Approaches to Risk Analysis

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Why Do Risk Analysis?

- **What is the likelihood current budgets/R&D paths will achieve goals?**
  - **If a project's budget is cut or schedule slips, how will outputs/outcomes change?**
- **Where should the next dollar of R&D investment be made?**
  - **What are the best R&D pathways to pursue to achieve program goals? What are realistic estimates of the resources required for the R&D?**
  - **When should R&D investment be cut, or alternative pathways explored?**
  - **What are the risks/consequences of NOT investing in a research pathway?**
  - **To increase the likelihood of success, is it better to do (1) fewer projects with more resources or (2) a wider range of projects? Under what circumstances?**
  - **What is the "right" level of investment in a technology system?**
  - **What is the potential impact of basic science R&D on achieving goals?**
- **How can scoring of risk be made reasonably consistent across projects, programs, portfolios, markets, experts, over time?**
  - **How can this be validated? Are the results repeatable, auditable?**
  - **How can gaming/bias in risk estimates be identified, controlled, minimized? Who should do the risk analysis? How should they be identified, selected?**
- **How should the R&D budget be allocated across programs? How should a portfolio be balanced over risk, return, time, techs, markets?**

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Risk & Benefits Analysis

- **Current GPRA benefits estimates are based on R&D Goals**, with no treatment of risk and uncertainty in attaining R&D outputs and outcomes. In effect, this raises the possibility that the "Best Goal" wins in comparisons.
  - Consideration of risk changes benefits estimates, re-orders comparisons.
  - Consideration of risk highlights importance of balanced portfolio of R&D.
- **Goals and milestones often set without consideration of bottoms-up technical estimates**. In some cases, goals may instead be set on the basis of long-term political desirability, and milestones may be set on the basis of near-term ability to meet tracking requirements. The establishment of goals is not done consistently across programs.
- **Consideration of risk** has begun by: Risk Team; IWG; LWG; NRC
- **Risk Team:**
  - Literature Review, Interviews.
  - Best-Practice Review of Industry, DOE, other Agencies.
  - Case Studies: Biomass, Geothermal, Hydrogen, Industry, Solar, Wind, etc.
  - Best-Practices Guide under development.

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Representative Risks

- **Technical: w**hether the technology meets specified levels of performance, reliability, cost, etc. due to scientific or technical limitations.
- **Budget-Cost:** whether the R&D is completed at the planned budget.
- **Schedule:** whether program milestones or goals are met on schedule.
- **Market:** whether a technology that meets its goals is accepted by the market.
- **Managerial/Organizational:** whether contractor management is effective in operations.
- **Safety/Regulatory/Environmental:** whether a technology meets safety or other requirements.
- **Financial/Economic:** whether a technology finds financial support; suffers economic shifts.
- **Political/Strategic:** whether R&D receives political support or provides strategic value.

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Goals/Principles of Risk Analysis

- **GOALS:**
  - Risk analysis that provides comparable results at each level—project, technology system, program, portfolio.
  - Identify, quantify, evaluate, manage, monitor, document, communicate technology R&D risks in a systematic way. Improve project, program, portfolio design and performance.
  - Conduct risk-adjusted benefits analyses and portfolio analyses that help align/balance portfolios with strategic goals.
- **PRINCIPLES:**
  - Provide scaleable methodologies/tools that can be rolled up/drilled down as needed, and that are reasonably comparable at and across each level to enable comparisons of risks across projects/programs;
  - Control biases, both internal and external;
  - Analyze and document risks in a manner that is objective, credible, fair, transparent, trackable, and auditable with all important assumptions and uncertainties clearly identified; make as simple as possible.
  - Provide value to and support decision-making by project, program, and portfolio managers in a timely manner;
  - Minimize cost of conducting risk analyses (&best-practice stopping rules)

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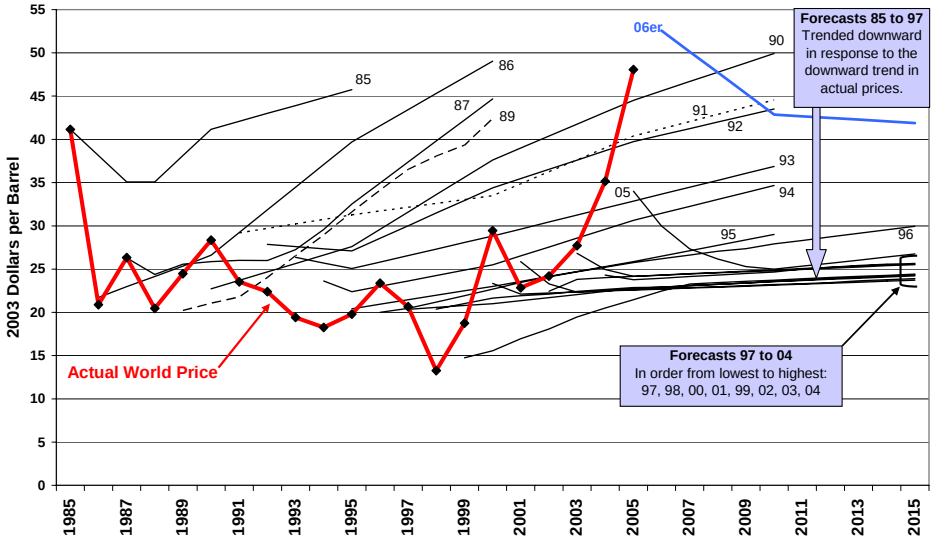
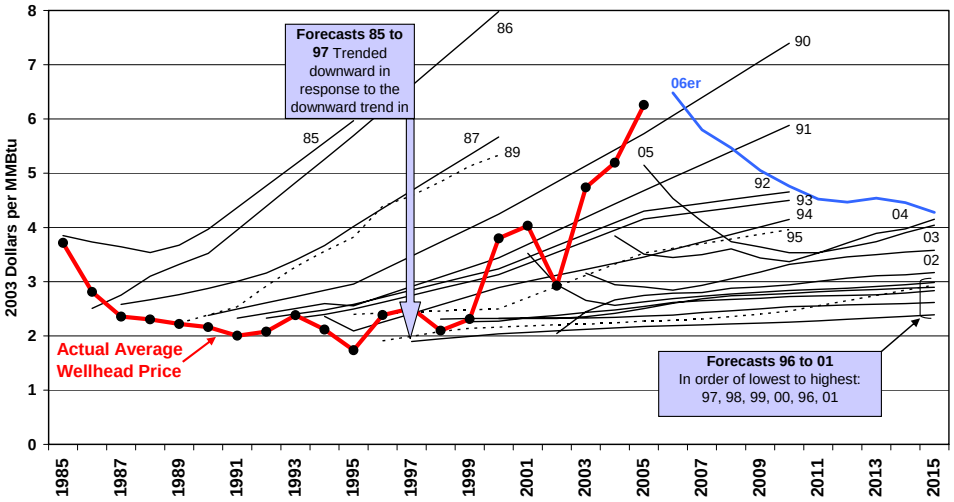
Uncertainties

