LEAST-COST DECISION RULES FOR UTILITIES AND REGULATORS IN 21ST CENTURY ELECTRICITY MARKETS

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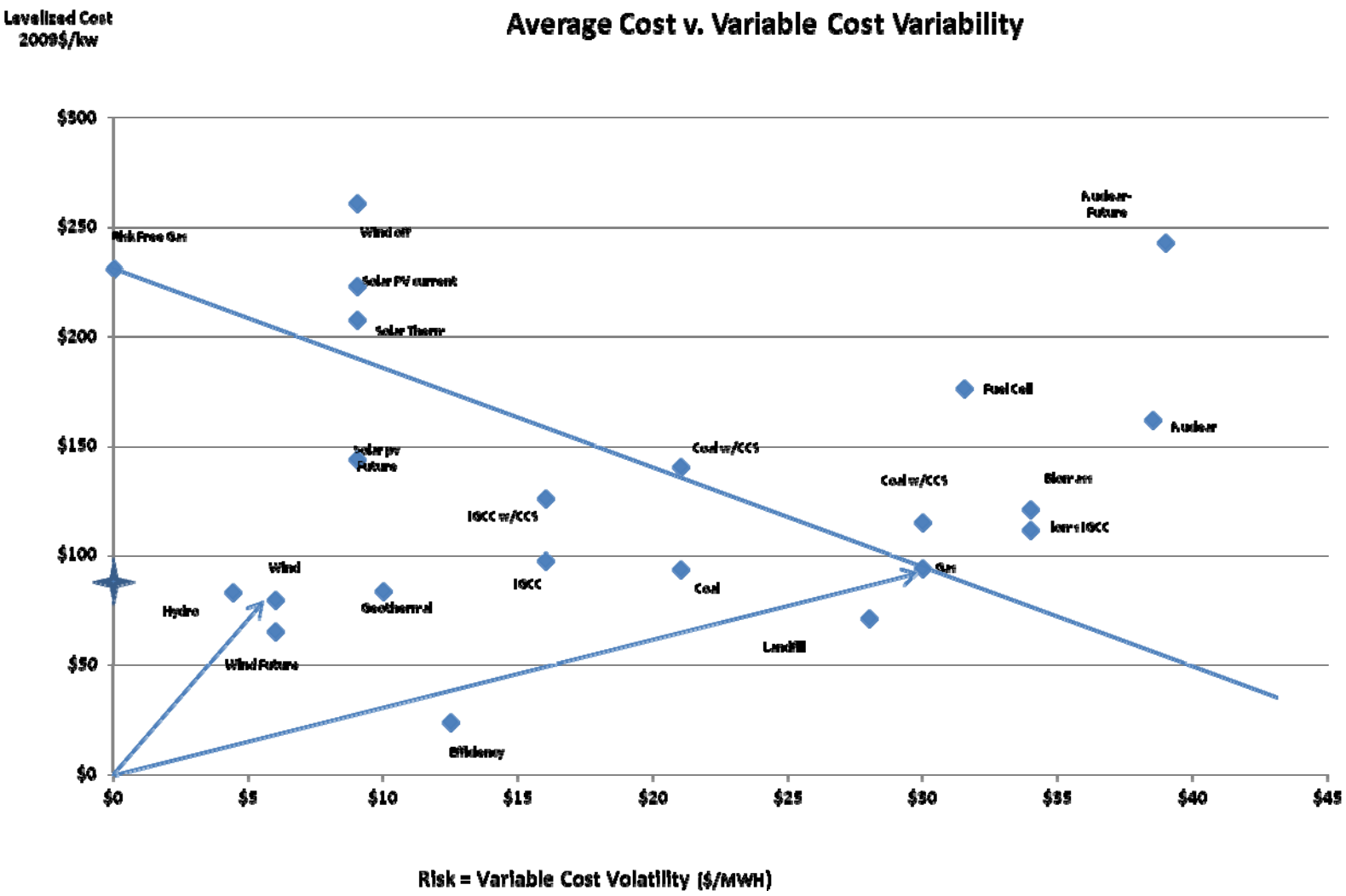
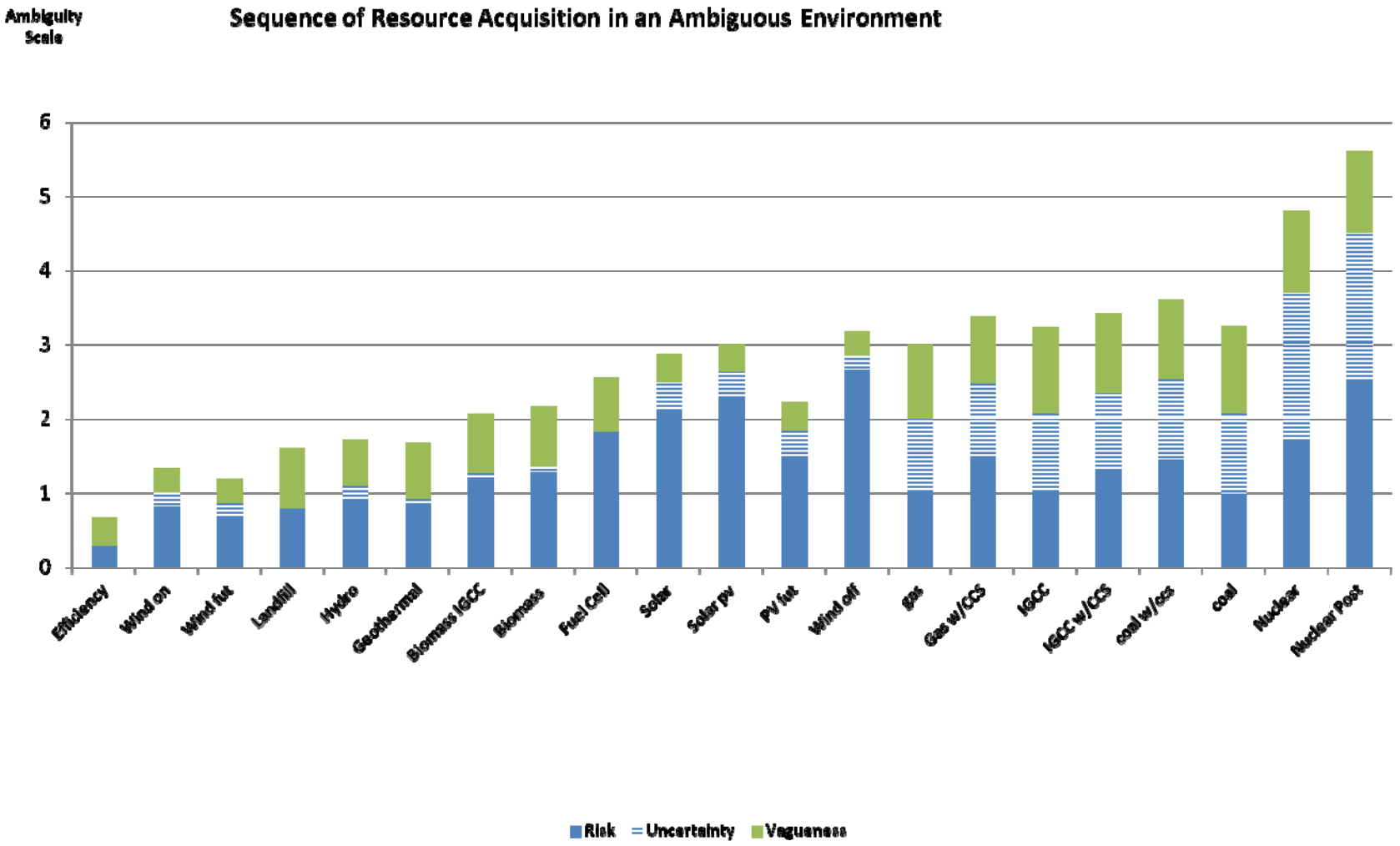
EXHIBIT II-1: TOPOGRAPHIC FEATURES AND NAVIGATION TOOLS FOR THE REGIONS OF KNOWLEDGE

