Hollywood entertainment industry. Thus, public opinion on nuclear energy is often not rational and not based on facts. Professor Spencer R. Weart writes in his book, *Nuclear Fear*: *A History of Images:*

> *Our thinking is inhabited by images. Images of sometimes curious and overwhelming power. The mushroom cloud, weird rays that can transform the flesh, the twilight world following a nuclear war, the white city of the future, the brilliant but mad scientist who plots to destroy the world. All these images and more relate to nuclear energy, but that is not their only common bond. Decades before the first atom bomb exploded, a web of symbols with surprising linkages was fully formed in the public mind. The strange kinship of these symbols can be traced back, not only to medieval symbolism, but still deeper into experiences common to all of us.*[43]

Brief History

The importance of public acceptance of nuclear power is not a new topic. In his speech before the General Assembly of the United Nations on Peaceful Uses of Atomic Energy on December 8, 1953, "Atoms for Peace", President Dwight Eisenhower presented a new energy policy for the U.S. The American public at the time proved to be leaning more toward the positive side of atomic energy. During the

[43] Weart, S. R. (1988). *Nuclear Fear, A History of Images.* Boston: Harvard University Press.

seventies, due to the oil crises, voices for energy independence were heard even more loudly, and support for nuclear energy was at an all time high.

During Carter's administration, different opinions emerged. In 1979, two important events occurred within several days. The movie *The China Syndrome* was released and the Three Mile Island accident occurred. The incident at Three Mile Island, where a leak occurred in the nuclear reactor, is in fact an example of where appropriate safety measures contained and prevented substantial environmental damage and human injury.[44] Coincidentally, the movie dealt with a fictional nuclear accident and a governmental attempt to cover up the truth at any cost. The time proximity of the movie release to the accident made the film a blockbuster and contributed to the distorted public opinion regarding nuclear energy despite its fictional nature and regardless of the realities of the Three Mile Island incident.[45] The panic created by the movie was destructive to the nuclear energy industry. It is no coincidence that since the year 1979, no new nuclear power plants have been built in the U.S.[46]

The 1986 Chernobyl disaster further contributed to public fear of nuclear power plants. The horrific pictures and stories were pumped daily to the public without proper framing or differentiation between reckless Soviet treatment of nuclear facilities and the much safer and more advanced technology used to construct American nuclear facilities. The infamous Chernobyl accident rings terror in many minds despite the fact that it was caused by human error and lack of appropriate safety measures which are standard in today's nuclear power installations.[47]

Therefore, it is highly possible that media frenzies and fictional Hollywood portrayals of nuclear events have been the main cause for public disdain towards nuclear energy worldwide.

---

[44] Modern nuclear power plants are much more technologically advanced and contain proven protective mechanisms to ensure against work accidents, especially within third-generation nuclear power plants.

[45] Gamson, W., & Modigliani, A. (1989). Media Discourse and Public Opinion on Nuclear Power: A Constructionist Approach. *American Journal of Sociology* .

[46] Nisbet, M. (2006, June 1). *Going Nuclear: Frames and Public Opinion about Atomic Energy.* Retrieved from csicop.org: http://www.csicop.org/scienceandmedia/nuclear/

[47] For further discussion of this issue, see: Taniguchi, T. (2006). *Inmprovement of nuclear safety and radiation protection initiated by the Chernobyl accident.* Retrieved from iaea.org: http://www-ns.iaea.org/downloads/coordination/DDG_statements/Chernobyl_DDG_speech.pdf

Current trends in acceptability of nuclear energy

Today, voices calling for energy independence can be heard again in the corridors of the American executive branch.[48]

> *For the sake of economic security and national security, the United States of America must aggressively move forward with the construction of nuclear power plants. Other nations are. Interestingly enough, France has built 58 plants since the 1970s, and now gets 78 percent of its electricity from nuclear power… China has nine nuclear plants in operation and—plan to build 40 more over the next two decades. They understand that in order to be an aggressive nation, an economic nation that is flourishing so that people can benefit, they better do something about their sources of electricity. They see it. I just came from India. They're going to build some nuclear power plants*[49]

World leaders are delivering pro–nuclear speeches in public hinting that public opinion is no longer an obstacle for nuclear power to be a real option for development. For example, in 2007, British Prime Minister Tony Blair made a powerful case for nuclear energy when the government's energy review concluded that it was necessary to avoid future energy shortages.[50] Many more nations are seriously considering the nuclear power.[51] While this shows the high levels of government interest in nuclear energy, it does not show the rate of general public approval. However, combined with rising awareness of global warming, the nuclear option is more relevant than ever with the general population much more inclined towards accepting nuclear plants as a viable option.

