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# **Case Study: Programme for Nuclear Energy Development in Jordan**

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Planning and Strategy Development

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Jordan Atomic Energy Commission



# Jordan Country Profile



- Total Area: 89 213 sq. Km
- Sea Port: Aqaba
- Coastline: 26 Km
- Population: 5.96 million  
31% (15- 29) 38% (below 15)
- Climate: Mediterranean & Arid Desert
- GDP: \$21.5 billion
- Per Capita: \$3,554
- Annual GDP Growth: 7% (2000-2009)

# Challenges

- Growing energy demand
- Increasing energy costs
- Lack of conventional energy resources
- Increasing dependence on imported fuel
- Scarcity of water resources
- Degradation of environmental conditions due to increasing consumption of fossil fuel resources

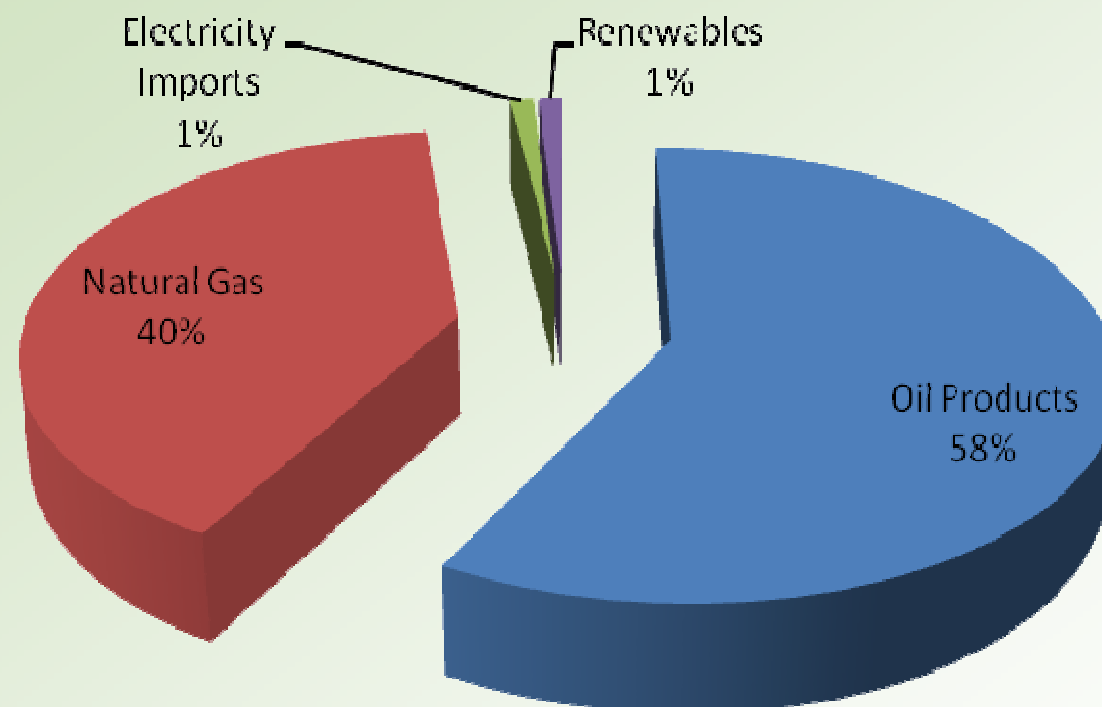


# Jordan Energy Options

- Options are limited:
  - Natural Gas is a short term option and cannot be relied on for mid or longer term .
  - Renewable Technologies are mainly high cost, limited utilization, and cannot be base load .
  - Oil Shale, a limited medium term, reserved for special uses .