Historic AEO World Oil Price Forecasts vs. Actual World Oil Prices



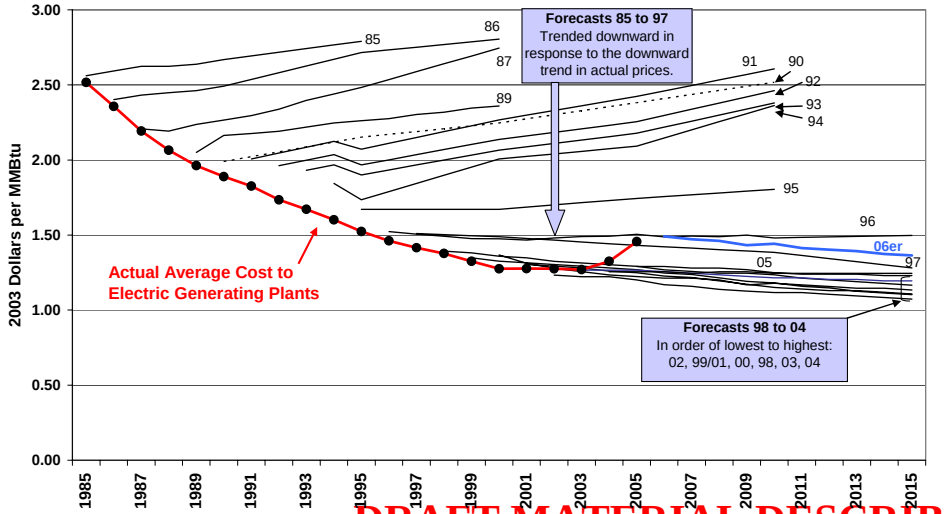
Sources: EIA *Annual Energy Outlooks* (2006 is Early Release)

Historical AEO Natural Gas Price Forecasts vs. Actual NG Prices
(Avearge Lower 48 Wellhead Prices)



Sources: EIA *Annual Energy Outlooks* (2006 is Early Release)

Historical AEO Coal Price Forecasts vs. Actual Coal Prices
(Costs to Electric Generating Plants)



Sources: EIA *Annual Energy Outlooks* (2006 is Early Release)

- **NEMS is the national standard**
- **Integrating Model Benefits**
  - Provide consistent framework for analysis.
  - Model linkages across the energy-economy.
- **Integrating Model Challenges**
  - Difficult for non-experts to understand;
  - Fuel price may show little correlation w actual;
  - Large effort to operate, maintain, update;
  - Constraints may not be well documented, can be over-constraining;
  - May not go out far enough in time
  - Usually do not include risk and uncertainty.

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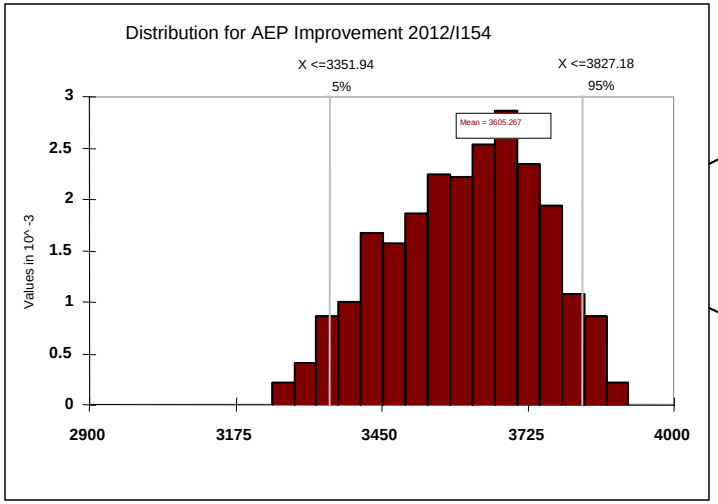
R&D "Riskiness"

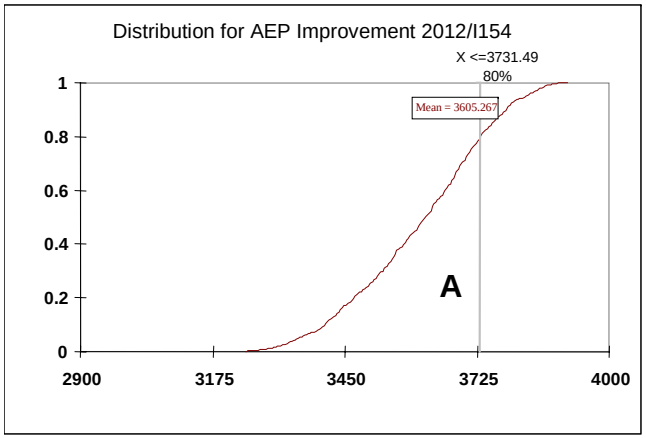
The "riskiness" of R&D performance improvement depends on how aggressive the Goal is; this varies by Program.

- Technical risk for the **same "physical" R&D project** is <u>higher</u> for case A than for case B because case A's Goal is more aggressive

