“The most **calamitous failures of prediction** usually have a lot in common. We focus on those signals that tell a story about the world as we would like it to be, not how it really is. **We ignore the risks that are hardest to measure, even when they pose the greatest threats**...

We abhor **uncertainty** even when it is an **irreducible part of the problem we are trying to solve.**”

-Nate Silver. The Signal and the Noise

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Università Ca'Foscari Venezia

Making Informed Investment Decisions in an Uncertain World: A Short Demonstration

Laura Bonzanigo & Nidhi Kalra

SDNCE, The World Bank

June 19, 2014

Many Policy Decisions Have Long-Term Consequences

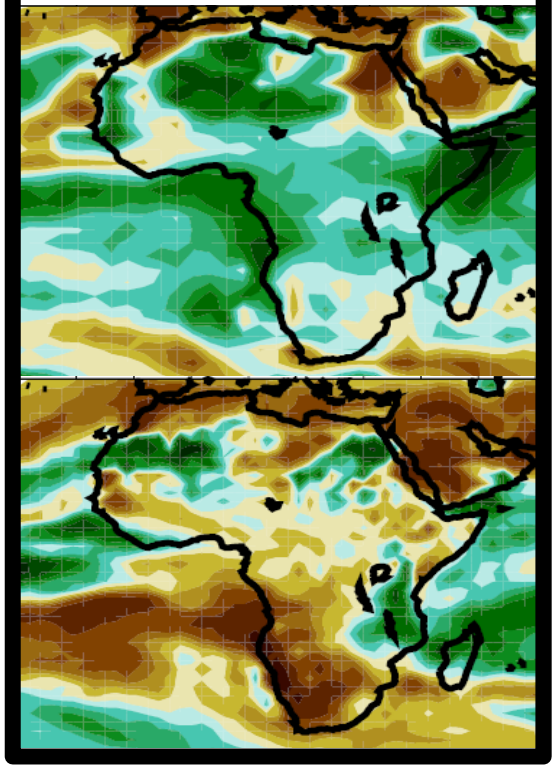
Good Decision Making Is Challenged By Uncertainty and Disagreement