# Energy Mix - 2009

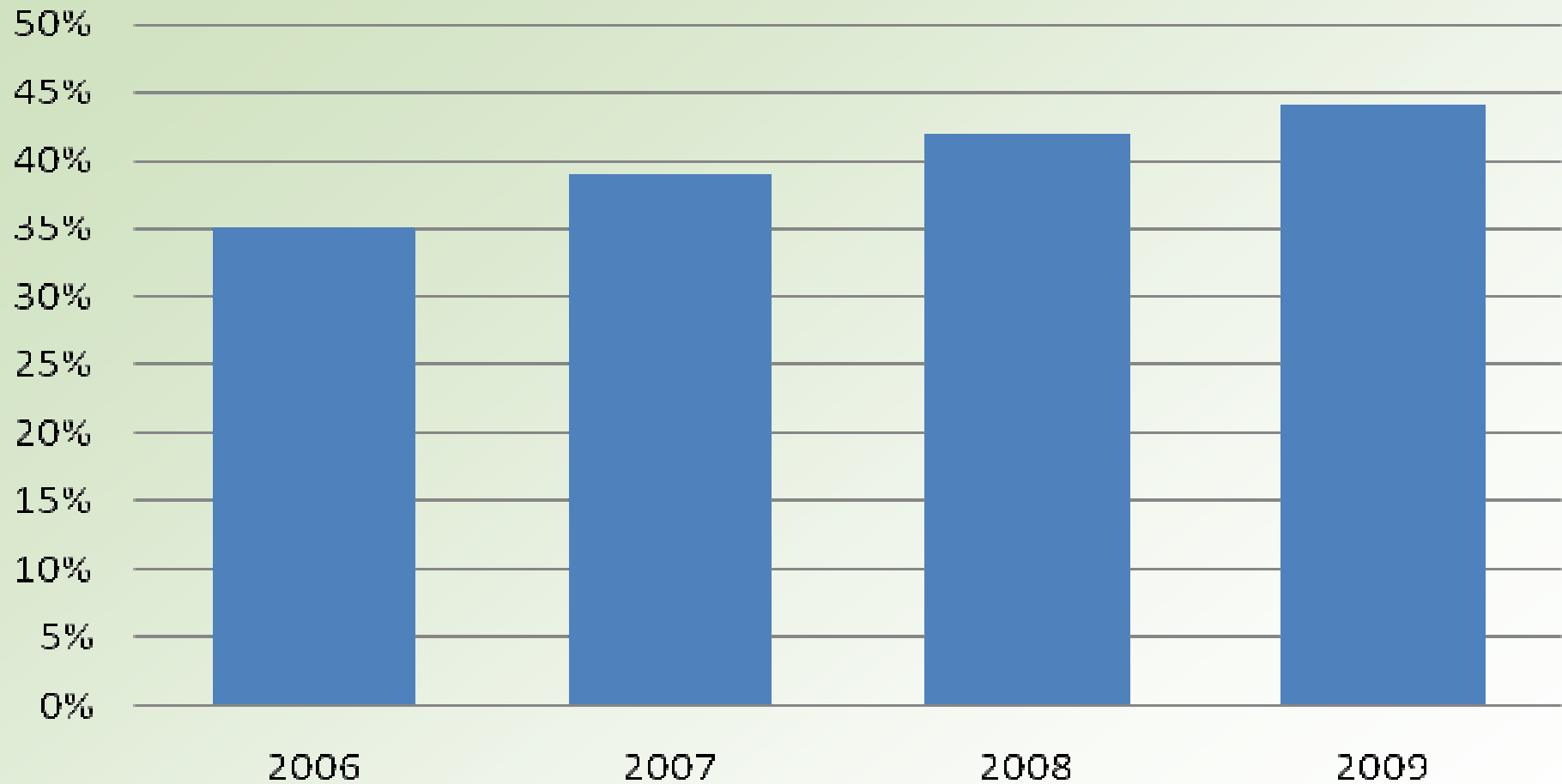


# Cost of Imported Energy

Year	Cost of Imported Energy (US\$ Billion )	Cost of Imported Energy Related to		
		Exports %	Imports%	GDP%
2003	1,1	27	19	11
2004	1,6	42	20	14
2005	2,5	58	24	20
2006	2,7	52	24	19
2007	3,2	57	24	20
2008	3,9	50	23	20



## Electricity Generation Percent of Total Primary Energy



# Jordan's Geographical Position

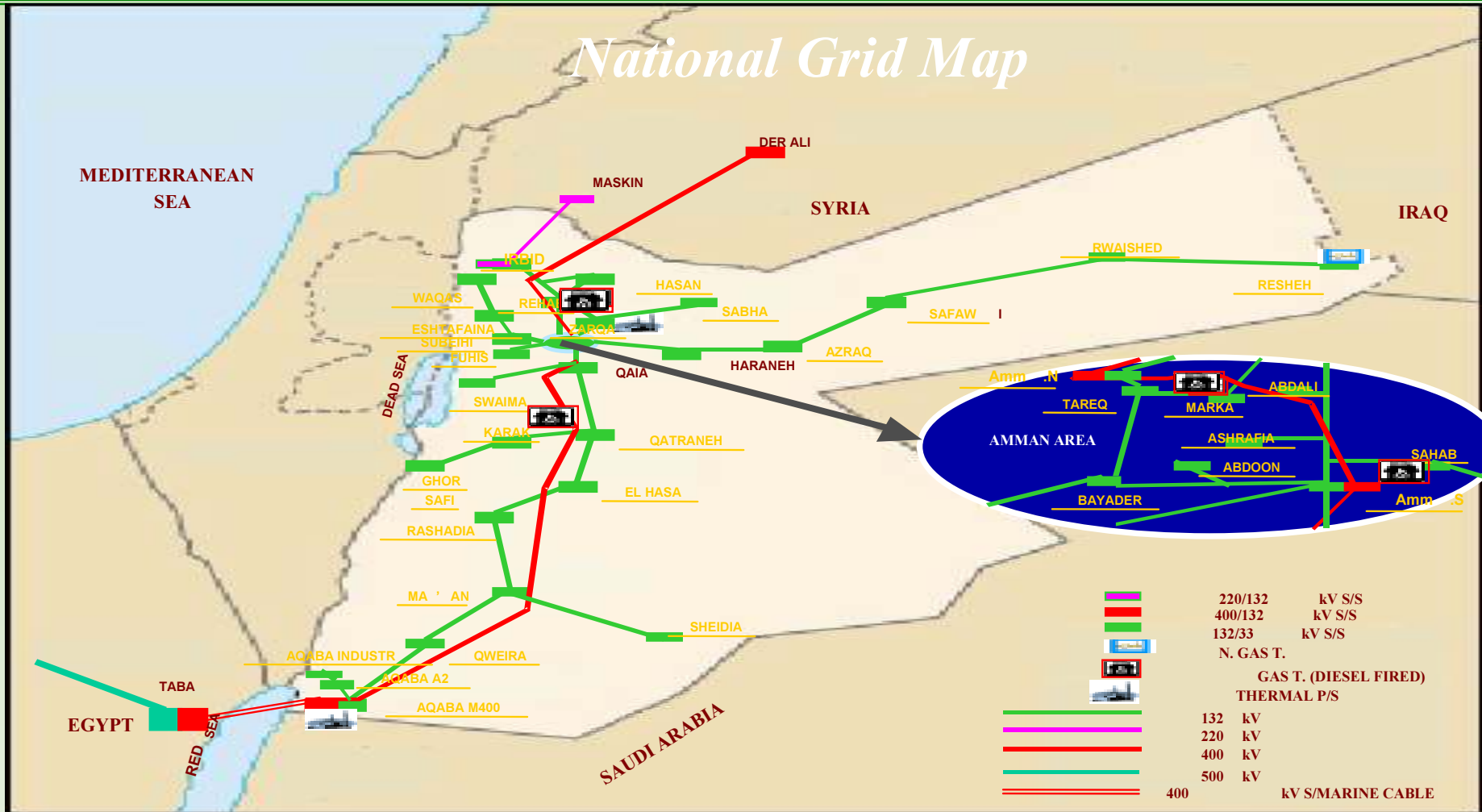
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Jordan is considered as a hub and transit country that can play a major role linking oil, gas and electricity networks among the region.