Same Project ***with*** **Different Goals**

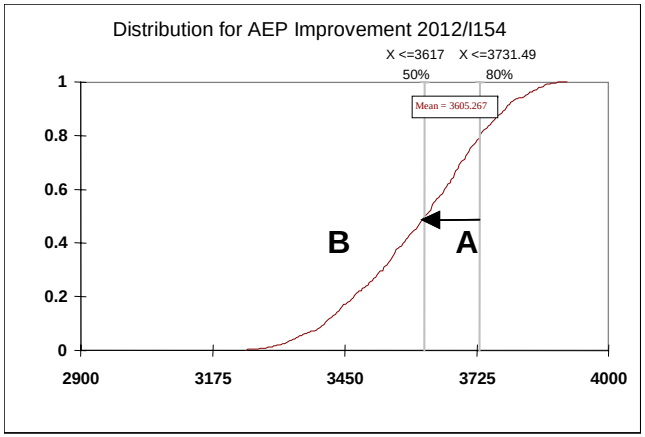


A



Cumulative PDF Showing 80% likelihood

B



Cumulative PDF Showing 50% likelihood

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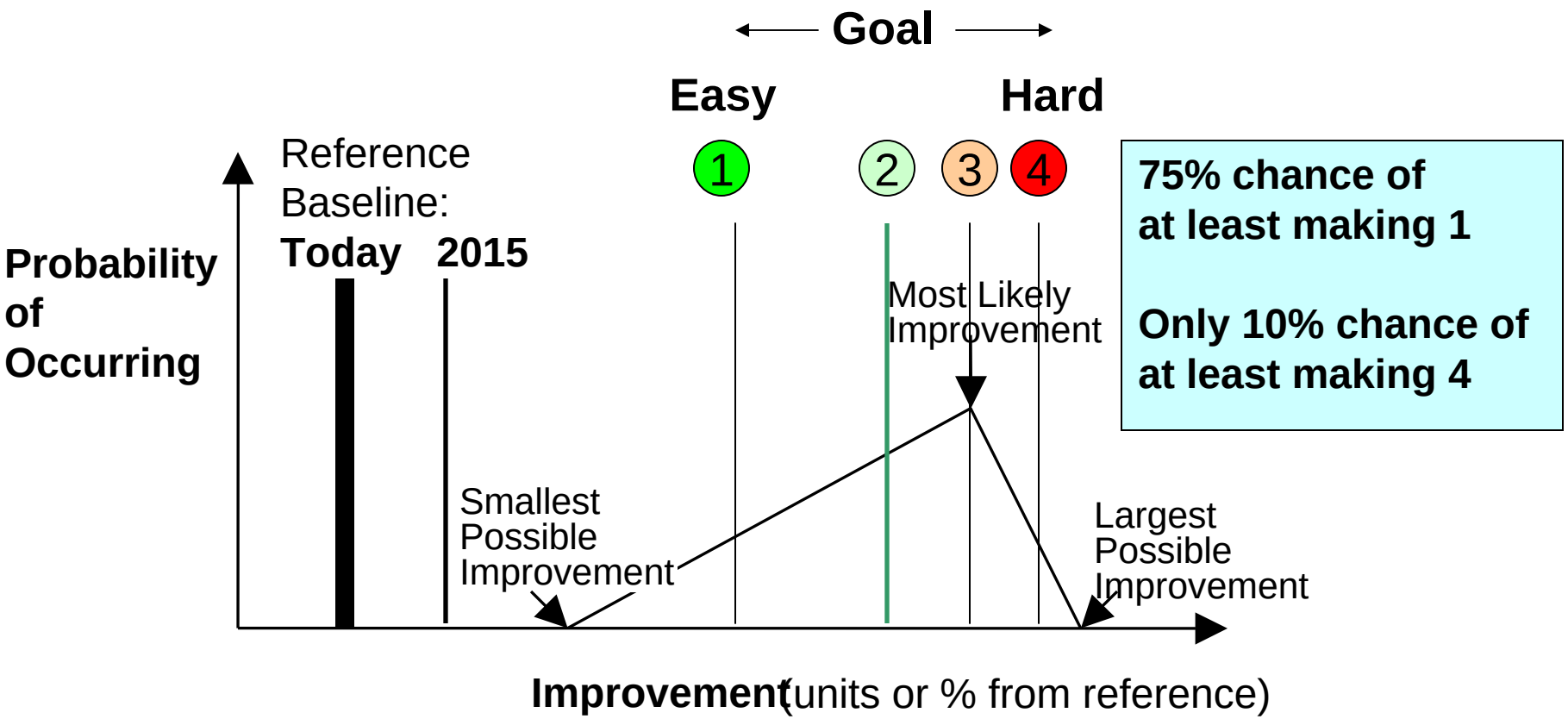
Estimating R&D output distributions

Selected Goals may align with the underlying R&D risk distributions in very different ways



The "riskiness" of R&D performance improvement depends partly on how aggressive the Goal is for a given year. Technical risk for the same "physical" R&D project is higher for Goal "4" than for Goal "1".

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Inputs

- **Baseline:** The TPMs (Technical Performance Measures—e.g. cost, performance, lifetime, O&M, reliability, etc.) of the Technology in the future without public R&D
  - Baseline TPMs.
- **Probability of Advance**: The probability that the R&D will be successful in advancing the technology.
  - Probability of Advance
- **Triangular Distribution:** The triangular distribution of the TPMs that the technology advances to if the R&D is successful
  - Least, Median, and Greatest Advance in the TPM (define as ±90% level)
- **Budget**: The needed and planned research budget and the triangular distribution of the expected earmark-free budget
  - Planned Budget; Least/Median/Greatest Budget; Base Fixed Cost Share
- **Schedule**: The planned schedule for the planned research budget and the triangular distribution for the expected time required to achieve the R&D for the planned budget.
  - Planned Completion Time; Least/Median/Greatest Completion time.

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Example

(illustrative values only)

SYSTEM	UNITS	Current	Prob. of Advance	Risk of Failure	FailureCas Expected Baseline	Triangular Distribution Most/Lst Advance	Median Advance	Lst/Most Advance
GoalYear	year	2005						
CapitalCost	$/kW	1110	0.9	0.1	1110	1060	1080	1100
Lifetime	Years	30	0.9	0.1	30	30	30	30
O&Mcost-Fixed	$/kW-yr	25	0.9	0.1	23	21	22	23
O&Mcost-Variable	$/MWh	4.31	0.9	0.1	4.3	4.1	4.2	4.3
Heat Rate	MMBtu/kW	9250	0.9	0.1	9200	9050	9100	9150
CapacityFactor	%	0.6	0.99	0.01	0.6	0.6	0.6	0.6
Supply/Efficiency	%	36.88649						
FuelCost	$/MMBtu	1.3						
EnergySupplied	kWh/year	5256						
FuelCost	$/kWh	0.012025						
CRF		0.080586						
Cost-NoIncentives	$/kWh	0.03811						
CarbonEmissions	kgCeq/kWl	0.237725						
BudgetTarget/Require			0.9	0.1	100	100	150	200
BudgetActual	$Million tot		0.9	0.1	100	100	150	200
R&D Schedule	Years							
On-Line Year	Years							

- Scale Budget/Schedule linearly; Factor in overheads.
- How best to parse risk, performance, budget/schedule?
- Linearly scale performance by year at subsystem/component level.
- No learning Curve-use R&D inputs (how to parse?); No Induced Innovation.
- Correlations.

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Example

(illustrative values only)

	A	B	E	F	G	H	I	J	K
6	SUBSYSTEM1					FailureCase	Triangular Distribution		
7	MODULE	UNITS		Prob. of Advance	Risk of Failure	Expected Baseline	Most/Lst Advance	Median Advance	Lst/Most Advance
8	GoalYear	year	2005						
9	CapitalCost	$/m2	470	0.6	0.4	380	110	150	190
10	Lifetime	Years	30	0.9	0.1	30	33	35	37
11	O&Mcost	%CapCos	0.003	0.9	0.1	0.003	0.0018	0.002	0.0022
12	Supply/EfficiencyExpert1		0.135	0.7	0.3	0.14	0.17	0.19	0.21
13	Supply/EfficiencyExpert2		0.135	0.8	0.2	0.135	0.18	0.2	0.22
14	Supply/EfficiencyExpert3		0.135	0.9	0.1	0.14	0.19	0.21	0.23
15	Supply/EfficiencyExpert4		0.135	0.8	0.2	0.145	0.18	0.2	0.22
16	Supply/Efficiency	%	0.135						
17	CapacityFactor	%	0.25	0.99	0.01	0.25	0.26	0.27	0.28
18	Solar Resource	kW/m2	1						
19	EnergySupplied	kWh/m2-y	295.65						
20	CapitalCost/kW	$/kW	3481.481481						
21	CRF		0.080586404						
22	AnnualCost-NoIncentives	$/m2	39.28560965						
23	BudgetRequired			0.9	0.1	100	100	150	200
24	BudgetActual	$Million total over period		0.9	0.1	80	80	100	120
25	R&D Schedule	Years							
26	On-Line Year	Years							

- Drill down to subsystem/component level.
- Compare parallel paths.
- Multiple expert estimates—generate a distribution of their inputs, weights.