Rapid Changes

Shanghai 1990 vs. 2010

Uncertain Future

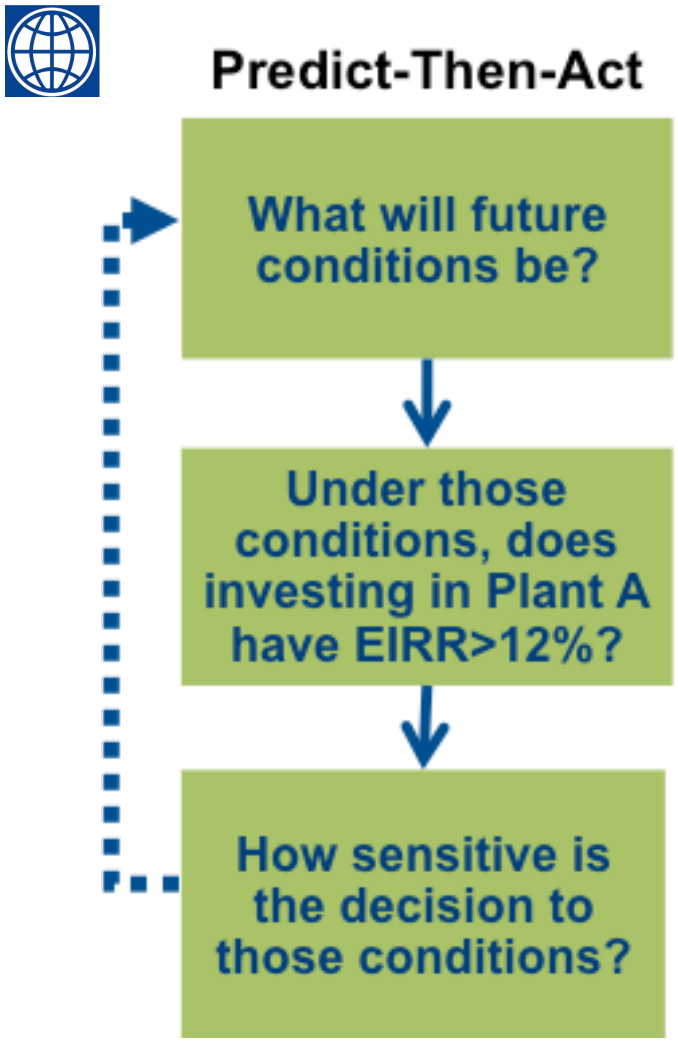
Climate Change



Competing Priorities

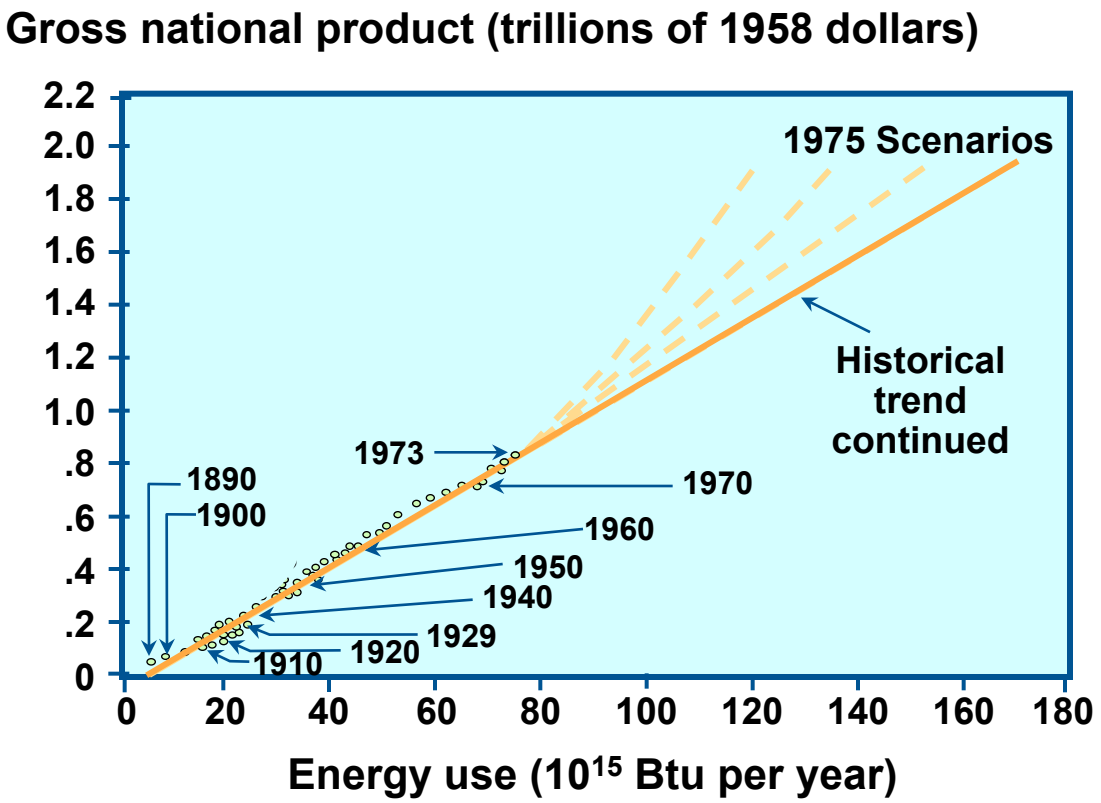
Conservation vs. Development

Traditional Decision Approach



Believing Predictions of the Unpredictable Can Contribute to Bad Decisions

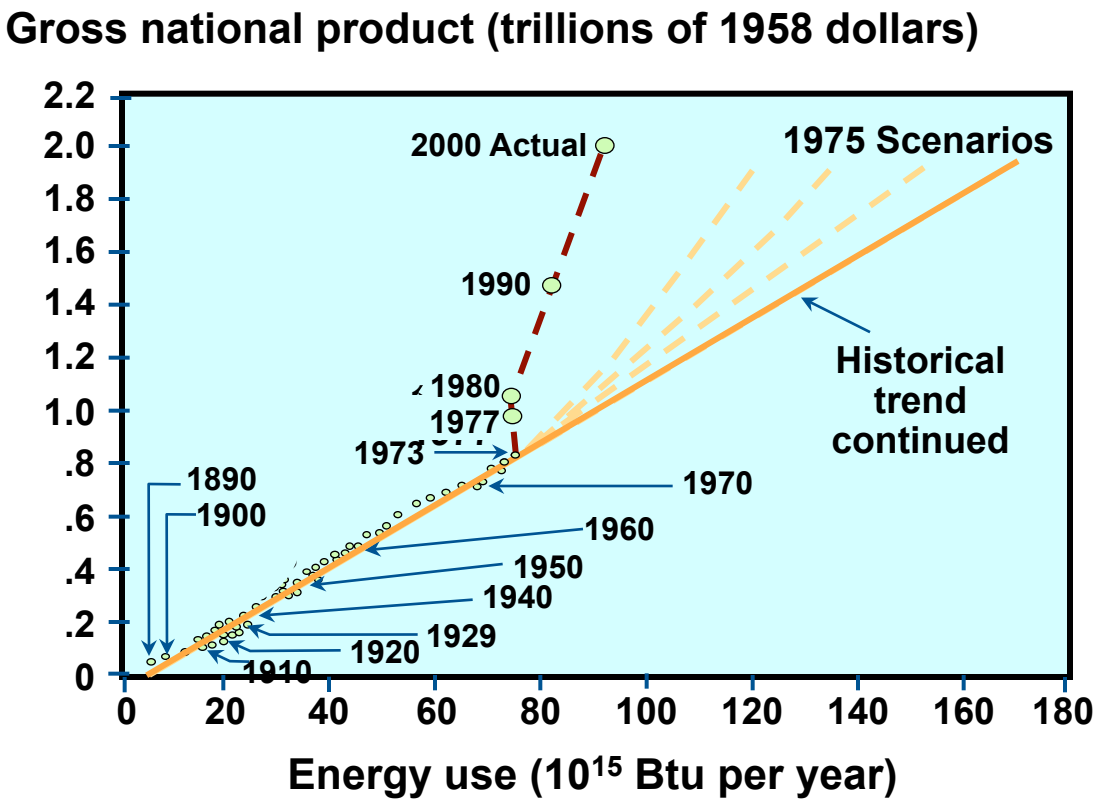
- **In the early 1970s forecasters made projections of U.S energy use based on a century of data**



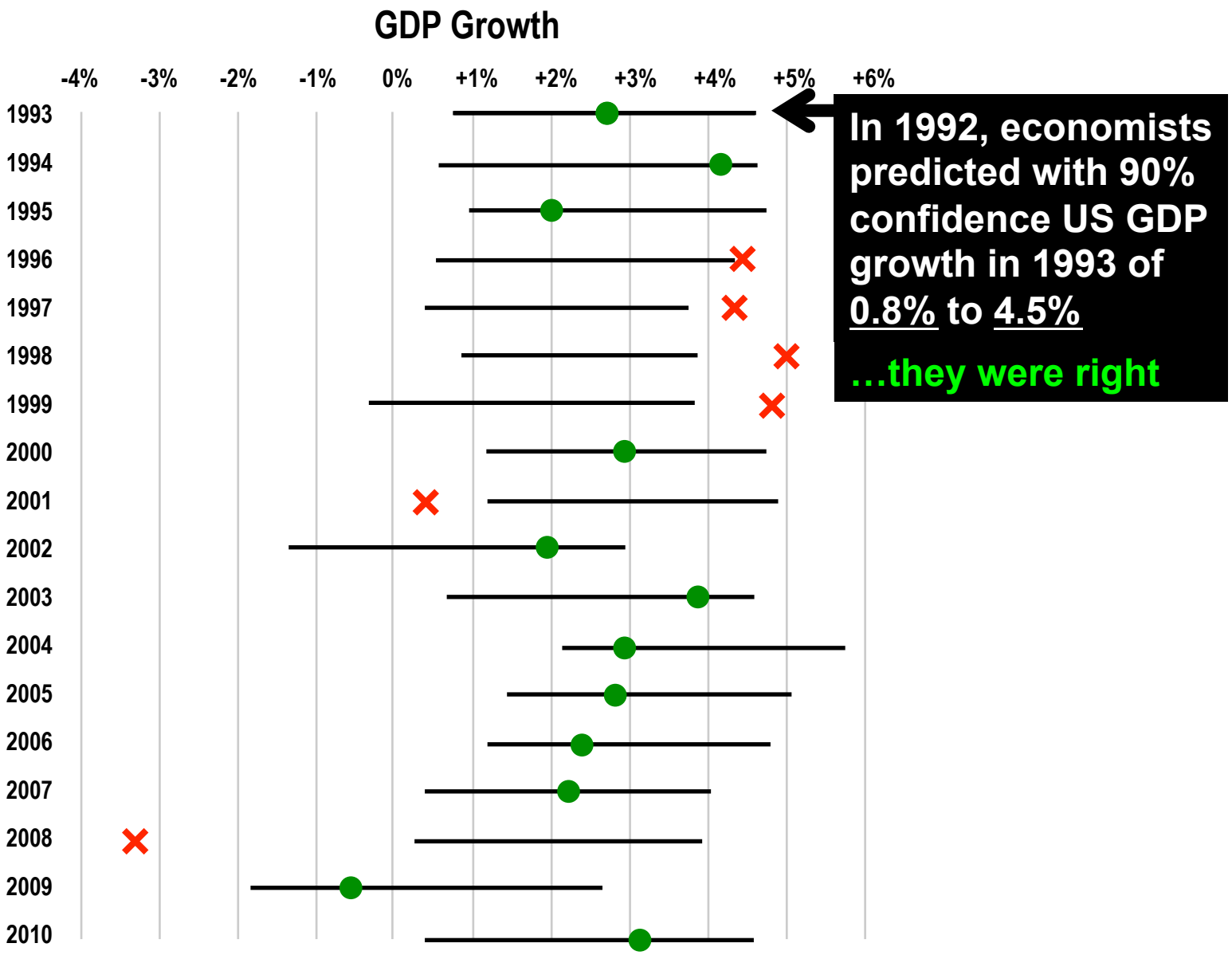
Believing Predictions of the Unpredictable Can Contribute to Bad Decisions

- **In the early 1970s forecasters made projections of U.S energy use based on a century of data**