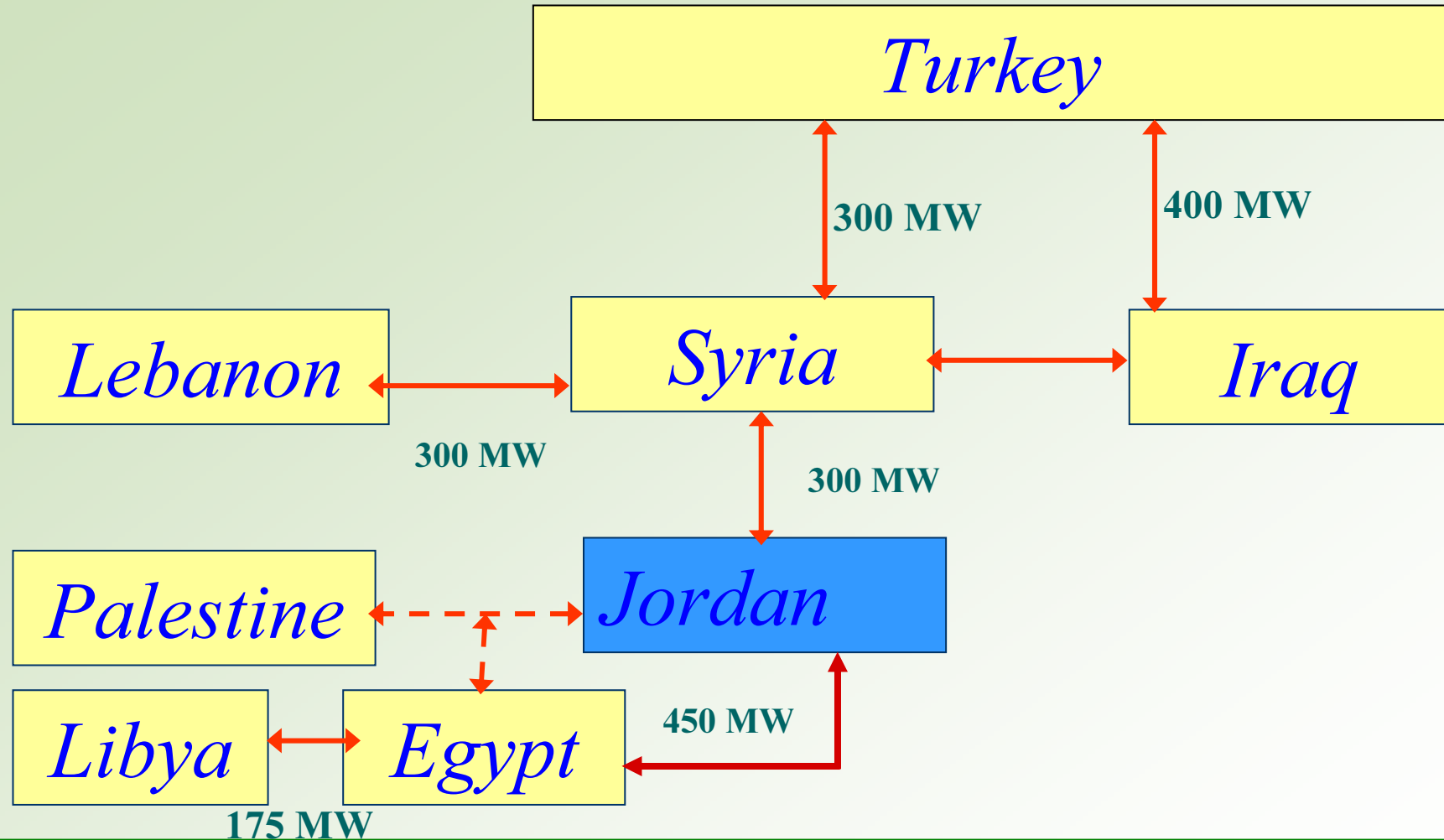




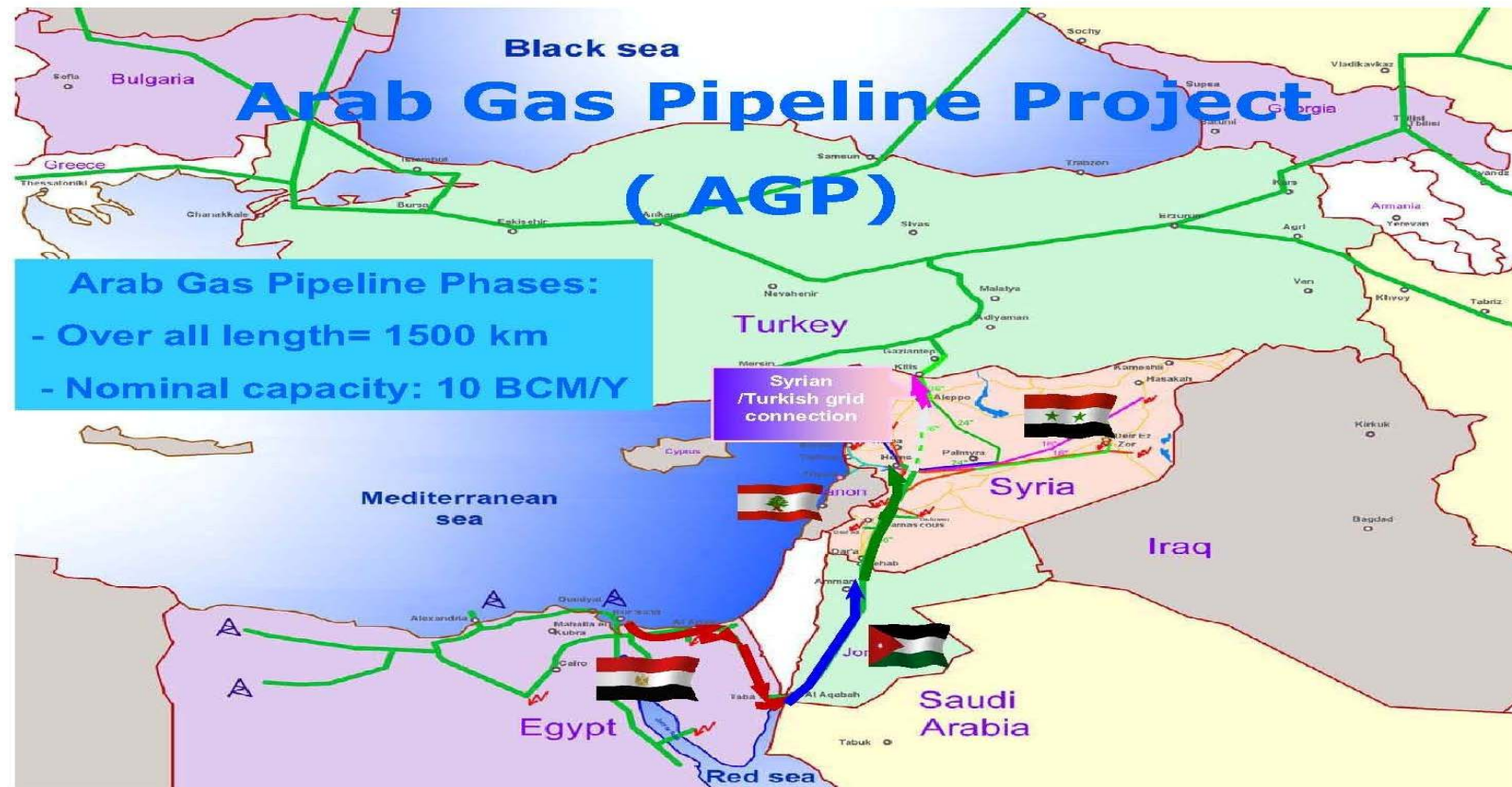
# Electric Interconnection with Neighboring Countries



# Electric Regional Interconnection



# Arab Gas Pipeline



# Jordan's Energy Strategy ( 2007-2020)

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- Diversifying the energy resources
- Increasing the share of local resources in the energy mix
- Reducing the dependency on imported oil
- Enhancing environment protection



# Jordan's Nuclear Strategy

- Ensuring security of supply including fuel
- Leveraging of national Uranium assets
- Promoting public/private partnerships
- Ensuring effective technology transfer and national participation in all phases
- Providing for water desalination and eventually hydrogen production
- Development of spin-off industries
- Enhancing electricity export
- Enabling competitive energy-intensive industries



# NPP Project Background and Benefits

## Project Background

- 99% of Jordan's electricity is generated from **either oil or gas, which is in turn 96% imported**
- 6800 MW of new power generating capacity **needed to satisfy the demand by 2030**
- Decision has been reached to **build a new Nuclear Power Plant**

## Project Benefits

- Increase **energy independence**,
- Provide electricity to the country at a **reasonable price**,
- **Ensure additional income** and balancing loads by exporting electricity to the neighboring countries (Egypt, Saudi Arabia, Iraq, Syria and Palestine),
- Utilize/ Leverage **domestic uranium reserves**,
- Provide opportunity to **develop nuclear capabilities**, including participation in project development, design, construction, and plant operation,
- **Multiplicative effect on local economy** via infrastructure upgrades, job creation, provision of services, and education of workforce,
- **Reduce CO2 emissions**, by switching to minimum CO2-intensive electricity production
- **Support major infrastructure projects**, such as Red Sea – Dead Sea Canal project



# Five Measures

1. **Generation.** Policy : privatized but with Gov. equity (PPP model). International nuclear operator with safe record + investment for the plant
2. **Uranium Exploitation.** Policy : maximize sovereignty while creating value from resource. Avoid concessions
3. **Fuel Cycle:** Negotiate assurances for fuel services including waste disposal
4. **Getting Country Ready:**
  1. Investment for all studies
  2. Investment in training and HR
  3. Investment in infrastructure
5. **Funding** : Investigate creative financing methods that minimize central Gov. resources