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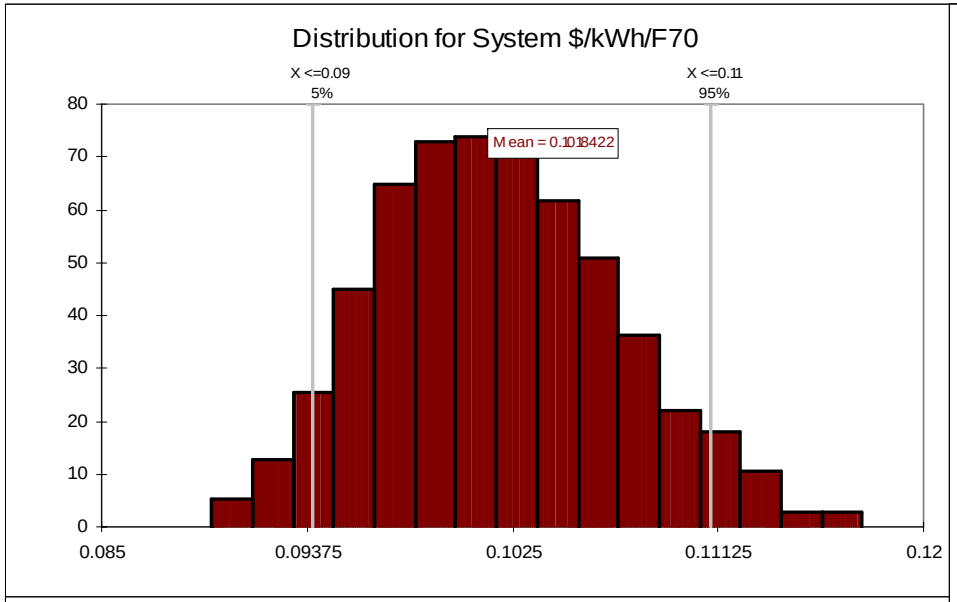
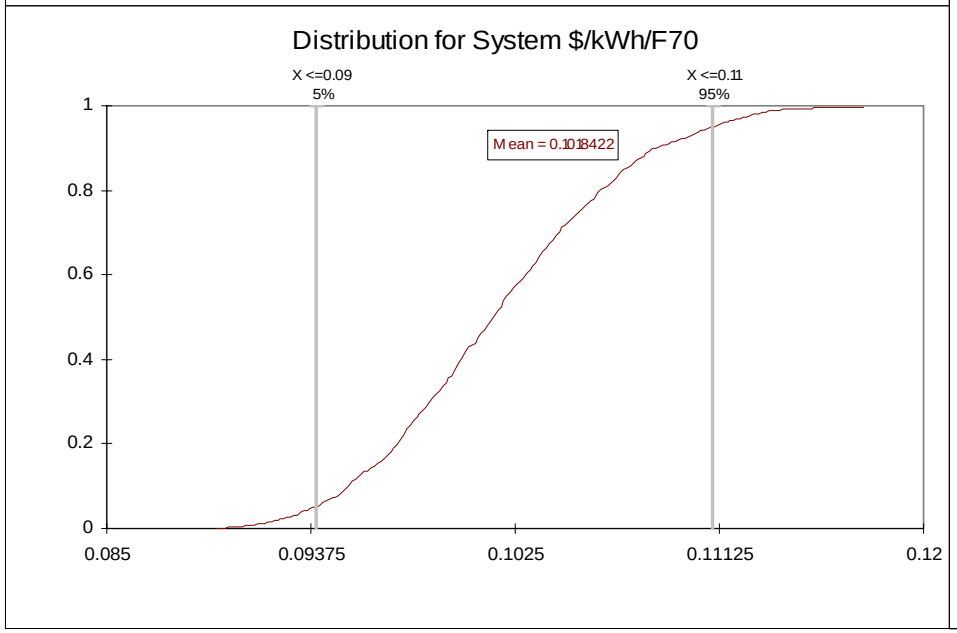
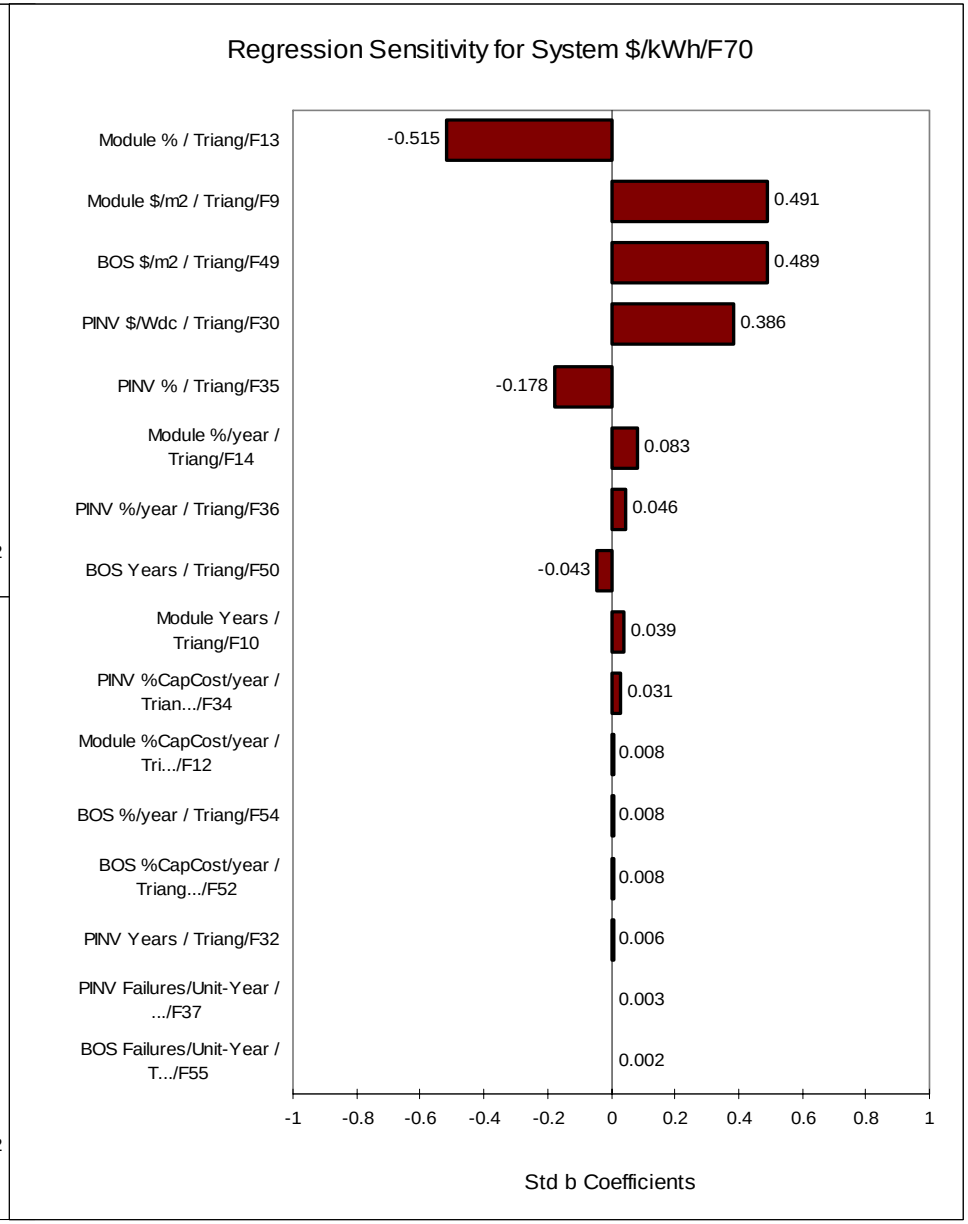
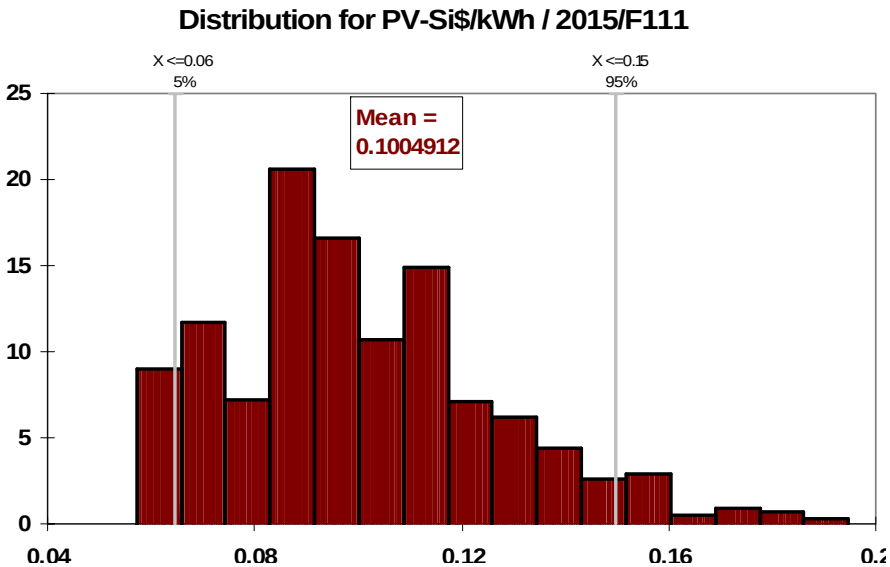
Quantitative Technical Risk: Outputs