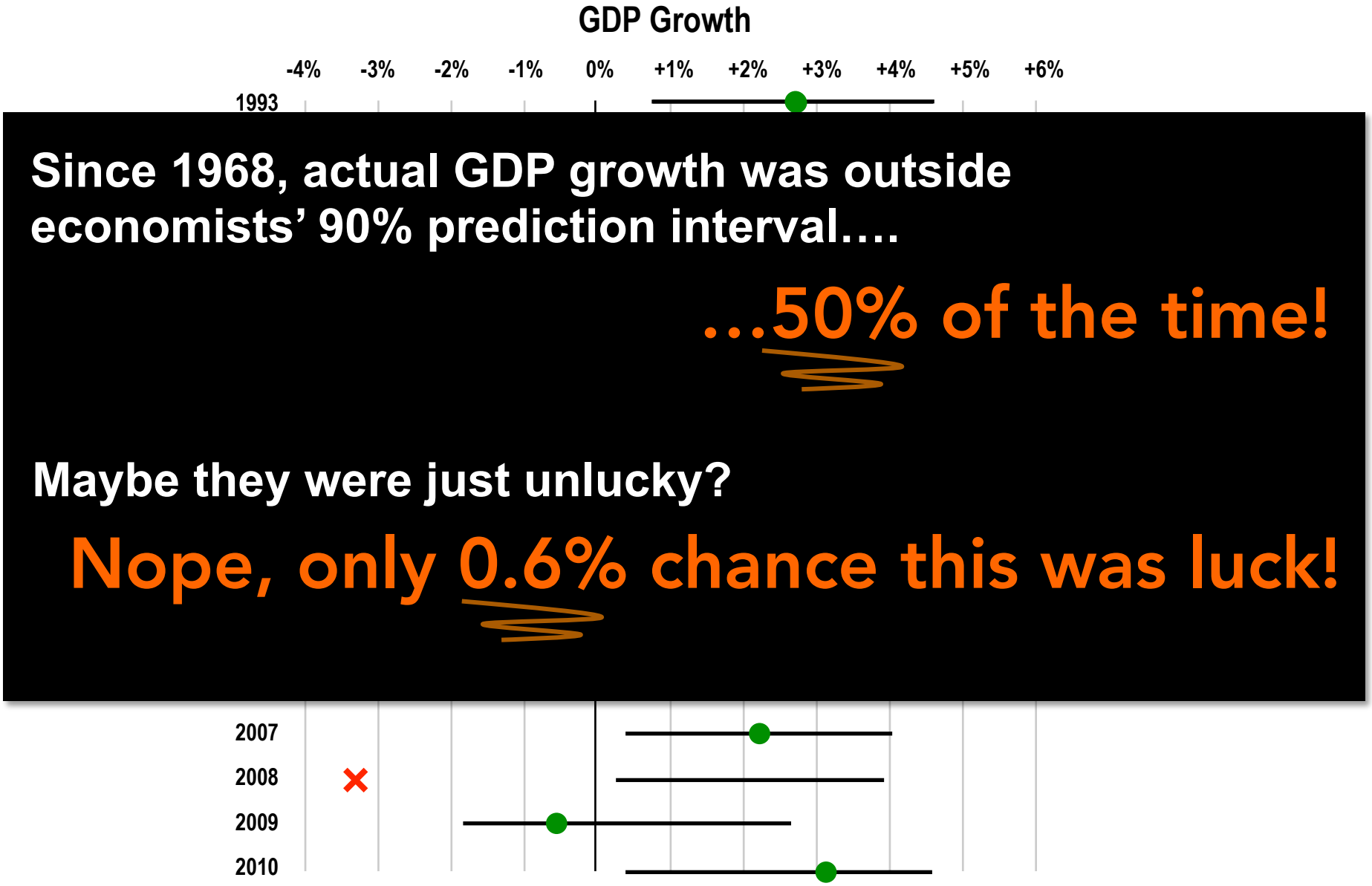
…they were all wrong



Maybe Economists Are Better At Predictions?



No! Economists Are No Better At Predictions!



Since 1968, actual GDP growth was outside economists' 90% prediction interval….

…50% of the time!

Maybe they were just unlucky?

Nope, only 0.6% chance this was luck!

We Are Highly Biased Towards….

1. Predicting the future will look like the past

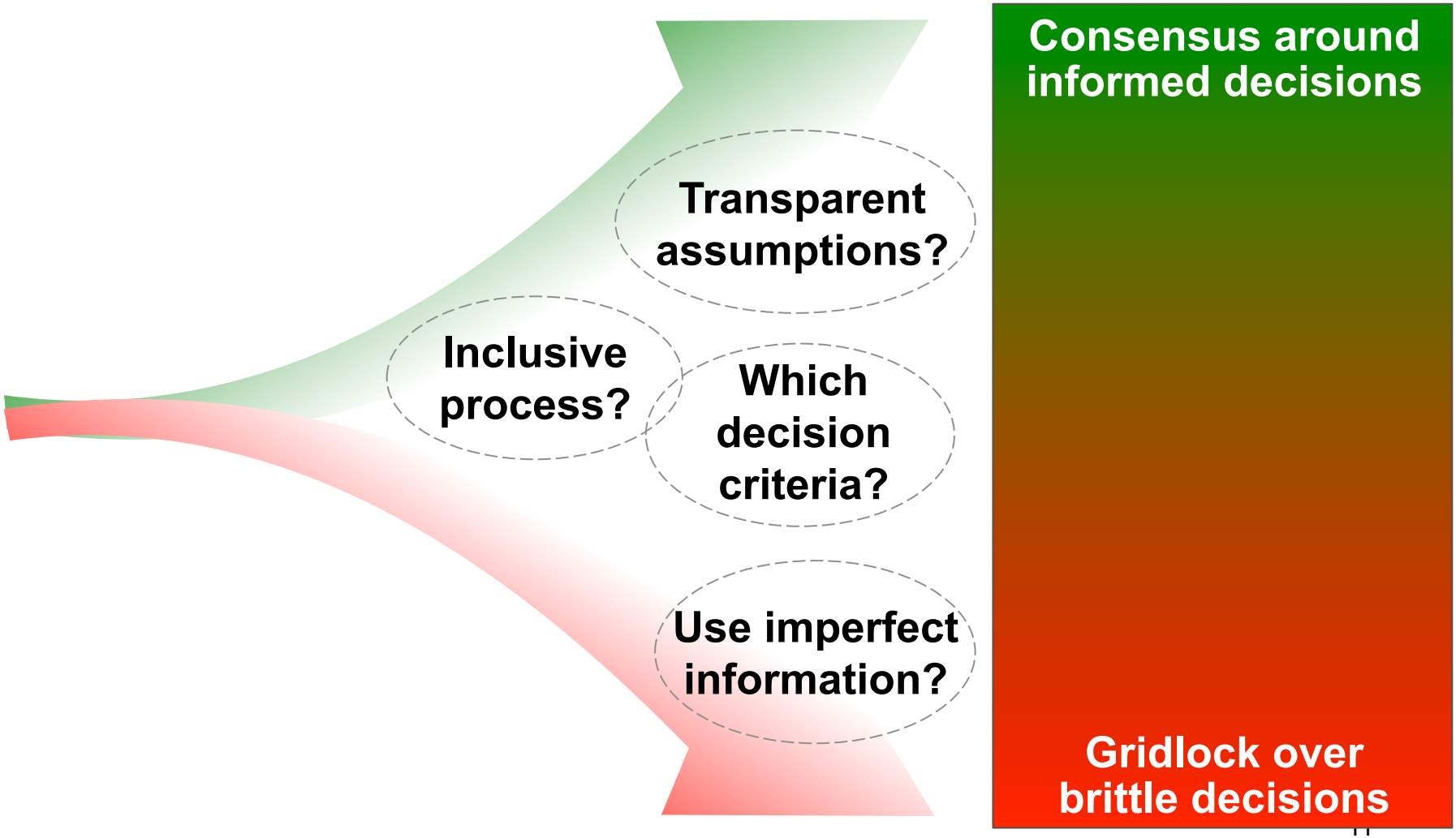
2. Being highly confident in our predi ions

During a 2008 panel for the IPCC's launch of a report on water and climate, a hydrologist, and an engineer called for additional monitoring and research to understand the effects of climate change. The third member of the panel, a frustrated World Bank infrastructure lender, declared in response,

"**I can't wait thirty years** for precise science to tell me how much global warming contributed to a particular drought or flood...

I need to make investment decisions now."

How We Make Decisions Matters



At CCGCE, We're Helping World Bank Analysts Make Good Decisions, Without Predictions*

- **Methods that focus on understanding merits of options, not on making controversial projections**

- **Methods like Robust Decision Making are used increasingly in US but need tailoring to Bank context**

*** Office of the Chief Economist of the Climate Change Group**

The Project in Brief

1. To **characterize the deep uncertainties** that affect the World Bank lending decisions and analyze the state of practice in managing them.