# Legal Framework

	In Force	Status
Agreement on the Privileges and Immunities of the IAEA	1982-10-27	Acceptance: 1982-01-27
Convention on Early Notification of a Nuclear Accident	1988-01-11	Signature: 1986-10-02 Ratification: 1987-12-11
Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency	1988-01-11	Signature: 1986-10-02 Ratification: 1987-12-11
Convention on Nuclear Safety	Feb. 2009	Signature: 1994-12-06
Revised Supplementary Agreement Concerning the Provision of Technical Assistance by the IAEA (RSA)	1989-02-05	Signature: 1974-12-05
Co-operative Agreement for Arab States in Asia for Research Development and Training Related to Nuclear Science and Technology (ARASIA)	2002-08-20	Acceptance: 2002-08-20





# Legal Framework (2)

	In Force	Status
<b>Application of Safeguards in connection with the Treaty on Non-Proliferation of Nuclear Weapons (with protocol)</b>	<b>1978-02-21</b>	<b>Signature: 1974-12-05</b>
<b>Protocol Additional to the Agreement between the Hashemite Kingdom of Jordan and the IAEA for the Application of Safeguards in connection with the Treaty on Non-Proliferation of Nuclear Weapons</b>	<b>1998-07-28</b>	<b>Signature: 1998-07-28</b>
<b>Convention on the Physical Protection of Nuclear Materials</b>		<b>Will be ratified next month</b>
<b>Civil Liability for Nuclear Damage</b>		<b>Under consideration</b>



# International Cooperation

- Engaged the following countries and explored with them solutions to Jordan's challenges :
  1. USA
  2. Canada
  3. France
  4. Russia
  5. China
  6. UK
  7. South Korea
  8. Romania
  9. Spain
  10. Argentina
  11. Japan
  
- Signed NCA with France, China, South Korea ,Canada , Russia , UK, Spain and Argentina.
  
- Ongoing negotiations with USA , Japan and Romania.



# Uranium Exploitation in Central Jordan

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- A beauty contest was conducted
- Three major companies were short listed
- Negotiations were concluded with Areva on Uranium exploration in Central Jordan and an Agreement was signed in Paris in Sep. 2008
- A mining agreement was signed with AREVA in Amman in Jan. 2010



# Human Resources Development

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- Jordan University of Science and Technology - established a nuclear engineering dept. to graduate future reactor operators holding BSc degrees in nuclear engineering
- An active training TC programme with IAEA
- JU, YU, BAU have started MSc programs in nuclear physics & students are trained on the Van de Graaf & SESAME
- JAEC signed an agreement with an international vendor to build a 5 MW research reactor in March 2010.



# Site Selection

- **Step 1 : Regional survey, Aqaba selected as a suitable location.**
- **Step 2 : Site selection & characterization which entails all the necessary data and reports such as:**
  - Geology- geophysics- cooling water requirements- risk assessment- grid connections- human induced events and land use- Environmental Impact Assessment...etc;*
  - **An RFP for site selection and characterization study has been launched on December 28<sup>th</sup> ,2008, where 17 international expert houses have been invited. Only 8 international consultants showed interest in this study and participated in the site visit conducted on February 1<sup>st</sup> ,2009.**
  - **Site selection and characterization contract signed with an International Consultant on September 12, 2009.**
- **Completion of the site selection and characterization work by the end of 2010.**
- **Site approval by the JNRC by mid 2011.**



# Grid Stability and Adaptability

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- An agreement was signed on Feb. 18, 2009 between National Electric Power Company and an international consultant to address the stability of Jordan's T&D network from introduction of large sized NPP.
  - The report is expected to be finalized in July 2010.



# Pre-Construction Consulting Services

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- An International Consultant was selected Nov. 15, 2009 as Consultant with scope:
  - Feasibility and Financial Assessment
  - Vendor-Technology/Investor Assessment
  - Preparation of Utility Structure
  - Support to JNRC for Siting Assessment



# EVOLUTIONARY WATER COOLED REACTOR DESIGNS

## Evolutionary LWRs

- 1380 MWe **ABWR** (Toshiba); 1360 or 1500 MWe **ABWR** (GE-Hitachi);
- 1700 MWe **ABWR-II** (Japanese utilities; GE-Hitachi or Toshiba);
- 1540 MWe **APWR** & 1700 MWe **APWR+** (Mitsubishi)
- 600 MWe **AP-600**; 1100 MWe **AP-1000**; and 335 MWe **IRIS** (Westinghouse)
- 1550 MWe **ESBWR** (GE-Hitachi)
- 1545 MWe **EPR** and 1250 MWe **SWR-1000** (Areva)
- 1100 MWe **ATMEA1** (Areva & Mitsubishi)
- 1000 MWe **APR** and 1400 MWe **APR (KHNP)**
- 1000 MWe **CPR** (CGNPC); 650 MWe **CNP** (CNNC) and 600 MWe **AC-600** (NPIC)
- 1000 MWe **WWER-1000 /1200 (V-392)**; WWER-1500; and WWER-640 (V-407) (**AtomEnergProm**)

## Evolutionary HWRs

- 700 MWe **Enhanced CANDU-6 (AECL)**
- 1000 MWe **Advanced CANDU (ACR) (AECL)**
- 540 MWe & 700 MWe **HWR (NPCIL)**
- 700 MWe **AHWR (BARC)**





# Quantified Long Term Energy Scenarios

- Load Forecast
  - Market Survey
  - Econometric Approach
  - MAED
  
- Expansion Plan
  - WASP
  - MESSAGE
  
- Financial Model
  - FINPALN



# Load Forecast

- **Load Forecast**

Electricity consumption (kilowatt-hour) is divided into homogenous groups (sectors) with similar consumption pattern; domestic, commercial, services, industrial, water pumping and public lighting sector. GDP growth, population growth and electricity prices are the main driving factors.