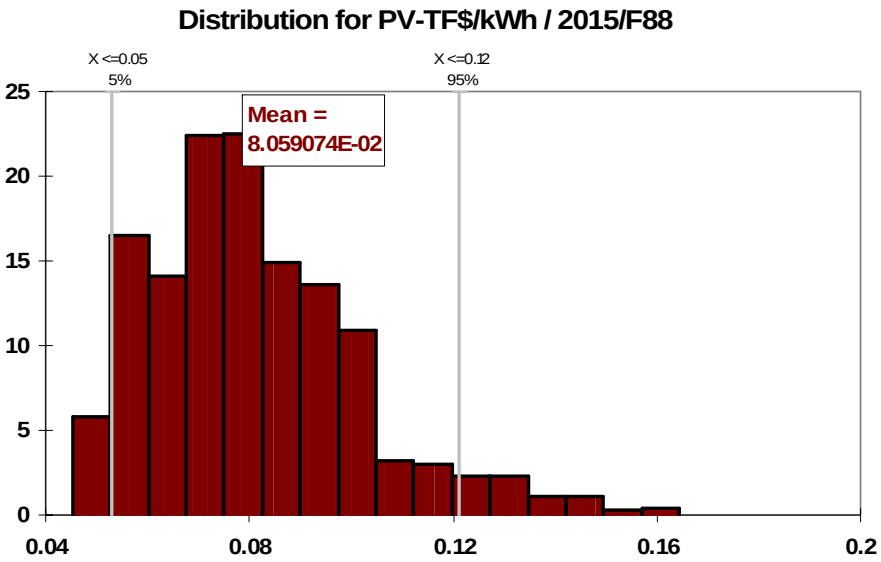


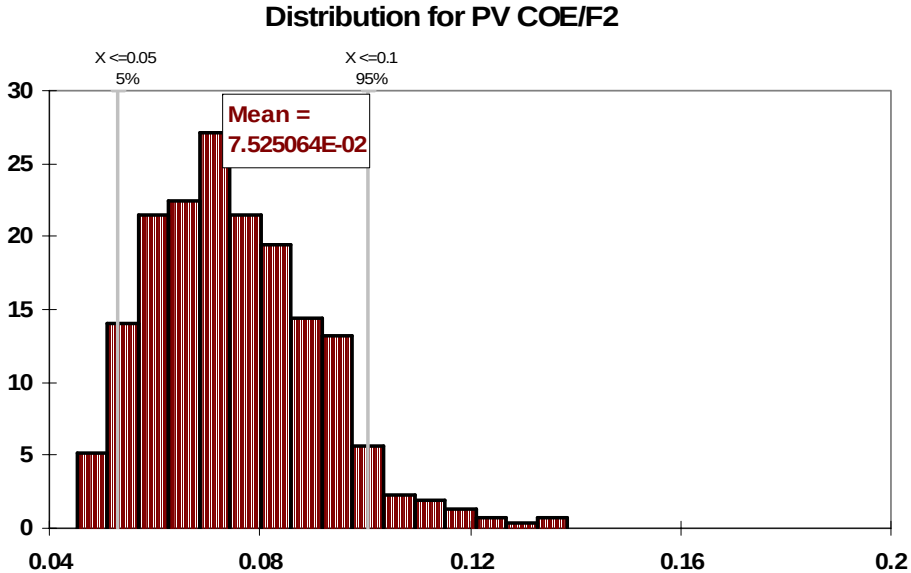




Quantitative Technical Risk: Outputs







- **Risk Distribution**
  - Likelihood of success
  - Risk of mission failure
  - Impacts of budget on schedule
  - Cumulative Risk
- **Tornado Diagram Sensitivities**
- **Parallel Path Analysis**

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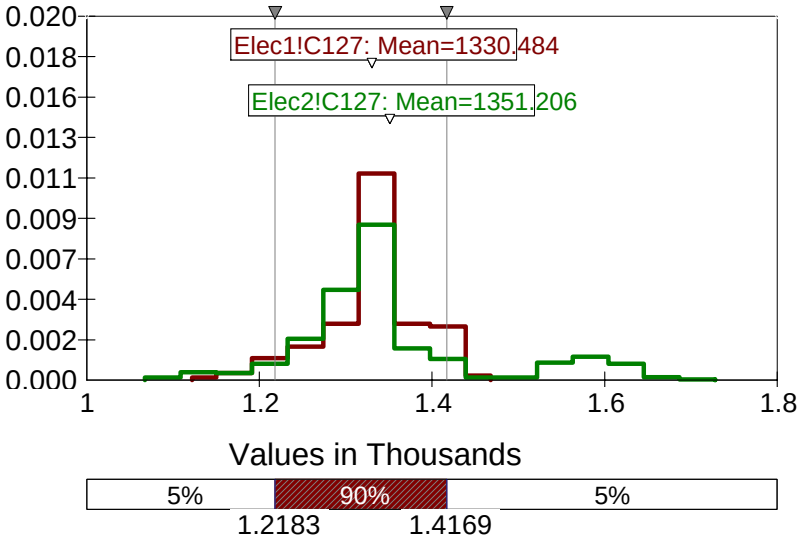
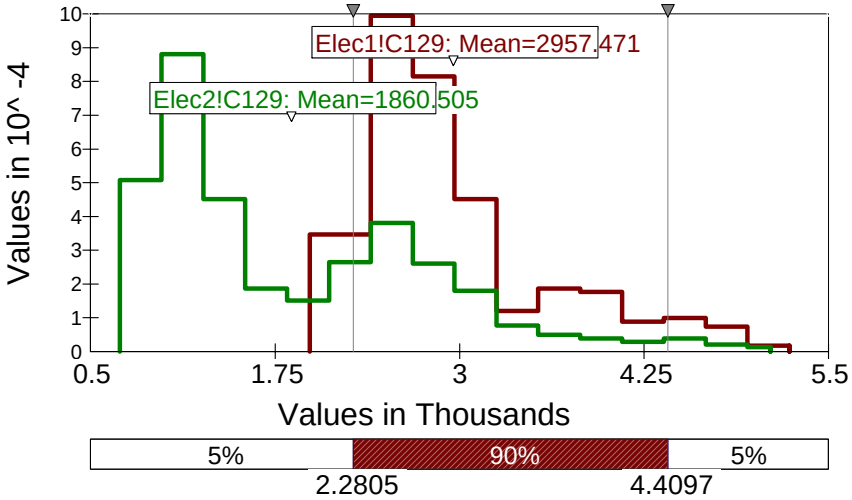
Risk and Benefits Analysis