A poll conducted in 2005 showed that 34% of British think that "[the UK] should continue using existing nuclear power stations, and replace them with new ones when they reach the end of their life."[52] In Scotland, poll commissioned by *The Sunday*

[48] While the US was considered the pioneer of nuclear energy in until the end of the 1980s, several other countries have surpassed the US in terms of investment in scale of nuclear electricity production. Given the recent rise in fossil fuel prices and pressing geopolitical that face America today, the nuclear energy alternative is becoming ever more lucrative.

[49] *President's George W. Bush public speech at Limerick Generating Station Pottstown, Pennsylvania .* (2006, May 24). Retrieved from Nuclear Energy Institute website: http://www.nei.org/index.asp?catnum=4&catid=954

[50] BBC News. (2007, May 24). *Nuclear power 'must be on agenda'.* Retrieved from BBC News UK website: http://news.bbc.co.uk/2/hi/uk_news/politics/6681377.stm

[51] World Nuclear Association. (2007, June). *Emerging Nuclear Energy Countries.* Retrieved from world-nuclear.org: http://www.world-nuclear.org/info/inf102.html

[52] Poortinga, W., et. al. (2006, January 17). *Public opinion of nuclear power, climate change and energy options in Britain: summary findings of a survey conducted during October and November 2005 by the School for Environmental Sciences at University of East Anglia.* Retrieved from tyndall.ac.uk: http://www.tyndall.ac.uk/publications/EnergyFuturesSummary.pdf

Times revealed that 45% of Scots believe existing nuclear stations should be replaced at the end of their working lives compared with 37% who think they should not be replaced.[53] In Sweden, a poll by Göteborg University showed that the year 2002 was a decisive point when the number of supporters of nuclear energy became greater than the number opposed.[54] Public opinion has changed so dramatically that the fashion magazine *Elle* listed nuclear energy among its top ten "cool, new things" for 2006.[55]

In July 2007, an event occurred that has the potential for greatly reducing public acceptability of nuclear energy. An earthquake measuring 6.8 on the Richter scale caused low-level waste to leak into the sea from Japan's largest nuclear power plant, the Kashiwazaki-Kariwa plant. While the environmental damage from the nuclear waste was minimal, it could have served as a catalyst for a downturn in public acceptability. However, within the first week of the event's occurrence media reports covered the event factually without the sensationalism that would have aroused a public outcry against nuclear energy development. Many nuclear reactors worldwide were built on sites sensitive to earthquakes. While Israel also suffers from earthquakes, albeit lighter than many of those in Japan, there should be little public concern about earthquakes causing nuclear disasters in Israel. The site set aside for a nuclear power plant in Israel, Shivta, was partially chosen for its seismological stability. Thus, the nuclear plant proposed by our research would be in no danger from an earthquake.

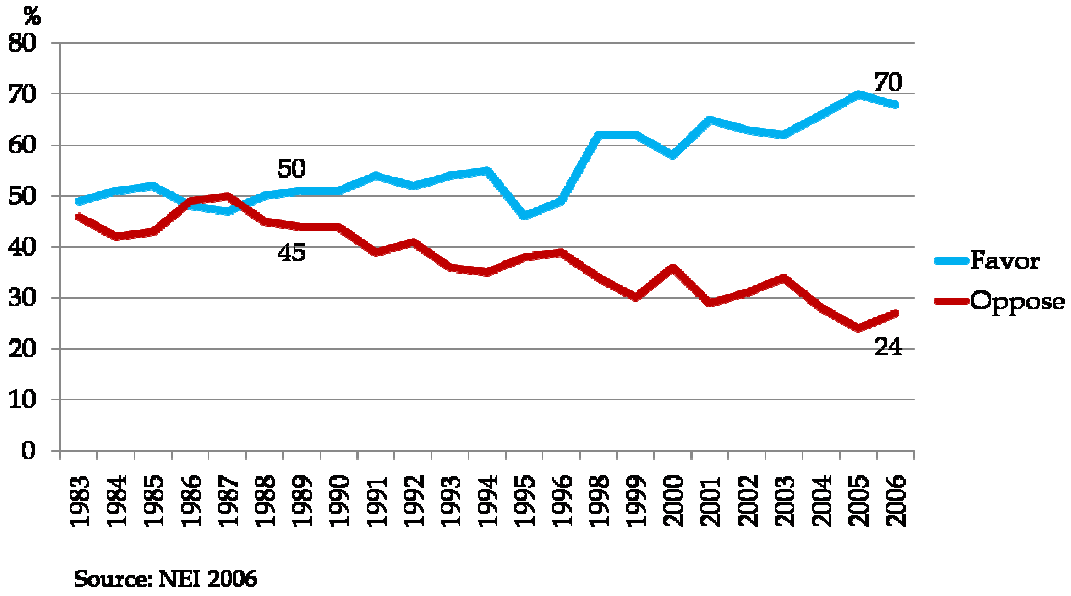
Having discussed the historical dissonance between the proven safety and environmental competitiveness and the negative popular perceptions of nuclear power, we have shown that there is a visible increase in government interest and general public acceptability of nuclear electricity production around the world. This growth of international acceptability could be utilized in an effort to educate the Israeli public regarding the environmental benefits of nuclear energy.