	REGIONS			
	IGNORANCE	VAGUENESS	UNCERTAINTY	RISK
TOPOGRAPHY				
Technology Risk Assessment				
Challenges	Unanticipated effects	Contested framing	Nonlinear systems	Familiar systems
Outcomes	Unclear	Unclear	Clear	Clear
Probabilities	Unpredictable	Predictable	Unpredictable	Predictable
Black Swan Theory				
Challenges	Black Swans Wild randomness	Sort of Safe	Safe	Extremely safe Mild randomness
Conditions	Extremely fragile	Quite robust	Quite robust	Extremely robust
Distributions	Fat tailed	Thin tailed	Fat tailed	Thin tailed
Payoffs	Complex	Complex	Simple	Simple
Reliability & Risk mitigation Management				
Conditions	Unknown/ Unknowns	Unknown/ knowns	Known/ unknowns	Known/knowns
Challenges	Chaos	Unforeseen uncertainty	Foreseen uncertainty	Variation
Characterizations				
Catholic	Hell	Limbo	Purgatory	Reality
Greek Mythology	Pandora, Pythia	Damocles, Cassandra	Cyclops	Medusa
NAVIGATION				
Analysis				
Approach	Multi-criteria analysis	Fuzzy logic	Decision heuristics	Statistics
Tools	Diversity assessment	Sensitivity analysis	Scenario analysis	Portfolio evaluation
Focus	Internal resources/ structure	Internal resources/ structure	External challenges	External challenges
Data	Swan Search Consistency Unintended consequences Externalities Diversity Statistical variety balance disparity Alternative Instrument Sufficiency	Vagueness Supply security Resource base Market scope Environmental impact Pollutants (air. Land water, waste) Greenhouse gasses	Uncertainty Capacity Construction period Sunk cost (Total capital = MW * $/MW)	Cost -Risk Levelized cost of energy Cost variability Fuel O&M Carbon ½ nuclear capital
Policy Tools				
Processes	Learning	Learning	Planning	Planning
Instruments	Insurance/diversity	Monitor & Adjust	Optionality	Hedging
Rules	TECHNOLOGY RISK ASSESSMENT Precaution Buy insurance for system survival Accept non-optimization Diversity Variety Balance Disparity	BLACK SWAN THEORY Truncate Exposure Buy insurance for system survival Accept non-optimization Redundancy Numerical Functional Adaptive	TECHNOLOGY RISK ASSESSMENT Resilience Adaptability BLACK SWAN THEORY Multi-functionality What Works	TECHNOLOGY RISK ASSESSMENT Flexibility Across Time Across Space BLACK SWAN THEORY Optionality	TECHNOLOGY RISK ASSESSMENT Resilience Robustness Hedge BLACK SWAN THEORY Robust to Error Small, Confined, Early Mistakes Incentive & disincentives Avoid Moral Hazard Hedge