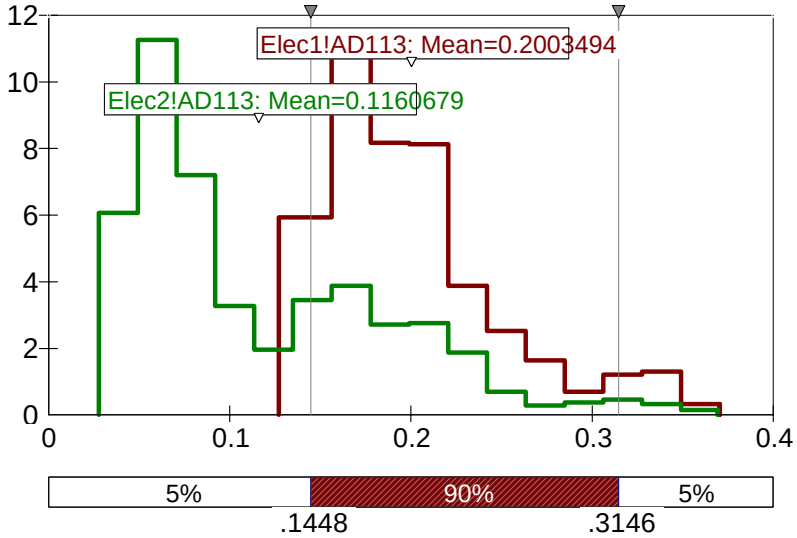
Distribution for ElectricityCostTotal/C127



Distribution for CarbonEmissionsTotalMTCe/C129



Distribution for PCFnlMktShare%2030/AD113

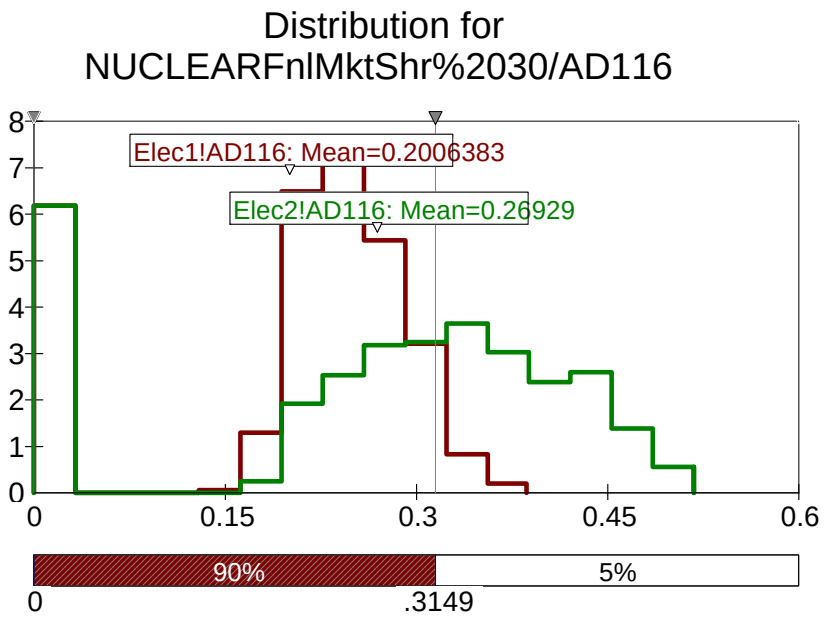


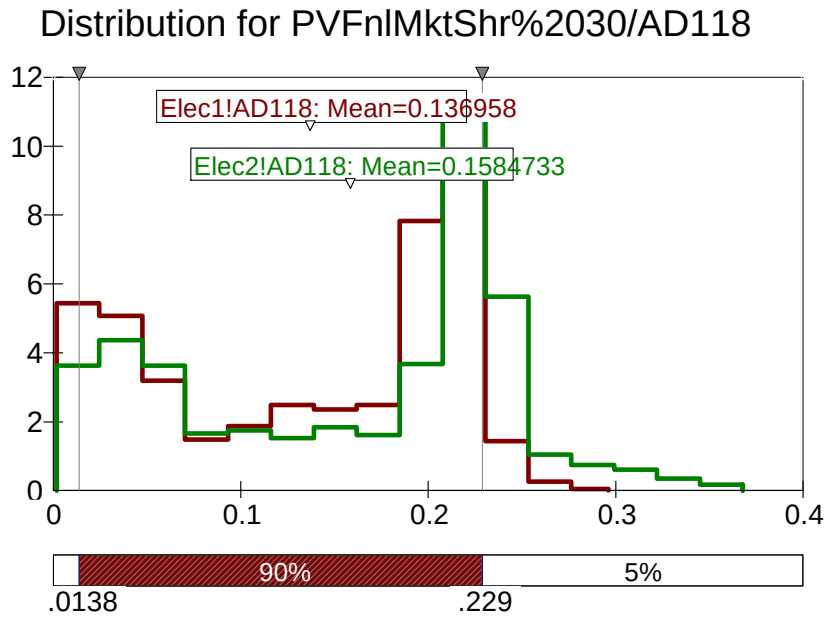
Logit Function:

Market Share A $= \dfrac{P_a^{-x}}{\{P_a^{-x} + P_b^{-x} + P_c^{-x} + P_d^{-x}\}}$.