[53] Allardyce, J., & Nutt, K. (2006, September 17). *New nuclear power plants win support.* Retrieved from timesonline.co.uk: http://www.timesonline.co.uk/tol/newspapers/sunday_times/scotland/article641705.ece

[54] Holmberg, S. (2006, June). *Swedish Public Opinion on Nuclear Power.* Retrieved from SOM Institute website: http://www.som.gu.se/rapporter/opinion_nucelar_power/Public_opinion_on_nuclear_power.pdf

[55] International Atomic Energy Agency. (2006, February 16). *The Shifting Sands of Nuclear Public Opinion.* Retrieved from IAEA.org: http://www.iaea.org/NewsCenter/News/2006/pime.html

Chart 5 – Public acceptability of nuclear power in the US



Source: NEI 2006

Educating the general public regarding the high safety, competitive advantages, and environmental sustainability of nuclear power is a key element in the steady rise in positive public opinion of nuclear power.[56] Since only a minority of the population will research, read and investigate the issues, generating public debates regarding nuclear energy is a healthy and important way to ensure a constructive flow of information to the public. The main issue that often concerns the public is the environmental and safety implications of nuclear plants. Indeed, decision makers and investors who would choose to take on the task of constructing a nuclear power plant in Israel may face strong opposition from local and international environmentalist groups.[57] Therefore, public debates should be generated regarding these issues and comprehensive public education campaigns should be planned in advance.

[56] See Chart 5 for a visual display of steadily rising acceptability of nuclear power in the United States.

[57] Marinov, U. (2007, April 25). Environmental implications of introducing nuclear power into Israel's electricity market. (A. Kroupenev, Interviewer). A summary of the interview with Prof. Uriel Marinov is available upon request.

Nuclear Waste

Nuclear waste is "any material that contains or is contained by radionuclides at concentrations or radioactivity levels greater than the exempted quantities established by the competent authorities and for which no use is foreseen."[58] Nuclear waste (the non-reusable by-products of the nuclear industry) can be divided into several categories. The four classes of waste are based on radioactivity levels:

1. Very low-level waste (**VLLW**) can be safely disposed of with ordinary refuse.
2. Low-level waste (**LLW**) from operations and maintenance, such as gloves, boots, face masks, etc., comprise 90% of the waste sent to licensed disposal facilities or treatment. Unless contaminated with alpha elements (which occurs only in rare cases) LLW does not require special handling.
3. Medium-level waste or intermediate-level (**MLW** or **ILW**), such as dismantled production equipment, measurement instrumentation, etc. (8%).[59]
4. High-level waste (**HLW**) mainly consists of fission products that have been separated during used fuel treatment and recycling operations (2%).[60]

Accordingly, the concept of nuclear "waste" is dependent on a country's ability (or will) to reuse its nuclear resources since most of the nuclear waste is treatable. The VLLW, the LLW and even the MLW can be treated. Two examples of treatment facilities for this type of waste are in Israel (EER)[61] and in France (ANDRA)[62]. The main problem lies with the HLW which is the used byproducts of fission.

[58] Retrieved from International Atomic Energy Agency official website: http://www.iaea.org

[59] AREVA. (2005). *Nuclear Safety Charter.* AREVA.

[60] Ibid.

