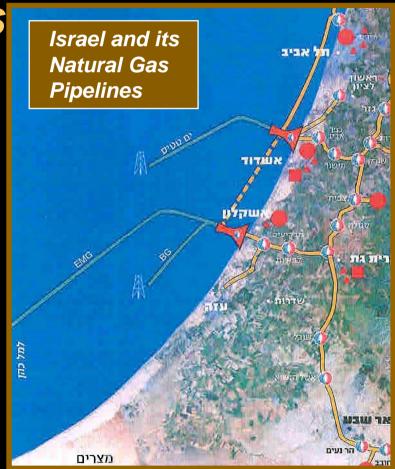


Environment, Energy, and Economic Development

A RAND INFRASTRUCTURE, SAFETY, AND ENVIRONMENT PROGRAM

Natural Gas and Israel's Energy Future: Near-Term Decisions from a Strategic Perspective

Steven W. Popper "IQ SCENE" Workshop University College London-CIRED 26 March 2014



2006: Israel Was A Small Energy 'Island'... ...Facing a Quiet Electricity Crisis

- Uncomfortable race between electricity demand and supply
 - Traditional reliance on imported fuel: oil, coal, natural gas
 - Growing demand, driven by population and economic growth
 - Need for large investments to produce more electricity
- National concern about energy-related issues
 - Environment and health
 - Economics and cost stability
 - Supply security
 - Land use

Choices would affect at least two generations of Israelis... ...and the political system had not been able to choose



Our Goal Was <u>Not</u> Better Forecasts

We wanted to show several things:

- Prediction: neither credible nor reliable for complex problem with many unknowns
- Instead, ask:
 - "What actions today will be likely to achieve long-term goals across many plausible futures?"
- Demonstrate a planning approach built on flexibility
- Encourage adoption of robust adaptive posture toward an uncertain future
- Potential for capacity building



גז טבעי ועתיד האנרגיה בישראל

קבלת החלטות בטווח הקצר מנקודת מבט אסטרטגית

סטיבן פופר, קלוד בר רבי, ג׳יימס גריפין, תומאס לייט, אנדי מין, קית קריין

מחלקת סביבה, אנרגיה ופיתוח כלכ

Our Work Was Framed in Line with the Project's Broader Objectives

- Maximize process contacts with end-user communities
 - Periodic meetings with government steering committee
 - Extensive interviewing and engagement with professional staff
 - Several workshops with important stakeholder or analytical communities
- Maintain accessibility, transparency, visibility
 - As much as possible use models, data already familiar
 - Use off-the-shelf software environments
 - Seek to understand rhetoric of argumentation and judgment
- Ensure multiple points of entry
 - Begin from the end: who needs to know what -- and why?
 - Lead with final form visualizations with drill-down capability

"XLRM" Format Lays Out Model Design

EXogenous Uncertainties

Price path for coal Price path for natural gas Cost of carbon dioxide (CO2) emissions Cost of fossil-fuel technology Cost of non-fossil fuel technology Availability of non-fossil fuel technology Demand for electricity Cost of efficiency improvements Administrative limits on GHG emissions Cost of capital Supply from foreign pipelines Discovery of new domestic reserves Fixed cost of LNG installation Variable cost of LNG supply Fixed cost of new domestic natural gas Variable cost of new domestic natural gas Cost of storage capacity

Relationships

WASP package MAED RAND Israel energy sector model - LEAP - Excel RAND natural-gas supply model: - Excel

Levers Under Control

New plant type and primary fuel National infrastructure construction Level of reserve generation capacity (policy) Share of generation capacity from coal and nonfossil fuel (policy) Dispatch order of electricity generation Administrative control of GHG emission levels Administrative control of land use Imposition of price on carbon emissions Adoption of non–fossil fuel technology and capacity Energy-efficiency enhancement Target level of reserve capacity Rate of domestic reserve depletion Level and timing of LNG capacity Fuel storage types Fuel storage levels

Measures of Outcomes

Total system costs Total fuel costs Balance of cost-sharing over generations Annual natural-gas supply requirement GHG emissions Land-use requirements Level of reserve generation capacity (actual) Share of generation capacity from coal and nonfossil fuel Depletion of domestic reserves (actual) Cost of providing a given level of supply insurance Cost of implementing supply insurance Potential unmet demand for electricity

We Built a Detailed, Easily Modified Model of Israel's Energy Sector...