Constraints for market share; cost adders

Risk and Benefits, contd





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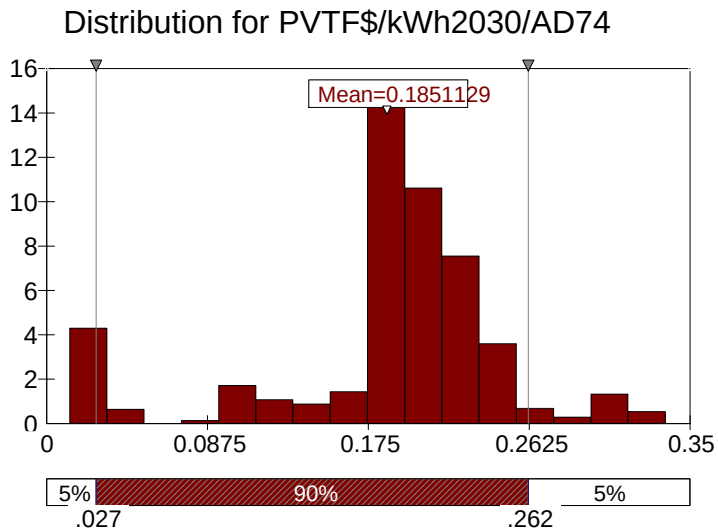
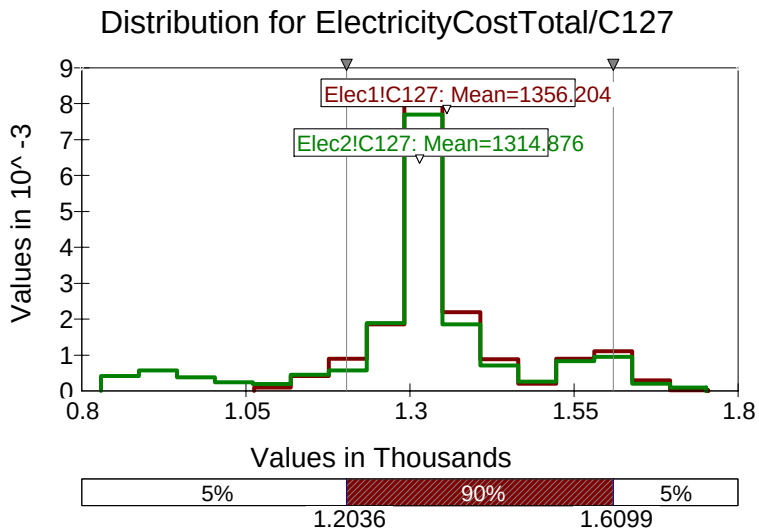
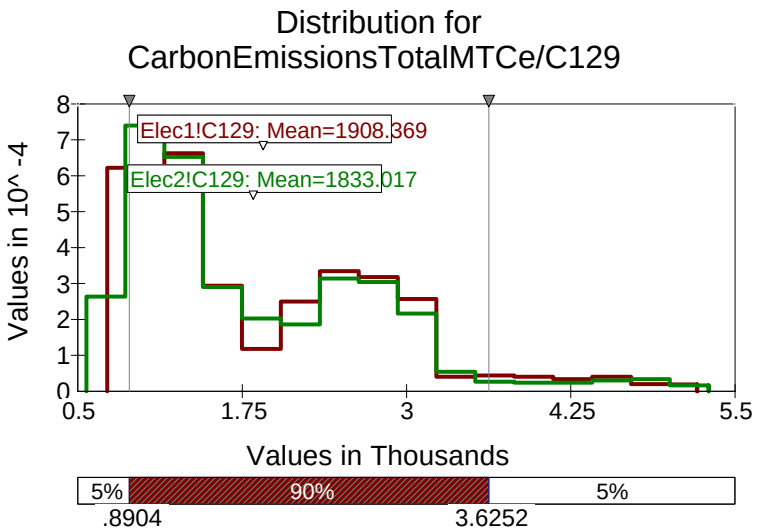
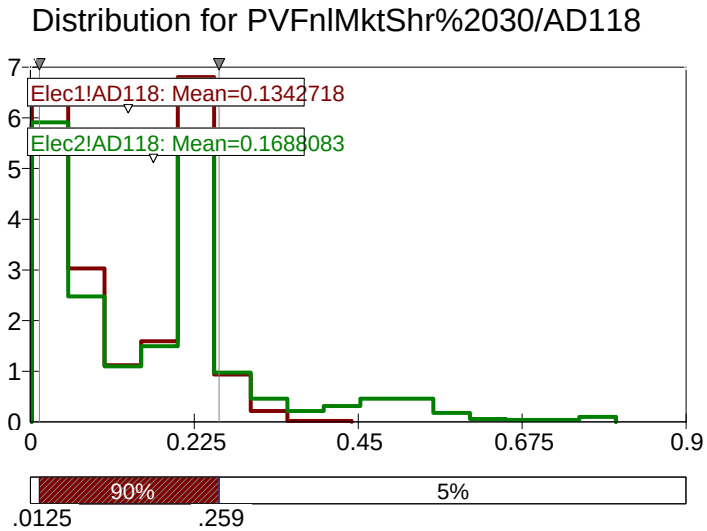
High Risk Science: QD PV









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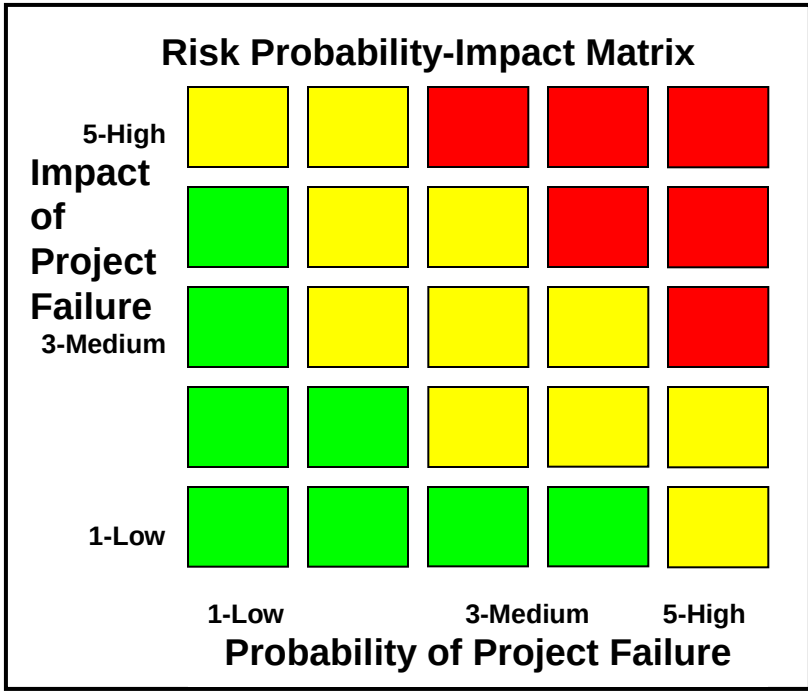
Identify/Evaluate (Qualitative) Risks

- **Primarily focused on improving project/program performance**
  - May also inform decision-making
- **Identify potential risks and their (qualitative) probability P of occurring:**
  - Managerial: Contract negotiations; contractor performance; oversight; WBS;
  - Safety/Regulatory/Environmental: Changes in requirements;
  - Market: Non-cost Market Factors—Market disconnects/barriers; poor consumer response; competition;
  - Financial/Economic: Investment; valley-of-death; economic conditions;
  - Political/Strategic: budget changes; earmarks; strategic linkages;
- **Identify potential (qualitative) impacts I of risks:**
- **Evaluate Probability Impact Scores, P*I**
- **Prioritize Risks for Management Action**
- **Manage Risks.**



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Manage Risks

- **Develop Risk Management Responses for each priority risk**.
  - **Avoid Risks** by not pursuing the activity that leads to the projected risk or by bypassing it, such as with a new technology pathway.
  - **Prevent Risks** through various counter-measures or by side-stepping their impacts.
  - **Control/Reduce Risks** through counter-measures, or should they occur, their impact/negative outcomes can be reduced.
  - **Transfer Risks** to a third party through such mechanisms as insurance, penalty clauses, or by other such means.
  - **Risk Contingency** plans to manage if/when risks are realized.
  - **(**Abandon/kill; Hold; Switch/Shift; Contract/Expand; Extend; Recycle; Hedge/Diversify**)**
- **Re-estimate Risks and Impacts**. What will the new probability of risk—following the completion of the risk management plan—be to the R&D activity; what would the potential impact on the activity be if this risk—also following the completion of the risk management plan—is realized?
- **Owners**. Individuals responsible for overseeing the successful implementation of these actions are identified and empowered to respond.
- **Monitoring/Tracking**. To determine whether a risk is being appropriately managed and reduced over time and projects and programs are on schedule and budget to achieve their performance objectives. If not, this can indicate the need for alternative risk management strategies, or even Stage Gate termination.
- **Identify Best Practices in Risk Management;** case studies of risk management.
- **Risk Management Information System (RMIS).** An RMIS is an important tool to develop for use here and elsewhere for such monitoring and tracking.