[61] For more information, go to Environmental Energy Resources Ltd. (2003). *Technology Description*. Retrieved from EER-PGM.com: http://www.eer-pgm.com/description.htm

[62] For more information, go to the French National Agency for Radioactive Waste Management (ANDRA). (n.d.). *http://www.andra.fr/sommaire.en.php3*

Nuclear waste management

There are two opposing strategies to manage used fuel. Used fuel can be considered final waste or it can be treated to recover recyclable materials (96% of the used fuel content). Most countries have yet to decide on the issue. France and some other countries, including Japan, the UK, Russia, and China, treat their used fuel. Sweden and the U.S. are examples of countries that do not reuse the byproducts of fission[63] for economic feasibility reasons. In 2001, Finland decided to build a final repository for radioactive waste. The infrastructure will be operational in 2020. Up to 9,000 metric tons of waste could ultimately be disposed of there. Finland is the first country in the world that has decided to create a final radioactive waste repository.

Amount of nuclear waste produced

AREVA, the French energy giant, states that a family that uses 6,000 kWh a year will produce 0.6 cm^3 of HLW. This means that if a family of four people uses electricity from nuclear power for 25 years, it would generate 12 cm^3 of high-level, long-lived waste, or a cube measuring 2.3 centimeters on each side. Below, European numbers of electricity consumption patterns are adopted to calculate projected Israeli nuclear waste creation.[64]

7,114,600:4=1,786,150 families

1,786,150*12=21,433,800 cm^3

21,433,800:25=857,352 cm^3 a year

857,352:1,000,000=0.857 m^3

Using European consumption levels, every year Israeli households will produce a cube of 0.95 cm of High Level Waste annually. Given the size of Israel's electricity market, the management of such an amount of nuclear waste would not lower the relative economic competitiveness of nuclear energy production.

[63] International Atomic Energy Agency (IAEA). (1994). *Classification of Radioactive Waste, A Safety Guide, Radwass programme* . IAEA.

[64] The Israeli Chamber of Statistics latest report states that there are 7,114,600 citizens in Israel. The calculation assumes an average of persons per family.

In comparison, coal plants produce 300,000 tons of ash every year, containing other radioactive materials and heavy metals that are emitted into the atmosphere, the oceans and into the ground.

The International Nuclear Societies Council calculated that a 1000 MW(e) nuclear power station that can provide electricity for a city of the size of Amsterdam, producing $300m^3$ of low and intermediate level waste per year and approximately 30 tons of high level solid paced waste per year.

Today, scientists are working to develop the fourth generation of nuclear power stations that can use materials much more efficiently and thus cut down the quantity of waste - both the low, intermediate level, and the high level waste.

There is a vast assortment of practices of waste management (the treatment, transport, storage and disposal). There exists a variety of government and private agencies that entirely or partly treat or store nuclear waste. Companies like COVRA[65] in the Netherlands, ONRAF in Belgium or ENRESA[66] in Spain are responsible for the entire waste management process, while in the UK and the US the treatment, transport and storage of nuclear waste is carried out by the waste producers.[67] The long term nature of the high level waste makes it challenging to be handled by a private company. Thus, most countries leave the waste disposal in governmental hands.

Financing

There are three main possibilities for financing nuclear waste disposal:

1. By waste producers -- tariff payment to waste disposal organizations.
2. By electricity producers -- through payments into a fund from levies on electricity generation and then to the waste disposal organization.
3. By government and third parties -- subsidies to waste disposal organizations.

[65] For more information, go to COVRA (Radioactive Waste Management). (n.d.). *http://www.covra.nl/*

[66] For more information, go to ENRESA (Environmental Solutions). (n.d.). *http://www.enresa.es/*

[67] International Nuclear Societies Council. (1998, October). *Radioactive waste.* Retrieved from http://www.ne.jp/asahi/mh/u/INSCAP/Radwaste.html

Regardless of which option is chosen, the cost of disposal will be paid by the public, whether through electricity prices, the prices of products (indirect payment) or by tax money. Thus, the most efficient way has to be calculated by the government and not by private companies that seek profit.

Methods of disposal

The main two options for nuclear waste disposal:

1. Near Surface Disposal - A grid of near surface trenches with engineered barriers, suitable for all LLW and some MLW. International examples include: Drigg[68] in UK, Centre de I'Aube[69] in France, Rokkasho-Mura[70] in Japan, El Cabril[71] in Spain.
2. Deep Disposal - A long term solution for waste. Deep disposal lowers the risks of exposure to radiation. In order to prevent resurfacing of radioactive waste with groundwater, engineered and natural barriers are used. The packaging of the waste helps to prevent percolation. Access to materials is maintained for maintenance purposes. International examples include Yucca Mountain[72] in the U.S. and Gorleben[73] in Germany.