   → *Detailed Project Document (PADs) review*

2. To evaluate the **value added** of leading methodologies for managing deep uncertainty
3. To make **policy recommendations** on whether and how these methods should be mainstreamed

The Project in Brief

1. To **characterize the deep uncertainties** that affect the World Bank lending decisions and analyze the state of practice in managing them.
2. To evaluate the **value added** of leading methodologies for managing deep uncertainty

   → *Robust Decision Making (RDM) application to prior project*
3. To make **policy recommendations** on whether and how these methods should be mainstreamed

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   →*Recommendations*

1. PAD Review: Main Objectives

1. Identify **deep uncertainties** that affect projects
2. Assess **methods** used to address them
3. Characterize **gaps** between the deep uncertainties identified and analyzed, which may suggest hidden vulnerabilities of investments

1. PAD Review: Methodology

- **Decision Matrix (XLRM) for each of them**

X – Uncertainties • Which are recognised? • Which are assumed? • Which are ignored? • What are the scenarios addressed?	**L – Policy Levers** • Chosen policy • Alternatives considered
R – Model • Risk Analysis • Economic Analysis • Others?	**M – Metrics** • To make decision • To assess project success • Other metrics

1. PAD Review: Key Conclusions

- Project managers **seek robust investments** but lack the methodological and practical tools
- Use rather **weak prediction-based analysis**
  - Assume “everything goes according to plan”
  - Many uncertainties discussed but never analysed
  - Sensitivity analysis only for some variables and used after decision is made in order to compute the EIRR of winning investment
- **Never analyze merits of alternatives**, except to show that they are inferior to selected options

2. Retrospective RDM: Main Objectives

- Select 1 **project**
- Use **alternative decision methods** to characterize and quantify vulnerabilities
- Suggest and analyze **augmentations** to the investment plan that could hedge against these vulnerabilities
- NOT to prove the original project decision right or wrong

Turkey Electricity Generation Project Seeks Energy Security In The Mid Term

- Choose between options for energy supply
  - Rehabilitate existing coal plant
  - New coal plant
  - Alternative energy sources (i.e. gas)
- Criteria is
  - Lowest production cost ($/kWh)
  - Highest IRR (%)
- Sensitivity analysis of some parameters for preferred investment, which was rehabilitation

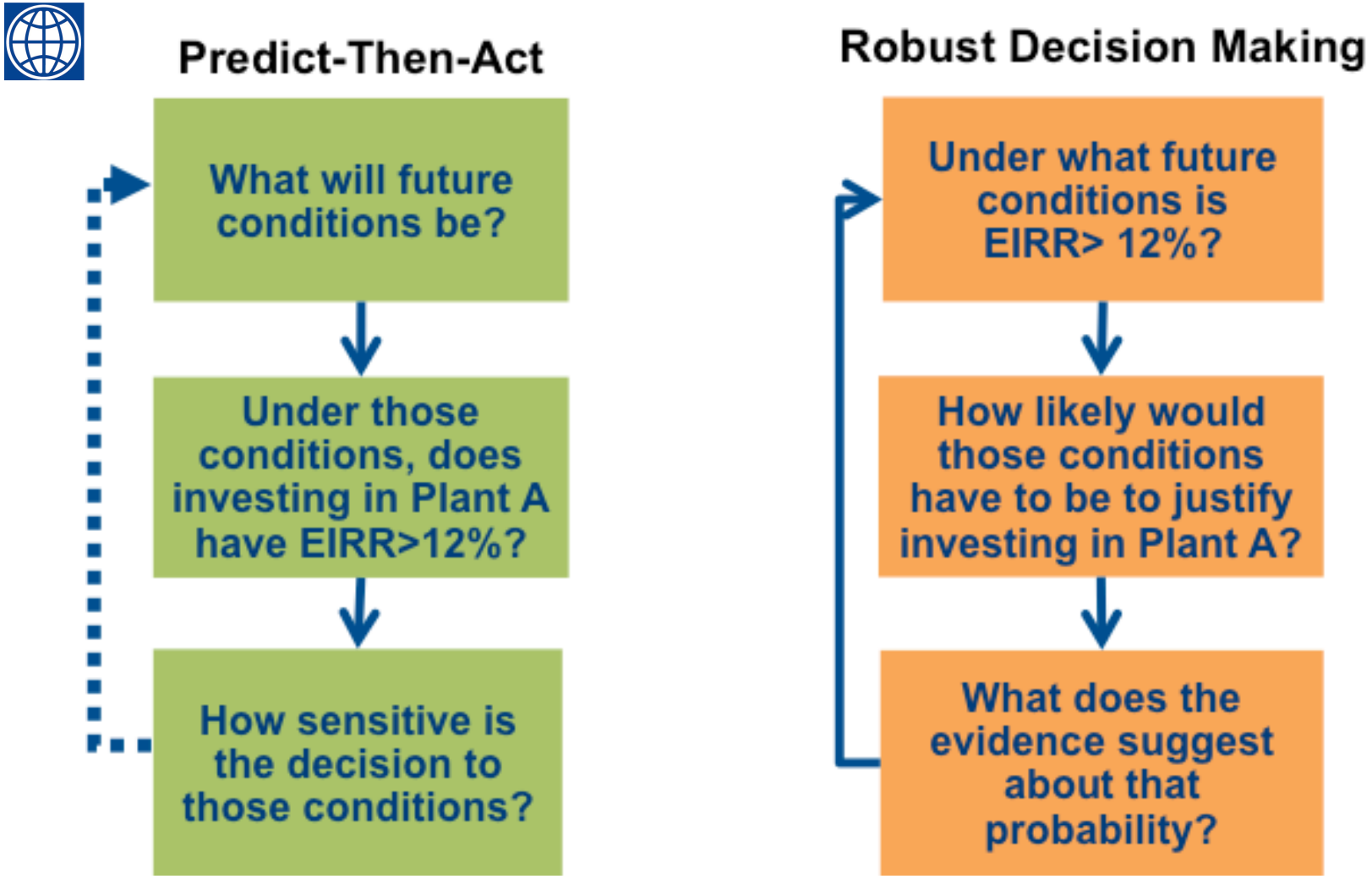
Original Economic Analysis

X – Uncertainties	**L – Policy Levers**
Estimated Life of the Plant Cost of Inputs Rate of Utilization Rehabilitation Costs Wholesale Price of Electricity Incremental Generation Sensitivity on Xs (+-20%)	Afsin Rehabilitation Afsin Rehabilitation with FGD New Combined Cycle 700Mw Imported Coal No FGD, 500 Mw Imported Coal FGD, 500 Mw Lignite Fluidized Bed New Afsin Wind Nuclear Imported from Bulgaria
R – Model	**M – Metrics**
.xls estimation of cost effectiveness/ cost benefit	Least Cost ($/KWh) IRR on Winning Option

Original Economic Analysis

X – Uncertainties	**L – Policy Levers**
Electricity Price	Afsin Rehabilitation
Estimated Life of the Plant	**Afsin Rehabilitation with FGD**
Capacity Utilization	**New Combined Cycle 700Mw**
Capital Costs	Imported Coal No FGD, 500 Mw
Cost of Inputs	**Imported Coal FGD, 500 Mw**
	Lignite Fluidized Bed
Sensitivity on Xs (+-20%)	**New Afsin**
	Wind
	Nuclear
	Imported from Bulgaria
R – Model	**M – Metrics**
.xls estimation of cost effectiveness/ cost benefit	Least Cost ($/KWh)
	IRR on Winning Option