- **Market Survey**

Forecast the electricity demand of the bulk supply consumers.

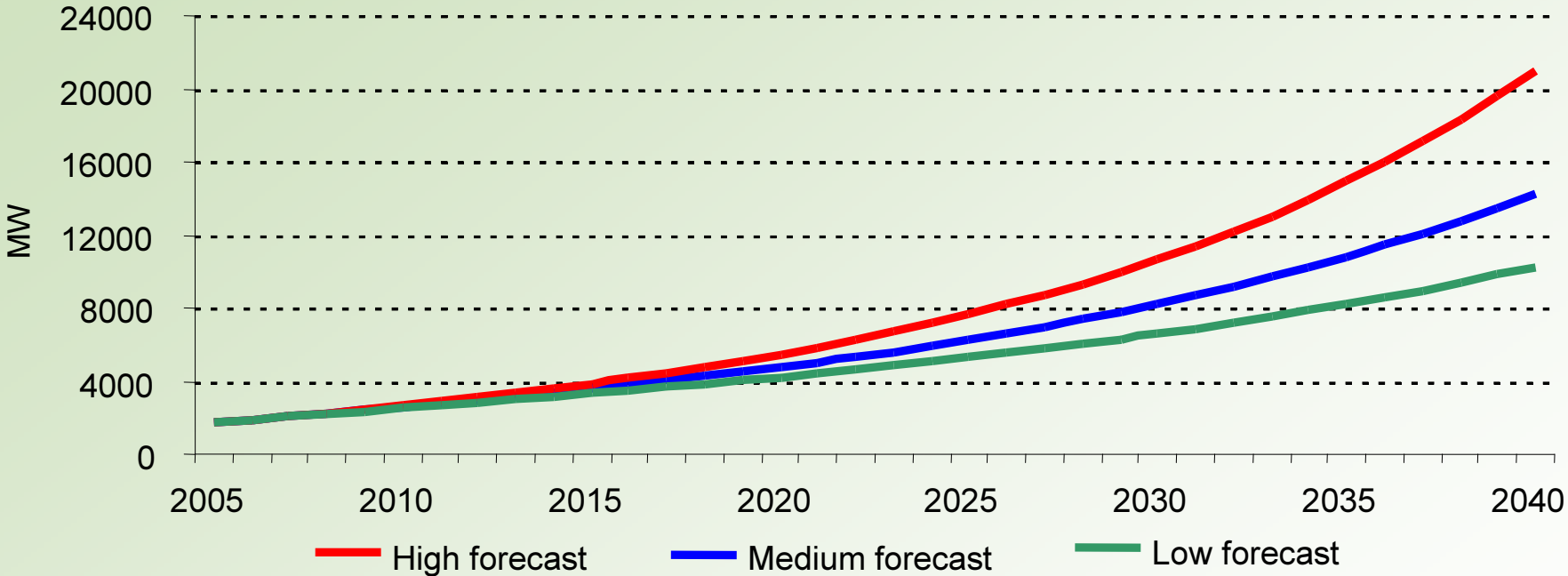
- **Econometric Approach**

Forecast using Single or multiple regression models.



- **Model for Analysis Energy Demand (MAED)**
  - MAED model evaluates future energy demand based on medium- to long-term scenarios of socio-economic, technological and demographic developments.
  - JAEC Currently is working with Ministry of Energy and Mineral Resources to develop future energy demand scenarios using MAED.