While nuclear waste is essentially detrimental to the environment, there are many ways of treating it properly. Moreover, only a small amount of waste would be produced in Israel and a smaller amount would have to be treated. In weighing the benefits versus the costs in terms of environmental sustainability, it must be taken into

[68] For more information, go to British Nuclear Group. (n.d.). *http://www.britishnucleargroup.com/content.php?pageID=266*

[69] Garrick, J. (2000, August 18). *ACNW VISITS TO NUCLEAR SITES AND INFORMATION EXCHANGES IN THE UNITED KINGDOM AND FRANCE, MAY 15-19, 2000.* Retrieved from U.S. Nuclear Regulatory Commission website: http://www.nrc.gov/reading-rm/doc-collections/acnw/letters/2000/1200158.html

[70] WMD Insights. (2006, February). *JAPANESE, SOUTH KOREAN PLUTONIUM PLANTS RAISE SECURITY CONCERNS IN REGION.* Retrieved from WMD Insights website: http://www.wmdinsights.org/I2/EA1_Rokkashos.htm

[71] ENRESA (Environmental Solutions). (n.d.). *El Cabril Introduction.* Retrieved from ENRESA website: http://www.enresa.es/Servicio+Publico/Actividades/El_cabril/en/cabril+introduccion.htm

[72] U.S. Department of Energy. (2007, June 19). *Yucca Mountain Repository.* Retrieved from U.S. DOE website: http://www.ocrwm.doe.gov/ym_repository/index.shtml

[73] Endlagerung in Deushland. (n.d.). *Gorleben Programme.* Retrieved from Final Waste Disposal in Germany website: http://www.endlagerung.de/generator.aspx/templateId=renderPage/lang=en/id=12502.html

account that nuclear power plants produce a miniscule amount of CO^2 emissions. In contrast, as described above, coal powered plants produce large amounts of CO^2 emissions and natural gas powered plants produce less but still largely contribute to air pollution and global warming. Currently, electricity production accounts for Israel's second largest air pollutant behind vehicle emissions. Building a nuclear power plant instead of one run by fossil fuels is an efficient way to reduce CO^2 emissions.

Only further in-depth scientific studies can provide accurate estimates regarding the amounts of nuclear waste that would be produced by a nuclear power plant in Israel and the best methods of treatment or storage of nuclear waste. A comprehensive study is needed to determine the most economically and environmentally efficient and geopolitically agreeable system of treatment that could be funded either by the government, private investors, or by including the waste management costs in the consumer-end electricity prices.

Conclusions

In conclusion, Israel's electricity consumption is rising while supply is lagging behind. Israel must introduce new power plants into its electricity sector. Without adding much needed additional capacity in base load electricity production, Israel will begin to suffer from chronic power shortages leaving the country highly vulnerable to geopolitical occurrences.

In selecting the future breakdown of Israel's electricity production, many issues must be taken into account. One very significant issue is economic viability. Currently, nuclear energy is the most economically competitive source of electricity for Israel. While natural gas may be a good short-term solution for ensuring enough electricity production capacity, it does not address pressing long-term issues such as energy independence through diversity or the increasingly dangerous consequences of greenhouse gas emissions and global warming. Moreover, natural gas is more expensive, its supply from other countries is not assured and its use makes electricity costs much more dependent on international market fluctuations. The alternatives such as renewable energies are insufficient even at their fullest projected capacity to provide Israel with any significant capacity for electricity production. In addition, the miniscule amounts of uranium needed to fuel a power plant and the fact that uranium producing countries are Israel's most trusted allies makes nuclear energy a lucrative option geopolitically. Combined with economic competitiveness, nuclear energy is thus a feasible solution for significant strategic energy diversification in Israel.

Nuclear energy is also safe and environmentally sustainable as opposed to gas, coal and oil. These fossil fuels used in electricity production are Israel's second biggest polluters behind vehicle emissions. To prevent serious environmental damage, fossil fuels must be replaced to the furthest extent possible. With today's highly advanced safety and security standards in nuclear reactors and efficient waste treatment methods, nuclear energy is viable solution to polluting fossil fuels.

The most significant obstacles that this initiative will face are minimal but nonetheless must be taken into account. Constructing a nuclear power plant requires government

legislation, approval, and support in the form of guarantees. These bureaucratic hurdles may take time to overcome. Despite these hurdles, a nuclear power plant in Israel is profitable investment that is likely to attract many interested parties.

Another issue of concern is the fact that nuclear power development in Israel remains subject to the nuclear Non Proliferation Treaty regime and other geopolitical considerations. However, recent shifts in the international and domestic environment described in the geopolitical section of this paper, have created new opportunities for nuclear feasibility research and development. Thus, the geopolitical concerns of the previous millennium are no longer a major obstacle for civilian-use nuclear power in Israel.