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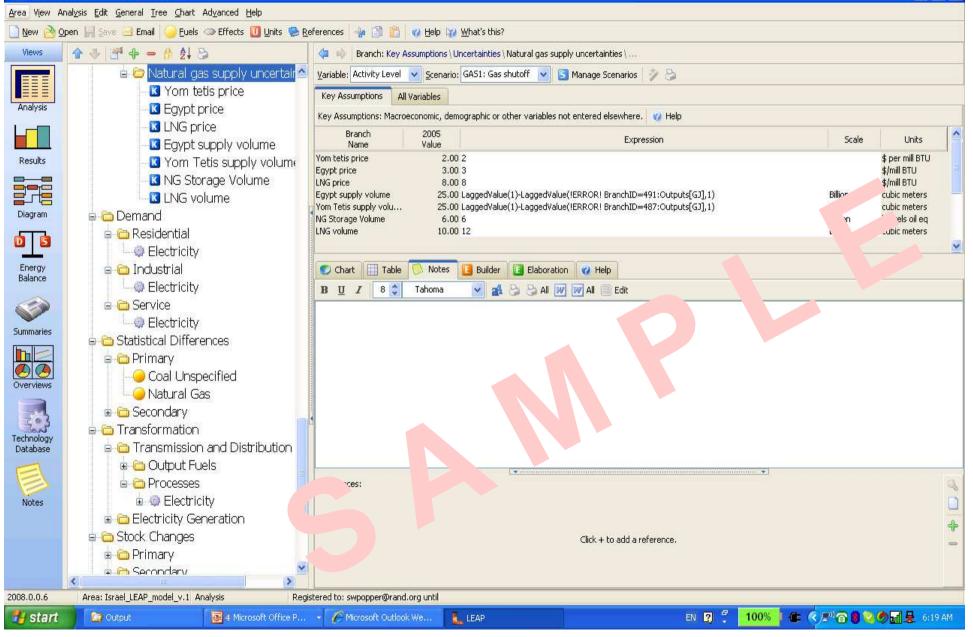
....Within the LEAP Energy Accounting and Simulation Software...

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	Carrier Annual Hovay_IT availability			Click + to add a reference.			-		

... Using Data from Ministry and IEC

LEAP: Israel_LEAP_model_v.1_constrained



We Analyzed Strategies in Two Steps

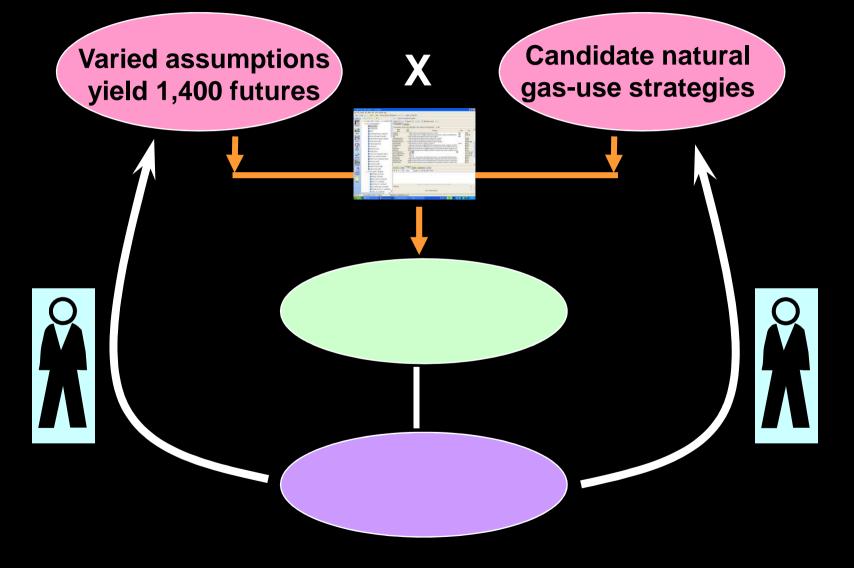
Israel's needs and goals ; but also future uncertainties ... Robust strategies for natural gas <u>utilization?</u>

 Robust strategies for supply infrastructure?