Sources: Nassim Nicholas Taleb, *The Black Swan* (New York: Random House, 2010). Postscript; Andrew Stirling, *On Science and Precaution in the Management of Technological Risk* (European Science and Technology Observatory, May 1999), p. 17, *On the Economics and Analysis of Diversity* (Science Policy Research Unit, University of Sussex, 2000), Chapter 2; "Risk, Precaution and Science: Toward a More Constructive Policy Debate," *EMBO Reports*, 8:4, 2007; David A. Maluf, Yuri O. Gawdisk and David G. Bell, *On Space Exploration and Human Error: A Paper on Reliability and Safety*, N.D.; Gele B. Alleman, *Five Easy Pieces of Risk Management*, May 8, 2008; see also, Arnoud De Meyer, ChristophER H. Lock and Michel t Pich, "Managing Project Uncertainty: From Variation to Chaos," *MIT Sloan Management Review*, Winter 2002.


Levelized Cost
2009$/kw
Average Cost v. Variable Cost Variability
$500
$250
$200
$150
$100
$50
$0
$0
$5
$10
$15
$20
$25
$30
$35
$40
$45
Risk Free Gas
Wind off
Solar PV current
Solar Therm
Solar pv
Future
Nuclear-
Future
Fuel Cell
Nuclear
Coal w/CCS
Coal w/CCS
Biomass
Biomass IGCC
IGCC w/CCS
IGCC
Coal
Gas
Wind
Hydro
Geothermal
Wind Future
Landfill
Efficiency
Risk = Variable Cost Volatility ($/MWH)


Ambiguity Scale
Sequence of Resource Acquisition in an Ambiguous Environment
6
5
4
3
2
1
0
Efficiency
Wind on
Wind fut
Landfill
Hydro
Geothermal
Biomass IGCC
Biomass
Fuel Cell
Solar
Solar pv
PV fut
Wind off
gas
Gas w/CCS
IGCC
IGCC w/CCS
coal w/ccs
coal
Nuclear
Nuclear Post
Risk
Uncertainty
Vagueness