Recommendations

Although many relevant issues are beyond the scope and the depth of the analysis we have presented in this paper, our research has shown the necessity of conducting a comprehensive feasibility study on nuclear energy in Israel. Our research can serve as a basic groundwork for such a scientific feasibility study. We are confident that our organizational structuring of the relevant issues can be of great use to those who will be tasked with carrying out such a project. The objective of the study should be the calculation and definition of economic, land, environmental, security and political costs of constructing a 1,000-1,400mW nuclear power plant by 2025. We suggest that this study will contain an inclusive cost-benefit analysis of nuclear power and consider the unique status of Israel's electricity market and take into account the effect of a nuclear power plant on the privatization process of the Israel Electric Company. In addition, a separate study regarding domestic public awareness and acceptability of nuclear energy for electricity production should be initiated. Moreover, we recognize the significance that public opinion can play in the realization of this initiative. We are confident that if sufficient public debate is generated among the public and in the media regarding nuclear energy, the building of a nuclear power plant in Israel will not only be acceptable to the public but will be encouraged by the public.

Our research has led us to believe that constructing a nuclear plant of the size mentioned above by 2025 is a viable solution to many pressing problems facing Israel. Economically, environmentally, and geo-politically, building such a plant in Israel should not only be a priority but should be viewed as a national obligation. In order for this project to be realized the issue of civilian nuclear power in Israel must be kept on the public and political agenda.

Works Cited

Allardyce, J., & Nutt, K. (2006, September 17). *New nuclear power plants win support.* Retrieved from timesonline.co.uk: http://www.timesonline.co.uk/tol/newspapers/sunday_times/scotland/article641705.ece

Arad, U. (2007, May 30). Geopolitical feasibility of civilian nuclear power development in Israel. (A. Kroupenev, Interviewer)

AREVA. (2005). *Nuclear Safety Charter.* AREVA.

BBC News International. (2006, December 10). *Gulf states announce nuclear plan.* Retrieved from BBC News: http://news.bbc.co.uk/2/hi/middle_east/6167041.stm

BBC News. (2007, May 24). *Nuclear power 'must be on agenda'.* Retrieved from BBC News UK website: http://news.bbc.co.uk/2/hi/uk_news/politics/6681377.stm

Blackwell Synergy. (2005, August). Egypt-Israel deal could pave way to wider gas trade. *Oil and Energy Trends Volume 30 Issue 8* , pp. 7-8.

British Nuclear Group. (n.d.). *http://www.britishnucleargroup.com/content.php?pageID=266.*

COVRA (Radioactive Waste Management). (n.d.). *http://www.covra.nl/*.

Dvali, A. (2004, March). *Issue brief: Will Saudi Arabia Acquire Nuclear Weapons?* Retrieved from Nuclear Threat Initiative Website: http://www.nti.org/e_research/e3_40a.html

Egypt Nuclear Overview. (2006, November). Retrieved from Nuclear Threat Initiative Website: http://www.nti.org/e_research/profiles/Egypt/Nuclear/index_1692.html

Eldar, A. (2007, January 20). *King Abdullah to Haaretz: Jordan aims to develop nuclear power.* Retrieved from Haaretz.com: http://www.haaretz.com/hasen/spages/815304.html

Endlagerung in Deushland. (n.d.). *Gorleben Programme.* Retrieved from Final Waste Disposal in Germany website: http://www.endlagerung.de/generator.aspx/templateId=renderPage/lang=en/id=12502.html

ENRESA (Environmental Solutions). (n.d.). *El Cabril Introduction.* Retrieved from ENRESA website: http://www.enresa.es/Servicio+Publico/Actividades/El_cabril/en/cabril+introduccion.htm

ENRESA (Environmental Solutions). (n.d.). *http://www.enresa.es/*.

Environmental Energy Resources Ltd. (2003). *Technology Description*. Retrieved from EER-PGM.com: http://www.eer-pgm.com/description.htm

French National Agency for Radioactive Waste Management (ANDRA). (n.d.). *http://www.andra.fr/sommaire.en.php3*.

Gamson, W., & Modigliani, A. (1989). Media Discourse and Public Opinion on Nuclear Power: A Constructionist Approach. *American Journal of Sociology* .