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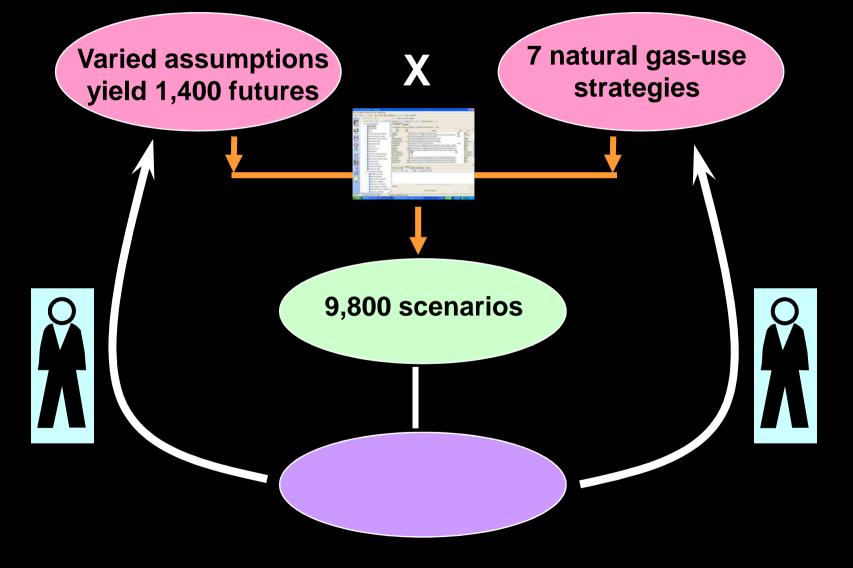
We Created Scenarios of Strategic Outcomes



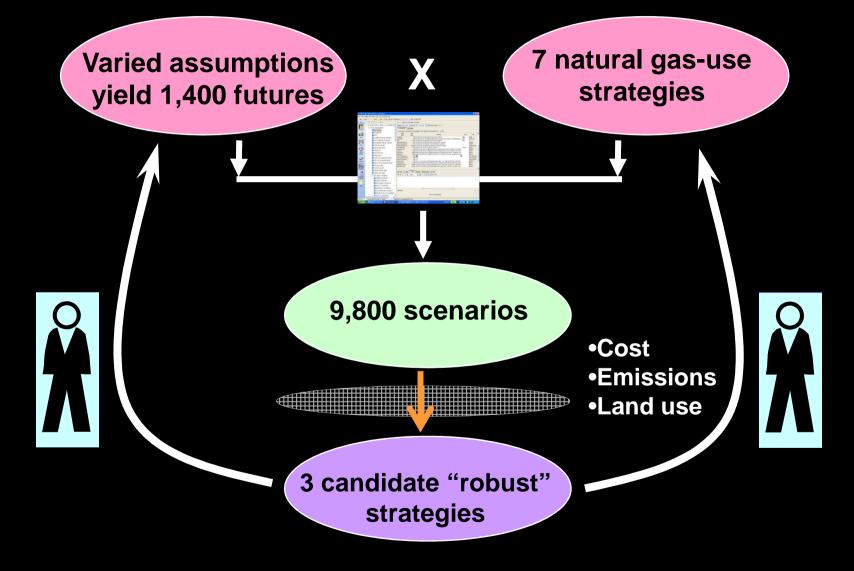
We Identified <u>Rule-based</u> Candidate Strategies: Built Up from Simpler, More Vulnerable Versions