# System Peak Load Forecast (High, Medium and Low)



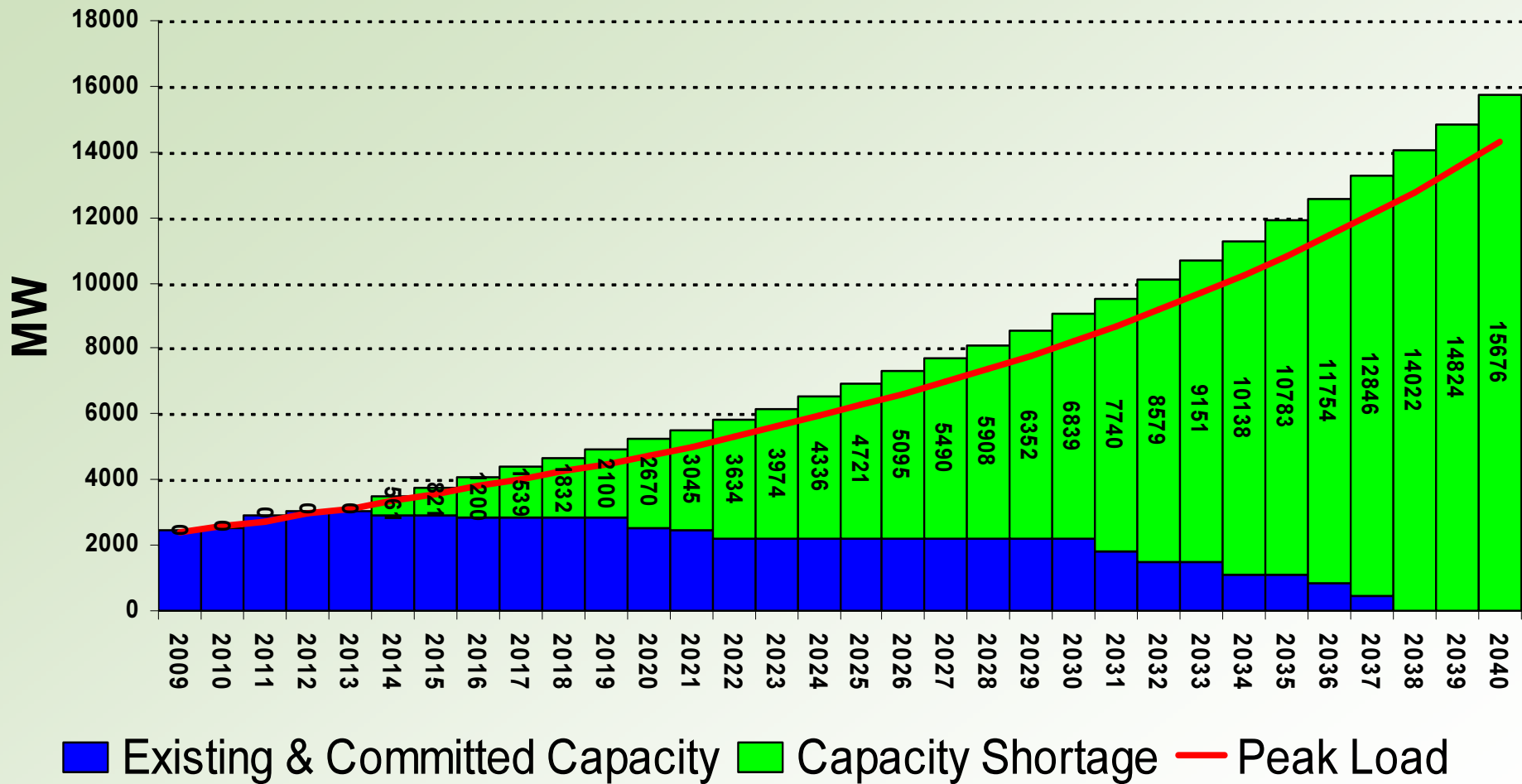
GDP: 7%  
 Pop: 1.5%  
 El-p: 1%

GDP: 6%  
 Pop: 1.4%  
 El-p: 1%

GDP: 5%  
 Pop: 1.3%  
 El-p: 1%



# Available and Committed Capacities versus the Electricity Median Load Forecast



# Economic Evaluation and Expansion Plan Main Assumptions

- Leveraging Jordan's local resources of uranium and oil shale.
- Importing oil from international markets at international prices.
- Importing natural gas from Egypt and international markets.
- Limiting the available quantities of natural gas.
- Capping the capacity of future NPPs and oil shale units.



# Future Candidates

<b>Technology</b>	<b>Size (MW)</b>
CCGT	380
GT	60
ST	300
OSPP	300
NPP	1000
NPP	700



# Economic Evaluation and Expansion Plan

- Wien Automatic System Planning Package (WASP)
  - Sixteen scenarios were developed to assess all future possible expansion plans for Jordan's power system. The analysis took into account the existing plants and equipment, the availability of domestic and imported energy resources and projected prices, and candidate technologies.





# Economic Evaluation and Expansion Plan

- Model for Energy Supply Strategy Alternatives and their General Environmental Impacts (MESSAGE)
  - MESSAGE was used to simulate the vintage, operational specifically and performance, current production structure of Jordan's current power system, and to model future system development options.
  - MESSAGE objective is to meet demand while minimizing total system cost.
  - MESSAGE accounts for the vintage structure of existing plants and equipment, the availability of domestic energy resources, energy trade links and prices, specific technology options for both capacity expansion and replacement of retired units, and relevant energy policy constraints.



# Economic Evaluation and Expansion Plan

- Evaluated Expansion Scenarios (2010-2037):
  - **Base Case Scenario (BCS).**
    - Business as Usual
  - **Nuclear and Oil Shale Scenario (NOS).**
    - Nuclear and Oil Shale
  - **Nuclear and Gas Scenario (NGS).**
    - Nuclear and Additional Quantities of Gas
  - **Nuclear, Gas and Oil Shale Scenario (NGOS).**
    - Nuclear, Additional Quantities of Gas, and Oil Shale
  - **Gas and Oil Shale Scenario (GOS).**
    - Additional Quantities of Gas and Oil Shale



# Analyzed Areas

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- Additional capacities.
- Generated electricity by technology.
- Generated electricity by fuel.
- Generation fuel requirements.
- Substitution effect by technology and fuel.



## Cont'd

- Sensitivity analysis
  - Capital cost of NPPs.
  - Capital cost of oil shale units.
  - Fuel and natural gas import prices.
  - Discount rate.
  - Low electricity demand forecast.
  
- Export of electricity.
  
- Electricity generation cost.
  - Capital
  - O&M
  - Fuel



## Cont'd

- Capital requirements per scenario .
- Levelized generation costs per scenario.
- Capital costs percent of future GDP per scenarios.
- Energy security.
  - Import dependency
  - Import dependency (electricity sector)
- Environmental impacts.