Garrick, J. (2000, August 18). *ACNW VISITS TO NUCLEAR SITES AND INFORMATION EXCHANGES IN THE UNITED KINGDOM AND FRANCE, MAY 15-19, 2000.* Retrieved from U.S. Nuclear Regulatory Commission website: http://www.nrc.gov/reading-rm/doc-collections/acnw/letters/2000/1200158.html

Holmberg, S. (2006, June). *Swedish Public Opinion on Nuclear Power.* Retrieved from SOM Institute website: http://www.som.gu.se/rapporter/opinion_nucelar_power/Public_opinion_on_nuclear_power.pdf

International Atomic Energy Agency (IAEA). (1994). *Classification of Radioactive Waste, A Safety Guide, Radwass programme* . IAEA.

International Atomic Energy Agency (IAEA). (2007). *LATEST NEWS RELATED TO PRIS AND THE STATUS OF NUCLEAR POWER PLANTS.* Retrieved from iaea.org: http://www.iaea.org/programmes/a2/index.html

International Atomic Energy Agency. (2006, February 16). *The Shifting Sands of Nuclear Public Opinion.* Retrieved from IAEA.org: http://www.iaea.org/NewsCenter/News/2006/pime.html

International Nuclear Societies Council. (1998, October). *Radioactive waste.* Retrieved from http://www.ne.jp/asahi/mh/u/INSCAP/Radwaste.html

Israel Ministry of Environmental Protection. (2006, January). *Israel's Experience in Sustanable Energy.* Retrieved from Unep.org: http://www.unep.org/GC/GCSS-IX/DOCUMENTS/Israel-energy3.pdf

Karam, S. (2007, February 12). *Russia could help Saudi in atomic energy-Putin.* Retrieved from Reuters Website: http://www.reuters.com/article/latestCrisis/idUSL1239787

Luft, G. (2006, May 15). International acceptability of an Israeli nuclear power program. (A. Kroupenev, Interviewer)

Marinov, U. (2007, April 25). Environmental implications of introducing nuclear power into Israel's electricity market. (A. Kroupenev, Interviewer)

Mor, A., & Saroussi, S. (2006). *Energy Master Plan for the State of Israel - תוכנית האב למשק האנרגיה- דוח מסכם ותוכנית חומש.* Herzliya, Israel: Eco-Energy M.S.(2001) Ltd.

Nisbet, M. (2006, June 1). *Going Nuclear: Frames and Public Opinion about Atomic Energy.* Retrieved from csicop.org: http://www.csicop.org/scienceandmedia/nuclear/

Nuclearweaponarchive.org. (1997, December 10). *Israel's Nuclear Weapons Program.* Retrieved from nuclearweaponarchive.org: http://nuclearweaponarchive.org/Israel/index.html

Poortinga, W. (2006, January 17). *Public opinion of nuclear power, climate change and energy options in Britain: summary findings of a survey conducted during October and November 2005.* Retrieved from tyndall.ac.uk: http://www.tyndall.ac.uk/publications/EnergyFuturesSummary.pdf

President's George W. Bush public speech at Limerick Generating Station Pottstown, Pennsylvania . (2006, May 24). Retrieved from Nuclear Energy Institute website: http://www.nei.org/index.asp?catnum=4&catid=954

Rajiv, S. S. (2006, December 22). *Olmert's 'Nuclear Slip' and Israeli Nuclear Ambiguity.* Retrieved from Institute for Defence Studies and Analyses website: http://www.idsa.in/publications/stratcomments/SamuelRajiv221206.htm

Schiff, Z. (2000, August 24). *How long can nuclear ambiguity last?* Retrieved from GlobalSecurity.org (Ha'aretz): http://www.globalsecurity.org/wmd/library/news/israel/000824-israel.htm

Taniguchi, T. (2006). *Inmprovement of nuclear safety and radiation protection initiated by the Chernobyl accident.* Retrieved from iaea.org: http://www-ns.iaea.org/downloads/coordination/DDG_statements/Chernobyl_DDG_speech.pdf

The Associated Press, Reuters. (2005, June 30). *Egypt and Israel sign 15-year natural gas deal.* Retrieved from International Herald Tribune Business Website: http://www.iht.com/articles/2005/06/30/business/gas.php

U.S. Department of Energy. (2007, June 19). *Yucca Mountain Repository.* Retrieved from U.S. DOE website: http://www.ocrwm.doe.gov/ym_repository/index.shtml

VandeHei, J., & Linzer, D. (2006, March 3). *U.S., India Reach Deal On Nuclear Cooperation.* Retrieved from WashingtonPost.com: http://www.washingtonpost.com/wp-dyn/content/article/2006/03/02/AR2006030200183.html

Verter, Y. (2006 , December 12). *Olmert's nuclear remark spurs damage control bid.* Retrieved from Haaretz.com: http://haaretz.com/hasen/spages/799736.html

Weart, S. R. (1988). *Nuclear Fear, A History of Images.* Boston: Harvard University Press.