Name	Prefers to Build:	Will Build Coal Plant <i>IF</i> :	Builds Renewable Plants?	Invests in Efficiency?	Retires Coal Plants?	Always Follows Rules?	
Less NG Rule	Gas CC	< 50% of generation; < GHG limit; & cost < gas cost or Coal and renewables < 40% of generation; & GHG < limit	If in scenario & cost ≤ cost of gas CT	If cost < cost of gas CT	No	Yes	
Least Cost Rule	Least cost among coal, gas, and renewable	Least cost	Yes, if cost < gas CC or coal	If cost < cost of gas CT	1 in 2020 and 1 in 2025 if operating costs > replacement)	Yes	
More NG Rule	Gas CC	One in 2020 & one in 2025 if cost < cost of gas or renewable	If in scenario & cost ≤ cost of gas CT	If cost < cost of gas CT	1 in 2020 and 1 in 2025 if operating costs > replacement)	Not if cost of gas CC > 130% of coal costs	
WASP (Base- line)	According to plan	According to plan	According to plan	Νο	Νο	Yes	
RANDNB: "Cost" = levelized cost of electricity (LCOE)A8778p- 11 04/2010							

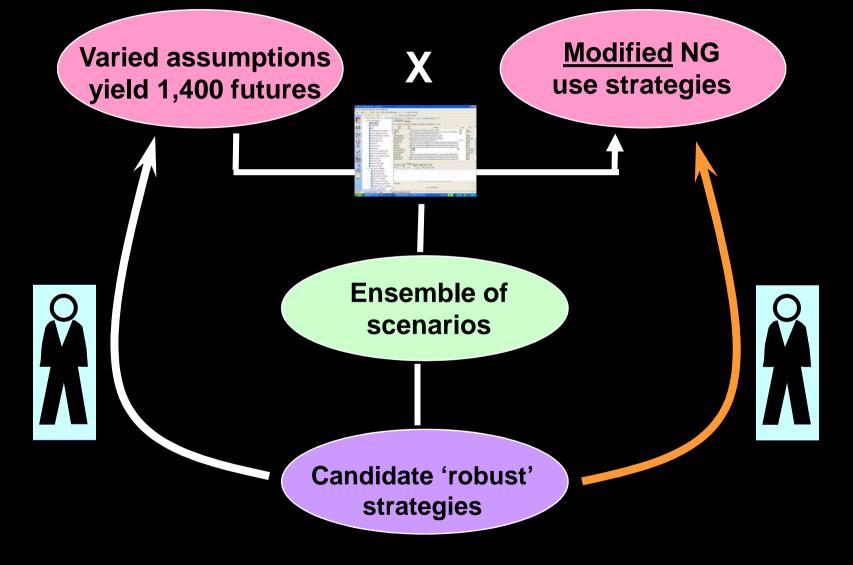
We Created Scenarios of Strategic Outcomes



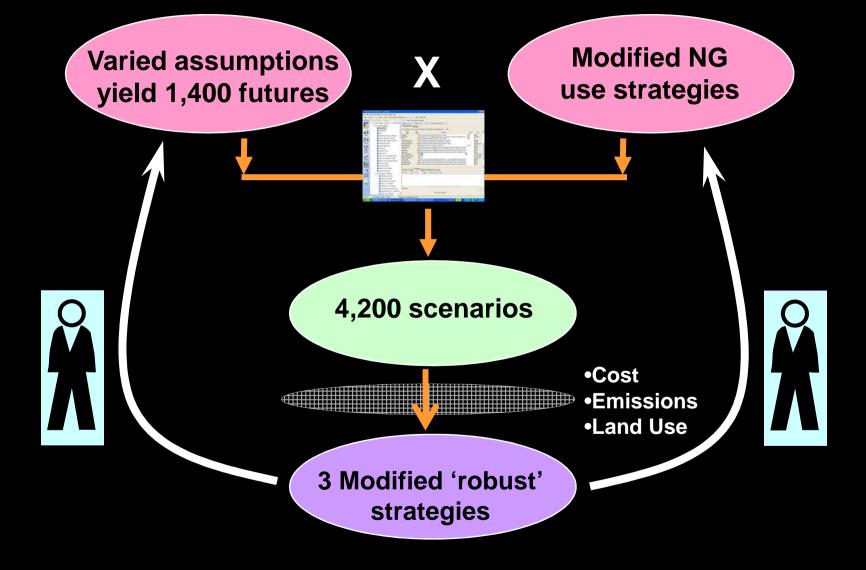
We Identified the Most Robust Strategies