Robust Decision Making

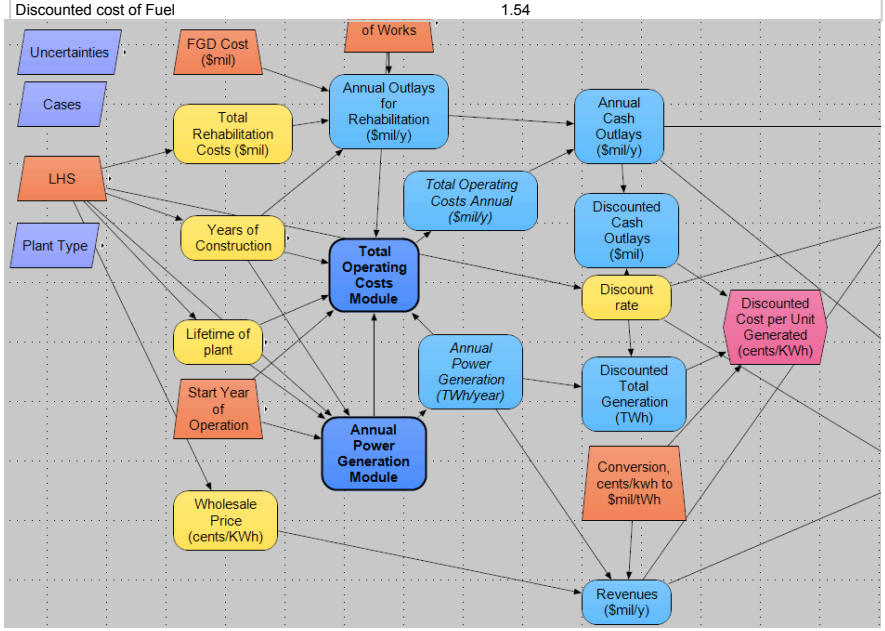


The Model

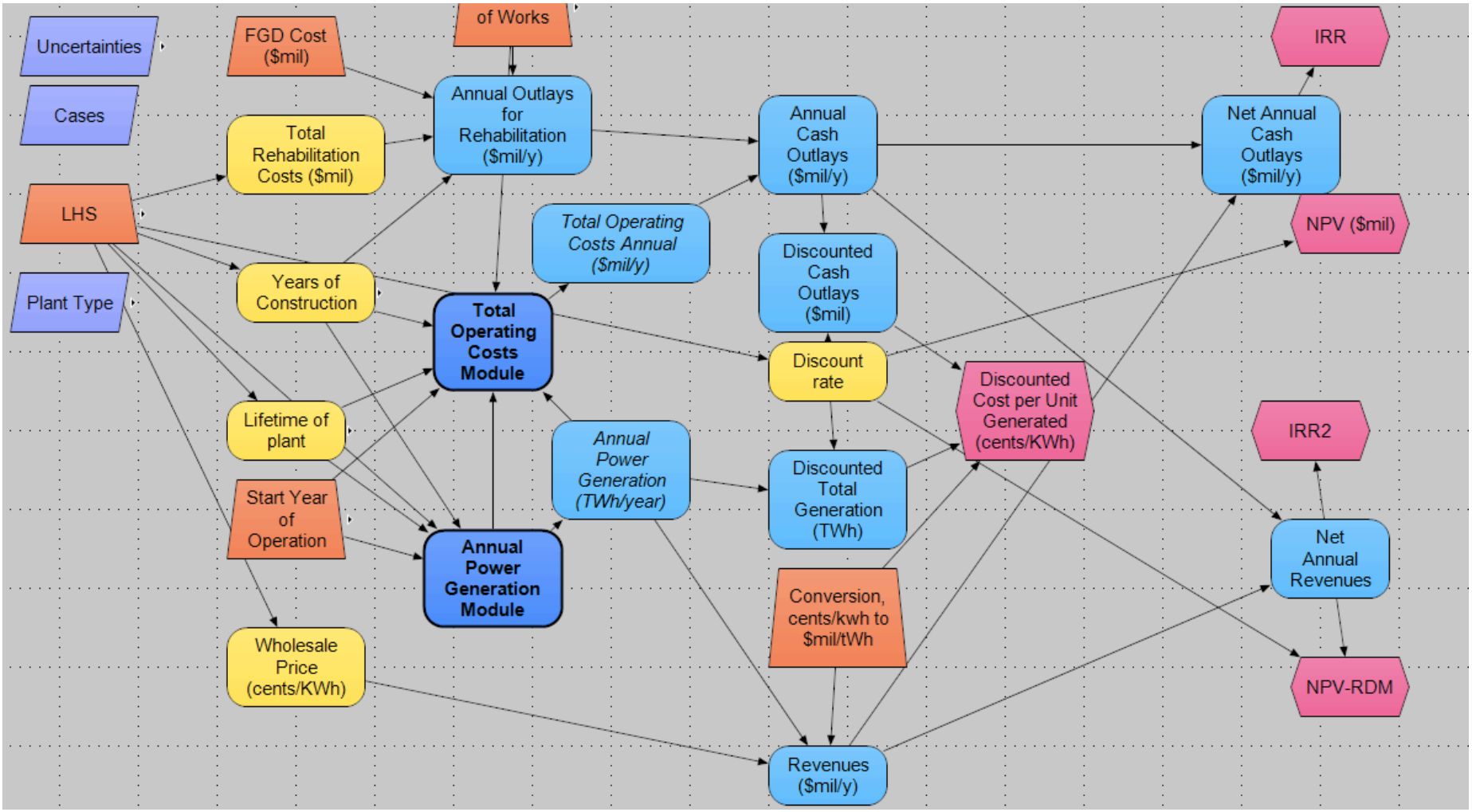
- **Same data as existing analysis**
- **Same model but different modelling environment**
  - **From Excel**
  - **To Analytica risk modeling environment, better suited to run hundreds of scenarios**

Cost of Generation from Re

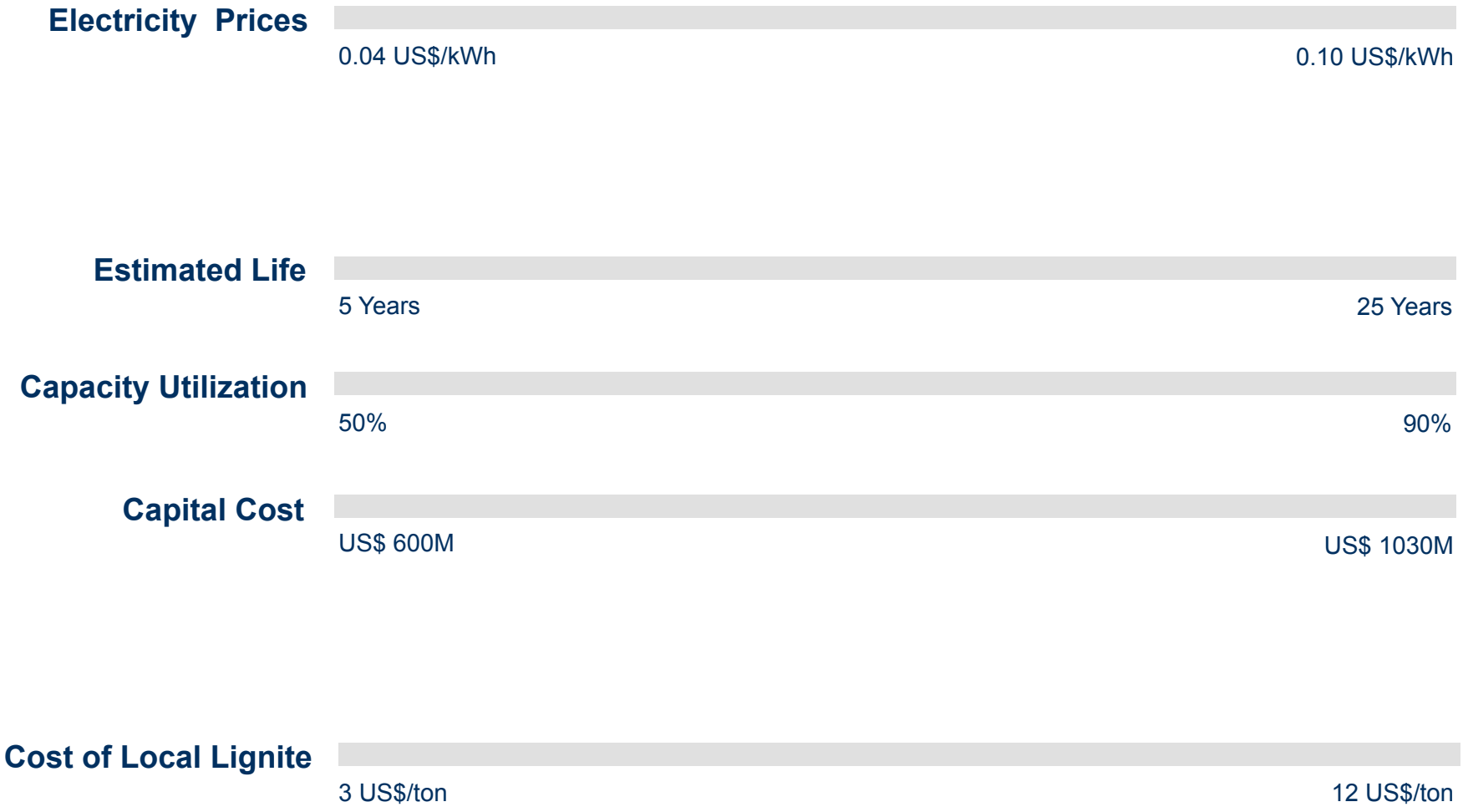
Year		2006	2007	2008	2009	2010
Cost of Rehabilitation $ mil.	453					
Outlays on Rehabilitation $ mil.			181.2	203.85	67.95	
Incremental Generation (Twh)	75%	0	0	2.6	5.1	5.91
Efficiency	31%					
Cost of lignite $/ton	6.06			7	7	6.4
	1					
Fuel Costs $mil				45.85	89.93	95.33
Other Costs $ mil.				14.30	28.05	32.52
Total operating Costs $ mil.				60.15	117.98	127.85
Cash Outlays		0.00	181.20	264.00	185.93	127.85
Discounted Value of Cash Outlays $ Mil.		1,628.08				
Discounted Generation Twh		53.53				
Discounted Cost per Kwh (cents/kwh)		3.04				
Undiscounted Cash Outlays $ Mil.		3578.69				
Undiscounted Generation Twh		135.815				
Undiscounted cost per Kwh (cents/kwh)		2.63				
Discounted cost of Fuel		1.54				