WMD Insights. (2006, February). *JAPANESE, SOUTH KOREAN PLUTONIUM PLANTS RAISE SECURITY CONCERNS IN REGION.* Retrieved from WMD Insights website: http://www.wmdinsights.org/I2/EA1_Rokkashos.htm

World Nuclear Association. (2007, May). *Advanced Nuclear Power Reactors.* Retrieved from world-nuclear.org: http://www.world-nuclear.org/info/inf08.html

World Nuclear Association. (2007, June). *Emerging Nuclear Energy Countries.* Retrieved from world-nuclear.org: http://www.world-nuclear.org/info/inf102.html

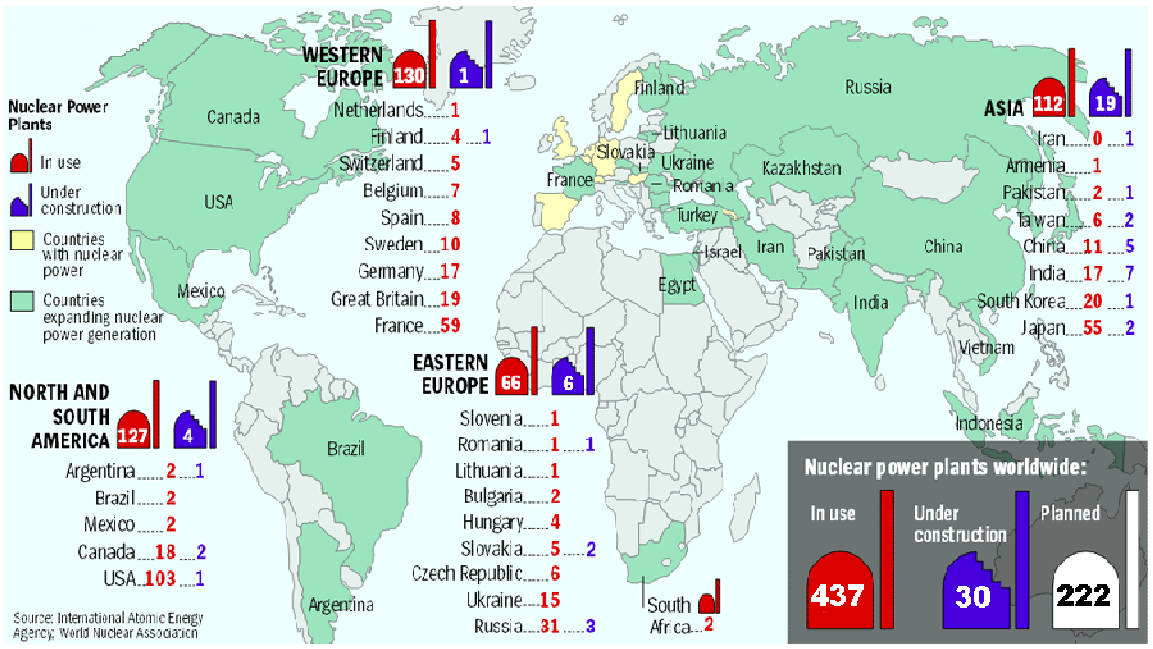
World Nuclear Association. (2007, April). *Policy Responses to Global Warming.* Retrieved from world-nuclear.org: http://www.world-nuclear.org/info/inf105.html

World Nuclear Association. (2007, May 31). *World Nuclear Power Reactors b2006-07 and Uranium Requirements.* Retrieved from world-nuclear.org: http://www.world-nuclear.org/info/reactors.html

Wrobel, S. (2007, February 11). *Israel considers building nuclear plant.* Retrieved from Jerusalem Post: http://www.jpost.com/servlet/Satellite?cid=1170359834179&pagename=JPost%2FJPArticle%2FShowFull

Appendix 1

World nuclear energy map



Original map retrieved from Spiegel.com website. Numerical values of the distribution of nuclear power plants have been digitally altered to concur with 2007 data retrieved from the International Atomic Energy Agency and World Nuclear Association. The image may be subject to international copyright and is used here solely as a visual aid. The authors of this paper bear no intention of publishing this image beyond the scope of the academic assignment at IDC Herzliya.

Appendix 2

Electricity Production Competitiveness Chart