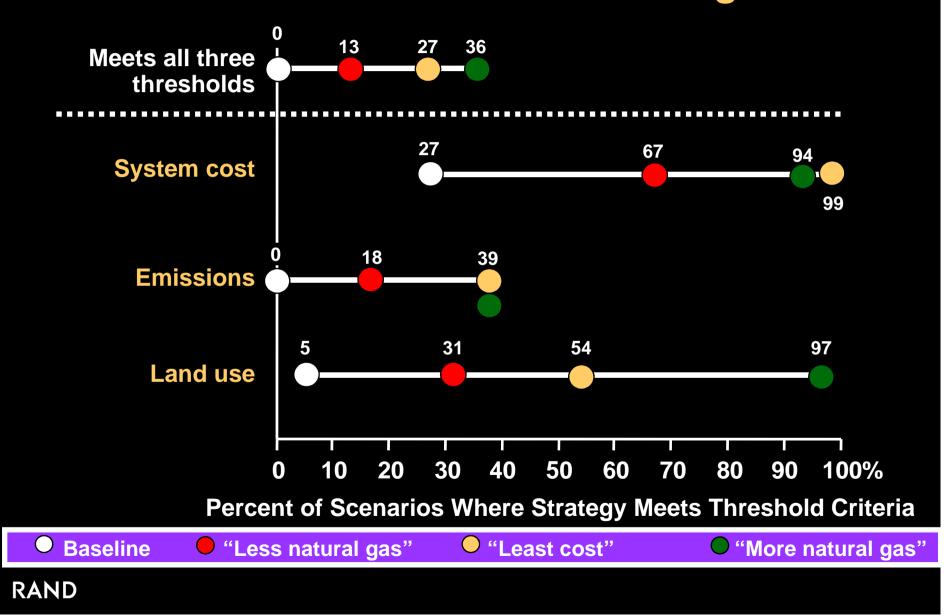
We Amended Strategies to Limit Weakness



Then, We Tested the Modified Strategies Again



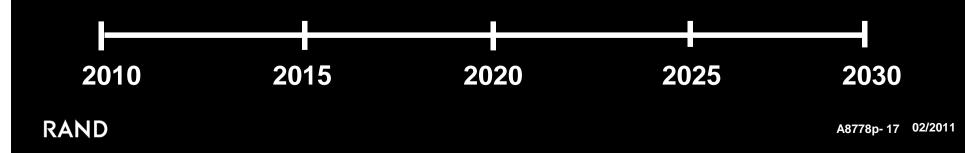
"More Natural Gas" Appears To Be the Most Robust of the Candidate Strategies



But What Are Reliable Sources for Future Additional Natural Gas Supply?

Strategies could draw natural gas from

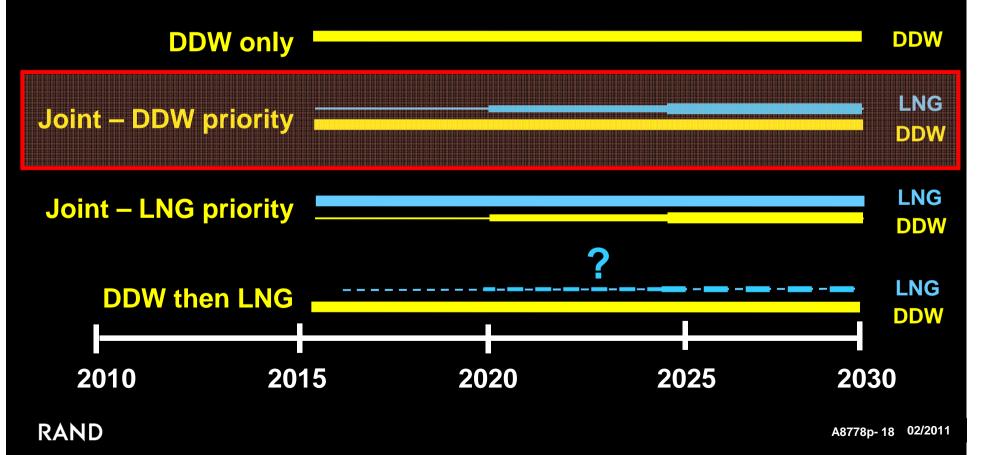
- Domestic deepwater (DDW) reserves
- Liquid natural gas (LNG) terminal