The Model


Uncertainties
Cases
LHS
Plant Type
FGD Cost ($mil)
of Works
Total Rehabilitation Costs ($mil)
Annual Outlays for Rehabilitation ($mil/y)
Years of Construction
Total Operating Costs Module
Total Operating Costs Annual ($mil/y)
Lifetime of plant
Start Year of Operation
Annual Power Generation Module
Annual Power Generation (TWh/year)
Wholesale Price (cents/KWh)
Annual Cash Outlays ($mil/y)
Discounted Cash Outlays ($mil)
Discount rate
Discounted Total Generation (TWh)
Conversion, cents/kwh to $mil/tWh
Revenues ($mil/y)
Discounted Cost per Unit Generated (cents/KWh)
Net Annual Cash Outlays ($mil/y)
IRR
NPV ($mil)
IRR2
Net Annual Revenues
NPV-RDM

Uncertainty Space For The Analysis Of Rehabilitating The Existing Plant



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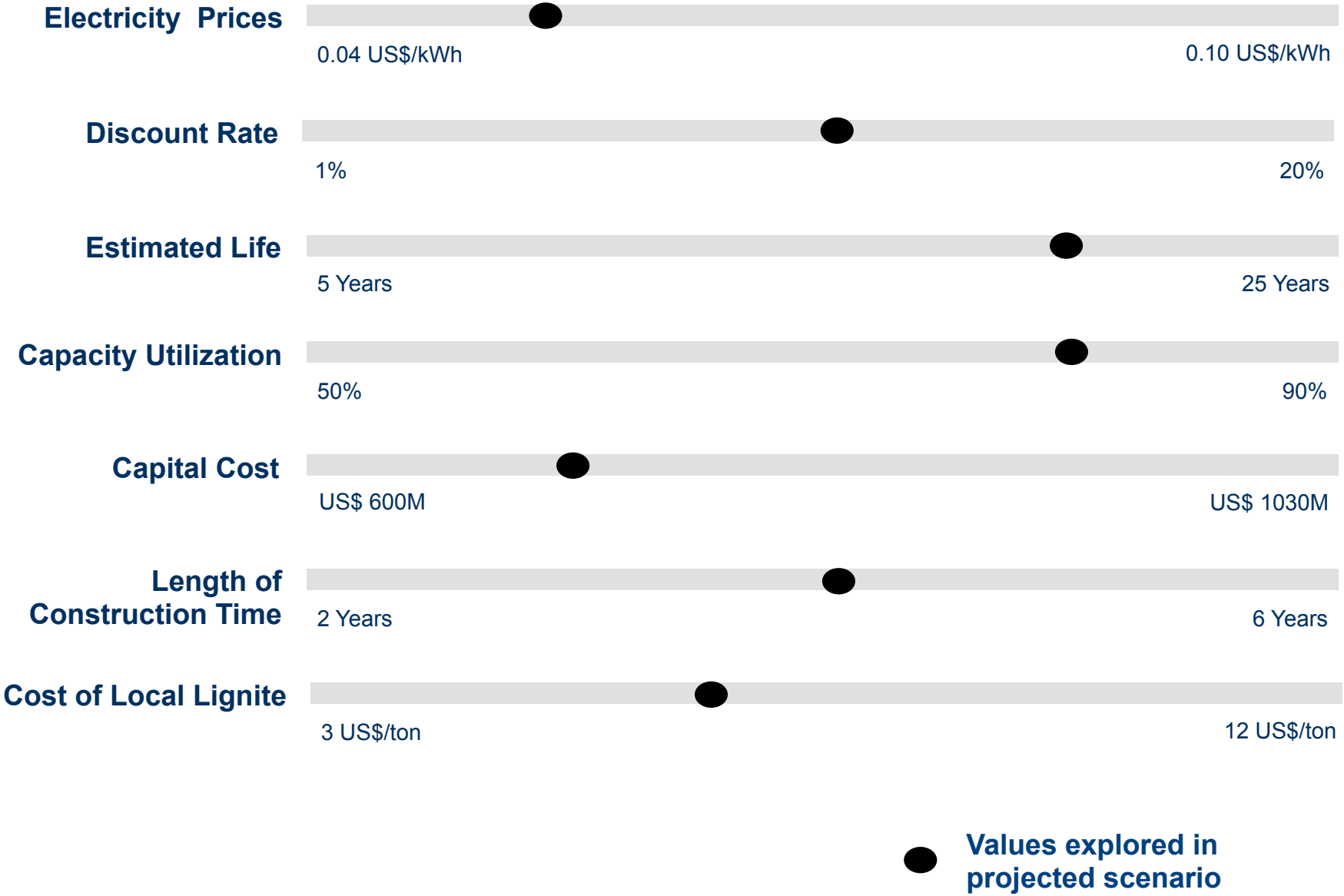

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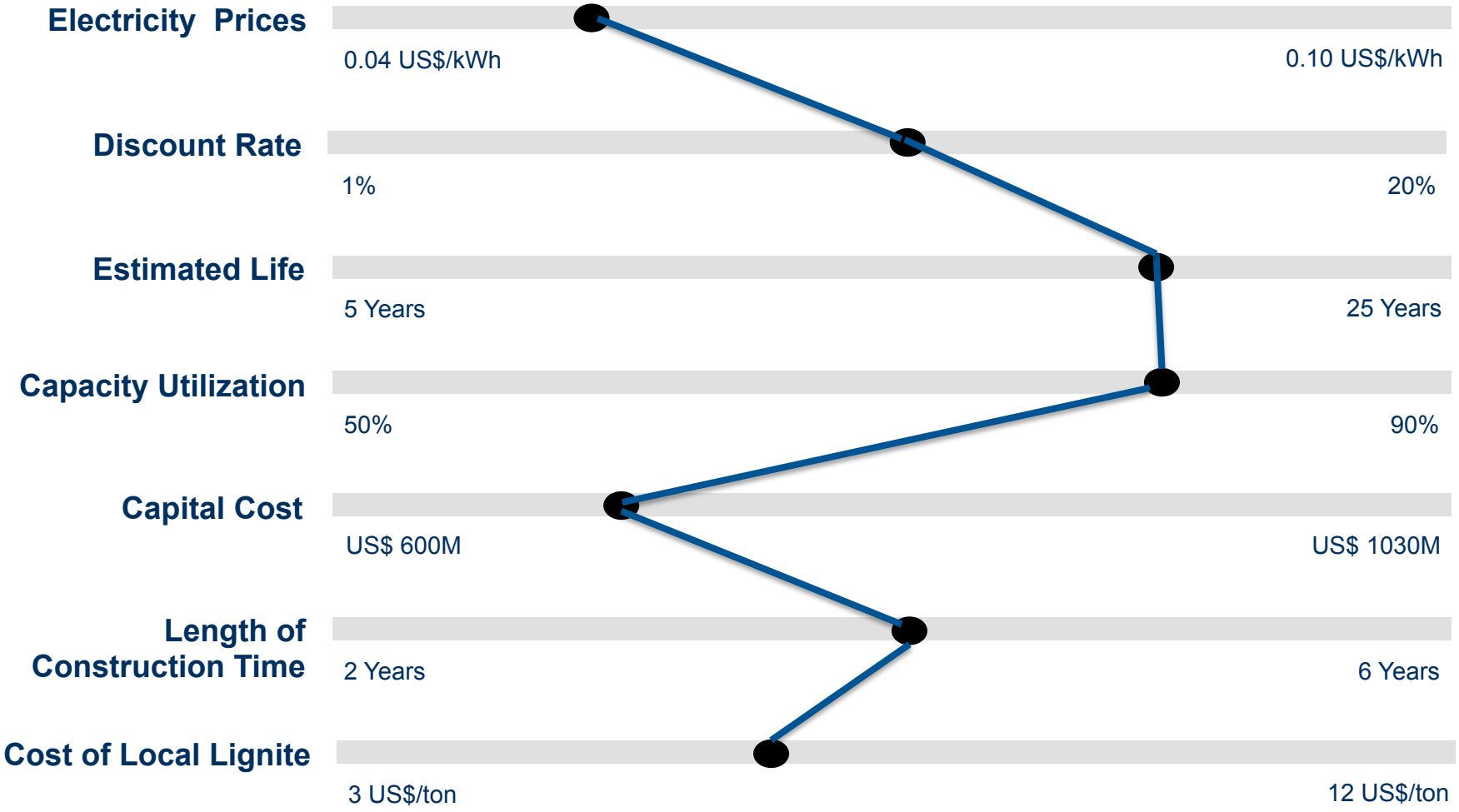