# Results

	<b>BCS</b>	<b>NOS</b>	<b>NGS</b>	<b>NGOS</b>	<b>GOS</b>
<b>Investment</b>	Ref.	42%	29%	37%	-3%
<b>O&amp;M</b>	Ref.	173%	156%	158%	11%
<b>Fuel</b>	Ref.	-58%	-55%	-57%	-20%
<b>Total</b>	Ref.	-27%	-28%	-28%	-15%



# Initial Findings

- Nuclear is a viable and competitive option, and it has been selected for future development.
- The choice of Nuclear is supported by an optimization process in all the scenarios where it is introduced as an option.
- Scenarios with nuclear require higher investment costs, but total generation costs of the system are lower.



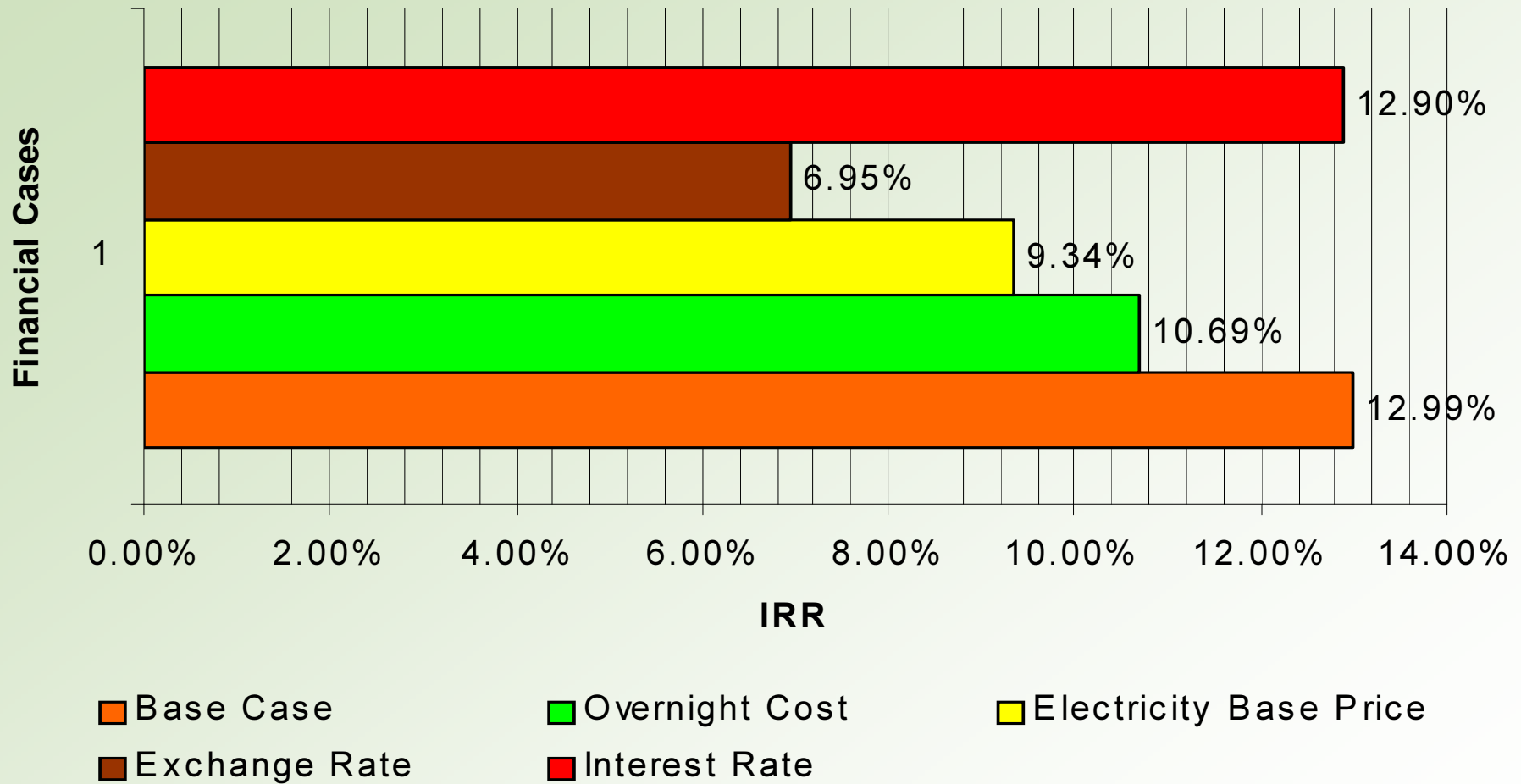
# Financial Analysis

- A financial model was developed with the support of IAEA using the FINPALN program for a 1000 MW NPP.
  - Base Case
  - Exchange Rate (40% decrease)
  - Electricity Price (20 % decrease)
  - Capital Cost (30% increase)
  - Interest Rate (30% increase)
- The model is currently under revision by the IAEA experts.





# Financial Results



# Regional Energy Planning

- ARASIA project “Comparative Assessment of Electricity Generation Options (RAS/0/043)”.
  - United Arab Emirates, Saudi Arabia, Syria, Iraq, Jordan, Lebanon and Yemen.
  - The first draft of the report was issued in January 2010.
  - The analysis was conducted using MESSAGE.
- ARASIA project “Supporting Strategic Planning to Meet Future Energy Needs in ARASIA Member States(RAS/0052)”.
  - United Arab Emirates, Saudi Arabia, Syria, Iraq, Jordan, Lebanon and Yemen.
  - The work plan is in place.
  - The analysis will be carried out using MESSAGE.
  - Emphasis on long-term supply scenarios (2050), clean technologies, and water supply.



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# Thank you

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Jordan Atomic Energy Commission