Analysis Suggests Joint DDW Might Be Most Robust for Additional Future Supply

Strategies could draw natural gas from

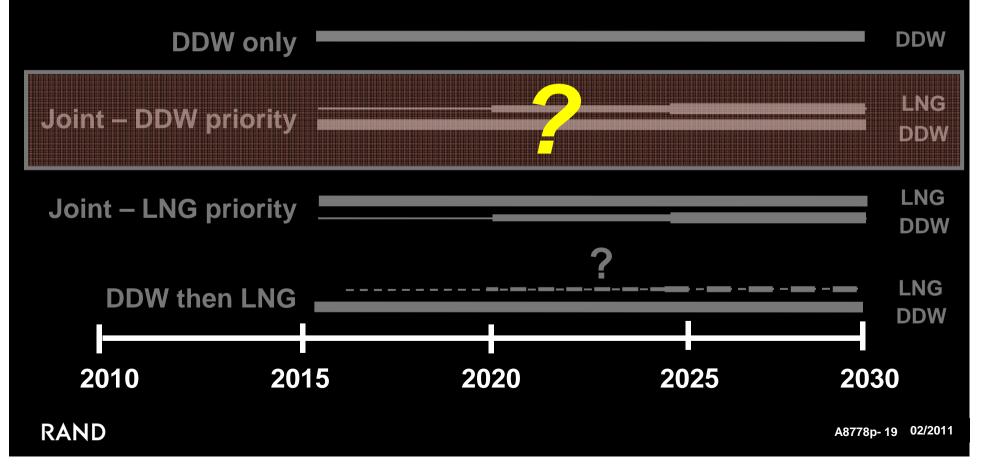
- Domestic deepwater (DDW) reserves
- Liquid natural gas (LNG) terminal



Is This Really True?

Strategies could draw natural gas from

- Domestic deepwater (DDW) reserves
- Liquid natural gas (LNG) terminal



What If Israel Actually Had a Supply Emergency?

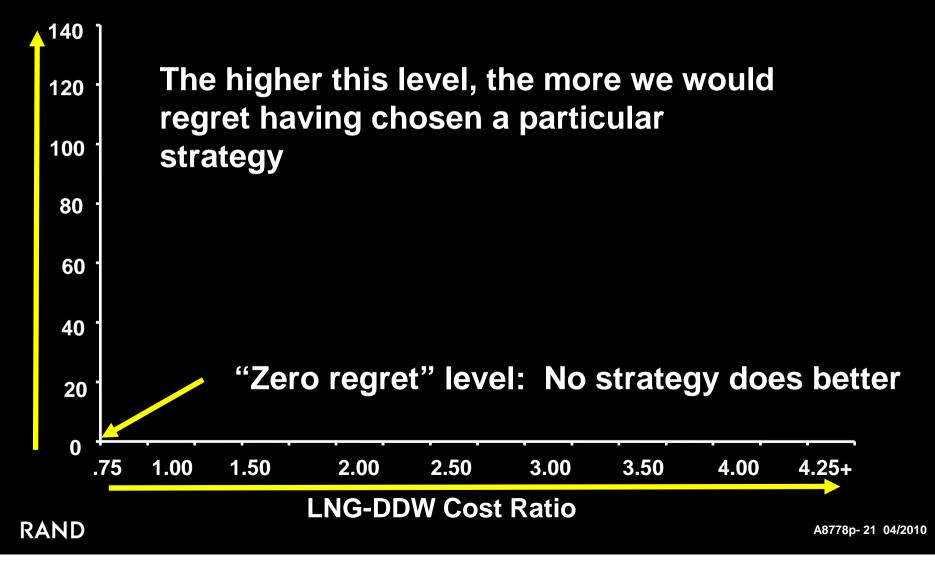
We anticipated current events by examining an especially vulnerable future year

- In 2025, there is a one-year supply shutoff from existing foreign natural gas pipeline
- Each strategy must pay costs for implementing its policies; for example
 - Draw on diesel or natural gas storage
 - Draw more from LNG or DDW reserve capacities
 - Impose brownouts

Which strategy performs best under these emergency conditions?