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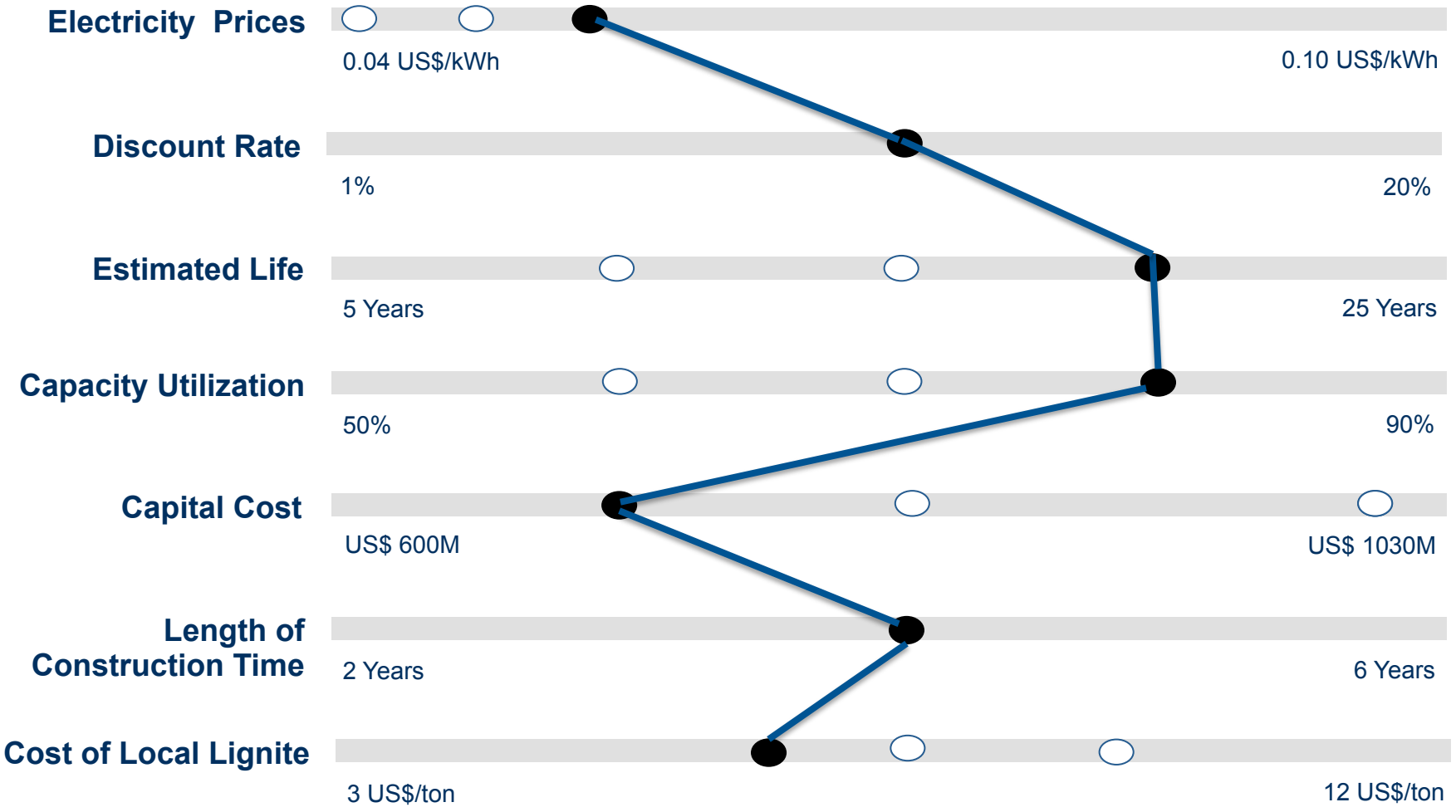
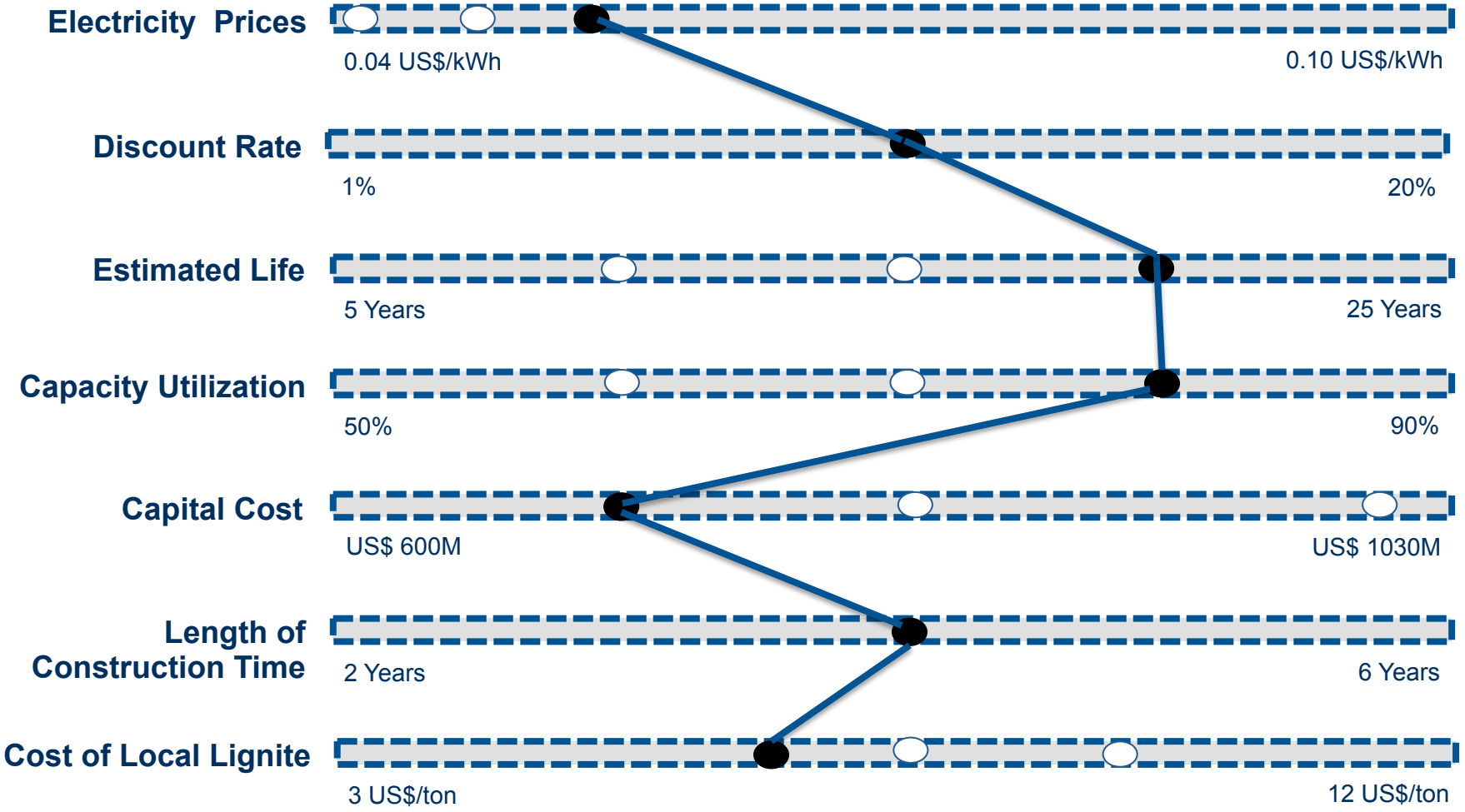