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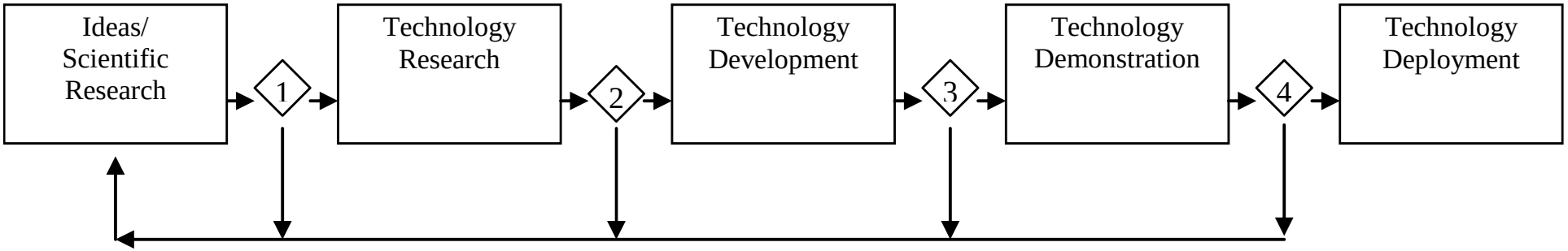
Make Risk-Informed Decisions

- **Resource Requirements** increase rapidly with stage of development.
- **Stage Gate:** Provide a formal process for decision-making on projects with stringency of requirements increasing with the stage of development/resources:
  - **Pass/Go:** Technology has successfully met goals and prospects favorable
  - **Continue**: Project needs further work for graduation; prospects favorable
  - **Hold/Recycle**: Project is worthy, but current prospects unfavorable
  - **Kill**: Project failing and cannot be saved; prospects unfavorable
- **Criteria for Stage Gates**:
  - **Program**: Risk-informed—Goals; Resources; Schedule; Pathways; Integration; Markets; Value; Safety/Regulatory; Competitive Position; etc.
  - **Portfolio**: Alignment; Balance; Strategic Value
- **Prioritize**



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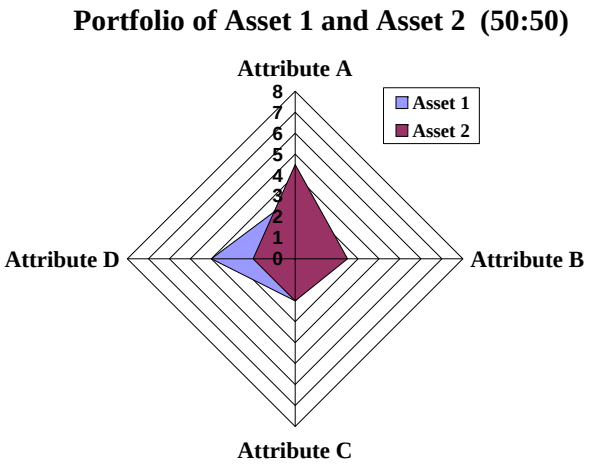
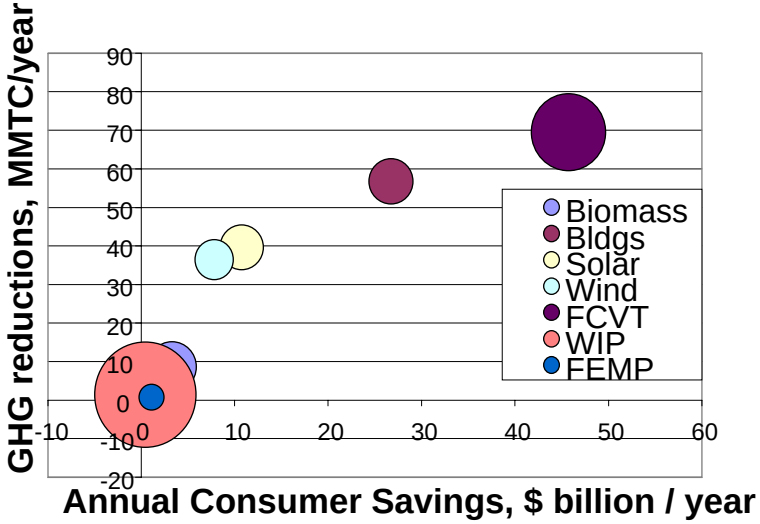
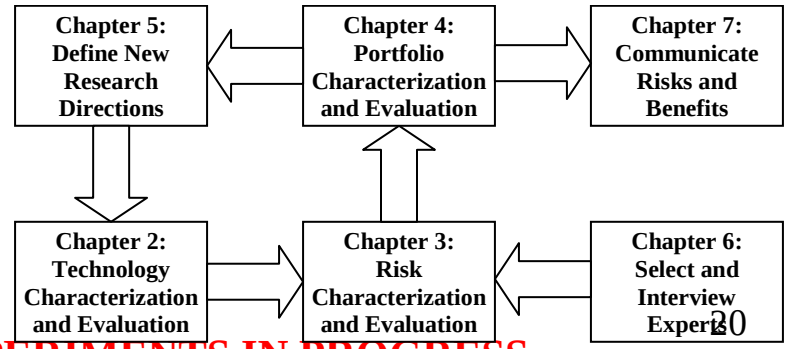
Analyze the Portfolio

- **Goals of Portfolio Analysis—**dynamic decision process; rapidly changing environment; many decisionmakers.
  - **Maximize Value** of the portfolio;
  - **Balance** across long vs. short-term, high vs. low risk, markets, technologies, right number of projects, etc.;
  - **Strategic Alignment** with national interests; The portfolio **IS** the national strategy
  - **Provide Strategic Value**; Open new opportunities for future.
  - **Build a robust portfolio**, value under range of conditions.
- **Outputs of Portfolio Analysis**:
  - **Evaluate** programs/projects;
  - **Prioritize** and select programs/projects
  - **Allocate resources** across activities;
- **Approaches:**
  - ***Strategic Buckets:** Top-down and bottoms-up
  - ***Scoring Models:** Strategy fit; strategic leverage; prob. of tech/market success...
  - ***Bubble Diagrams:** Risk/reward
  - ***Financial Methods:** Simple: NPV, IRR, ROI. Economy-wide: NEMS, MARKAL. Probabilistic: Monte Carlo, Decision Trees, Real Options.
  - **Sorting Models**: Group Pair-wise comparisons
  - **Mathematical Optimization Methods**







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