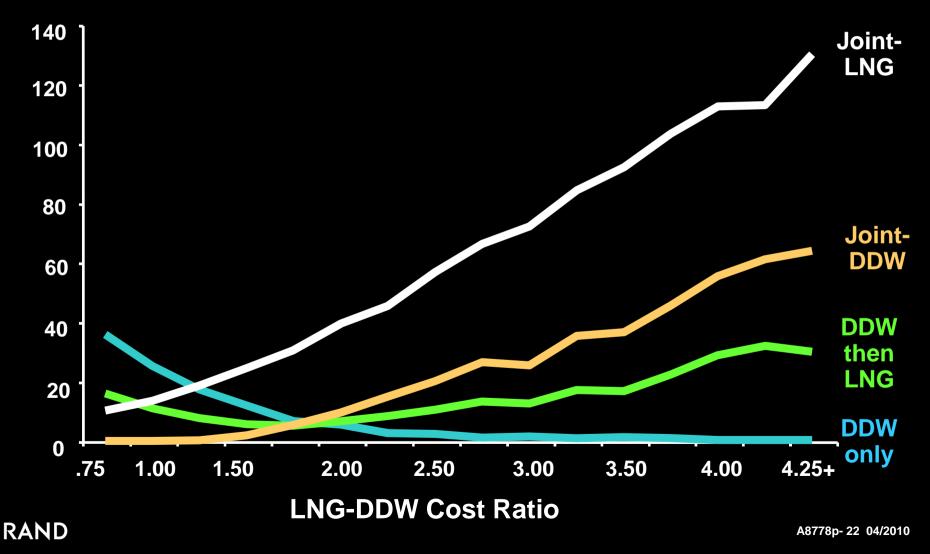
Without Prediction, We Want to Know Basis for Making Strategic Choices

Expected costs above least cost for each scenario (%)



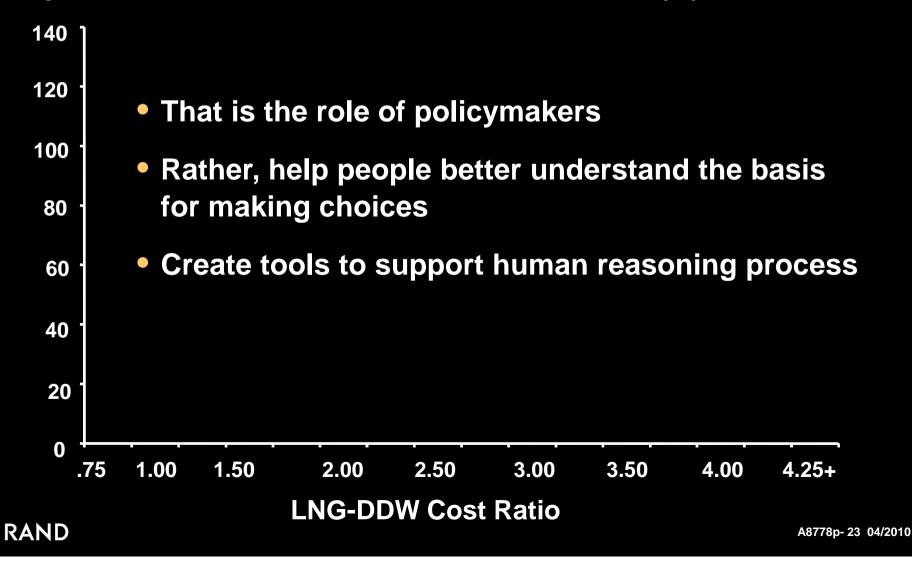
Total Cost in Emergency Depends on Future LNG and DDW Natural Gas Costs

Expected costs above least cost for each scenario (%)



Goal Is Not to Have Computer Provide Answers

Expected costs above least cost for each scenario (%)



Report Delivered in December 2009;

In 2010...

- Israel's Ministry for National Infrastructures decides:
 - To completely redo the energy master plan for the State of Israel...
 - ...based on the principles demonstrated in the RAND study





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