Uncertainty Space For The Analysis Of Rehabilitating The Existing Plant



Generating Futures

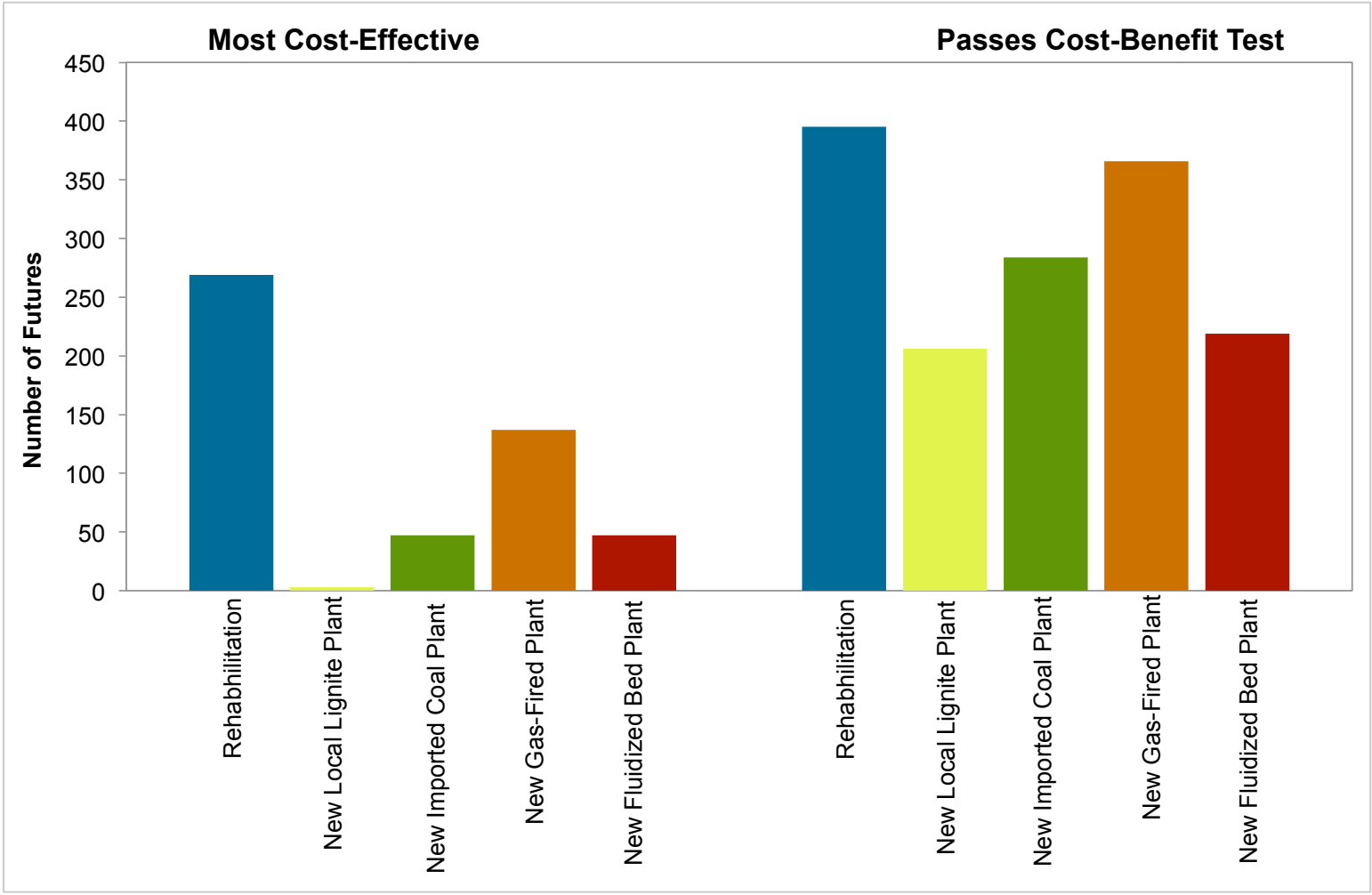
- We statistically generated **500 futures**
- We use them to **stress test the performance** of each project over the widest range of possible conditions
- We evaluate the the **cost-minimization** criterion and the **cost-benefit** criterion of each of the five options in each of these 500 futures

This generates a large table of inputs (the uncertain future conditions) and outputs (the metrics) for each option

		Inputs				Outputs	
Future ID	Option	Wholesale Price of Electricity	Capital Cost	Length of Construction time	Other four Uncertainties*	Discounted Cost per kWh	IRR
1	Rehabilitation	5.15	824.89	2.85	[…]	6.39	0.05
2	Rehabilitation	8.79	945.29	4.14	[…]	7.11	0.35
1	Gas-fired plant	5.15	526.68	4.01	[…]	4.21	0.27
2	Gas-fired plant	8.79	514.92	4.38	[…]	8.91	0.15

* Other uncertainties are the discount rates, cost of inputs, lifetime of the plants, and capacity utilization rates.

How Do Our Options Perform Across A Wide Range Of Potential Future Conditions?



Monte Carlo VS. RDM Analyses

Monte Carlo Analysis	RDM Analysis
Runs many simulations over randomly generated cases	Runs many simulations over randomly generated cases
Uses sample of cases to represent the likelihood of future conditions	Samples uniformly across the range of plausible values of our deep uncertainties
Uses results to make inferences about likely performance of project	Uses cases to stress test the performance of a project
	Data-mining to identify the set of threatening conditions
	Assesses the relative plausibility of these conditions, to present trade-off to decision makers
Works well when **we have reliable probability distributions**	Works well when **we do not have defensible probability distributions**

Under What Specific Conditions Does The Leading Option Fail To Meet Our Goals?

- We use statistical scenario discovery, running **data-mining algorithm**
- We identify the **common characteristics** of those futures in which rehabilitation is **NOT** the best option
- We identify the **key drivers** of the decision
- We ran the same statistical analysis also for the other options

Performance of Rehab Vs. Gas

- A gas-fired plant is more cost effective than rehabilitating the existing plant if:
  - The **cost of local lignite** (US$/ton) is more than 4.5% of the **cost of gas** (US$/tcm).
- Rehabilitating the existing plant fails our cost-benefit test, i.e. has an IRR below 12%, IF:
  - The **wholesale price of electricity** is below 0.059 US $/kWh

  AND
  - **Local lignite** costs more than 6.3 US$/ton

Are Those Conditions Sufficiently Likely That We Should Choose A Different Option?

Rehabilitating the existing power plant is a robust investment

- The **cost of lignite** is partially under decision makers' control, decision makers can take action to avoid those threatening conditions. (i.e. upgrading the lignite mine)
- Building a new gas-fired plant fails to pass the cost-benefit test under less constraining and more plausible conditions
  - More sensitive to decreases in **electricity prices** than rehabilitation

    (i.e., it fails if price < 0.073 US$/kWh *vs.* <0.059US/kWh)
  - **Gas prices**' threshold on the lower bound of historical series

2. Retrospective RDM: Results

- In this particular case
  - Selected option appears robust
  - But sensitivity analysis does not demonstrate this
  - Our analysis identifies threats to the options considered
- Vulnerability analysis
  - Can be **easily incorporated** into economic analyses
  - Would add value, as it shows **key threats** and **tradeoffs** between options

Main Conclusions

- Current Practice*
  - There is (increasing?) desire for robustness
  - Very limited uncertainty management
  - Analysis of alternatives is limited
- Implications Of Uncertainty Analysis
  - Practical to implement
  - Identifies vulnerabilities of investments
  - Offers systematic way to compare alternatives

*Small sample of projects

At The CCGCE We Are…

Tailoring tools and methodologies

Undertaking several pilot applications

Developing creative learning experiences

Current and Prospective Pilot Studies

Flood Risk in Ho Chi Minh City

Water Resources Management in Lima

Wetland Protection in Colombo

Drought Management in Brazil

Water and Sanitation (Global)

Multi-Purpose Dams in Nepal

Thank you!

Laura Bonzanigo

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