U.S. Department of Energy
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Portfolio Analysis: A Framework, and Review and Application of Some Portfolio Analysis Techniques

- A Discussion Document –

Energy Collaborative Analysis Initiative (ECAI)

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May 1, 2007*

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DRAFT - Revised

1: We would also like to thank Tobey Winters for contributions to parts of this analysis while at NREL

External Environment – including uncertainty

Some Key Elements of Portfolio Management

Strategic*
- Is the portfolio aligned with EERE's strategic goals?

Performance
- Is the portfolio achieving its performance measures?

Value**
- Do the portfolio's estimated benefits provide the near-, mid-, and long-term outcomes necessary to realize EERE's vision?

Outcome Correlation*

Balance**
Do we like the balance…
- Across the EERE Strategic Goals?
- Short vs. Long -term goals?
- High vs. Low -Risk?

Resource Constraints

Internal Environment – including uncertainty

*, ** Relative emphasis in this presentation

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No single tool addresses all the key elements of portfolio analysis – but understanding the connections between varying approaches is important

← Is there a common framework? →

Decision Maker Interests	Potential Portfolio Analysis Frameworks and Tools					
	Diversity Analysis	Attribute Mapping	Scoring Models	What If Impact	Bottom-Up Systems Analysis	Top-Down Opportunity Analysis
Opportunities and Gap Assessment						
Portfolio Balance (incl. Resilience and Hedge Value)						
Overall Portfolio Value						
Risk-Reward Representation						
Directing Marginal R&D Spending						
Alignment to Strategic Goals						

Applicability of Framework to Interest

- Strong
- Moderate
- Weak
- Not yet assessed

Focus today at Program/Technology level and above – rather than individual R&D projects

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Some Summary Findings

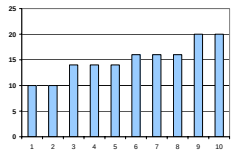
- Portfolio Analysis can provide a simple framework for viewing groups of assets – where "assets" might be financial investments, program activities and/or R&D projects
  - **Valuation of individual assets** (attribute values and uncertainty)
  - **Portfolio Analysis: Valuation and analysis of combinations of assets** (with attribute values, uncertainty and correlation between assets)
- Portfolio analysis frameworks and techniques often do a poor job of addressing risk and uncertainty, and the benefits that accrue from (lack of) correlation
  - How well analysis and/or figures represent these traits can be indicated

V	↔	Value
R	↔	Risk or uncertainty
C	↔	Lack of correlation of outcomes

- Portfolio Analysis frameworks and tools, and their application is as much "Art" as "Science". Understanding what these tools can <u>and cannot do</u> should help EERE is their decision making.
- Lack of credible data – or data relationships – can be a significant limiting factor on what analysis can be done

Structural considerations

Simplest case to consider is a single asset with a single value stream



Attribute A

Asset 1

Asset 1 (e.g. stock, generator, or R&D activity)

Attribute A (e.g. $, carbon or R&D outcome*)

is often characterized by

- An expected value for each year ($<a_i>$)
- Uncertainty about the expected value for each year (σ (a_i))

Assume attribute stream is uncertain over time

Discounted valuation techniques often used in simple cases *(e.g. defined by expected value and standard deviation)*

Other valuation techniques (decision tree analysis and/or us of real options) may be appropriate if attribute is volatile and operation of asset flexible *(e.g. a Combustion Turbine [CT] where attribute is the "spark spread")*

Numeric attributes also can be based on qualitative measures, such as alignment to strategic goals

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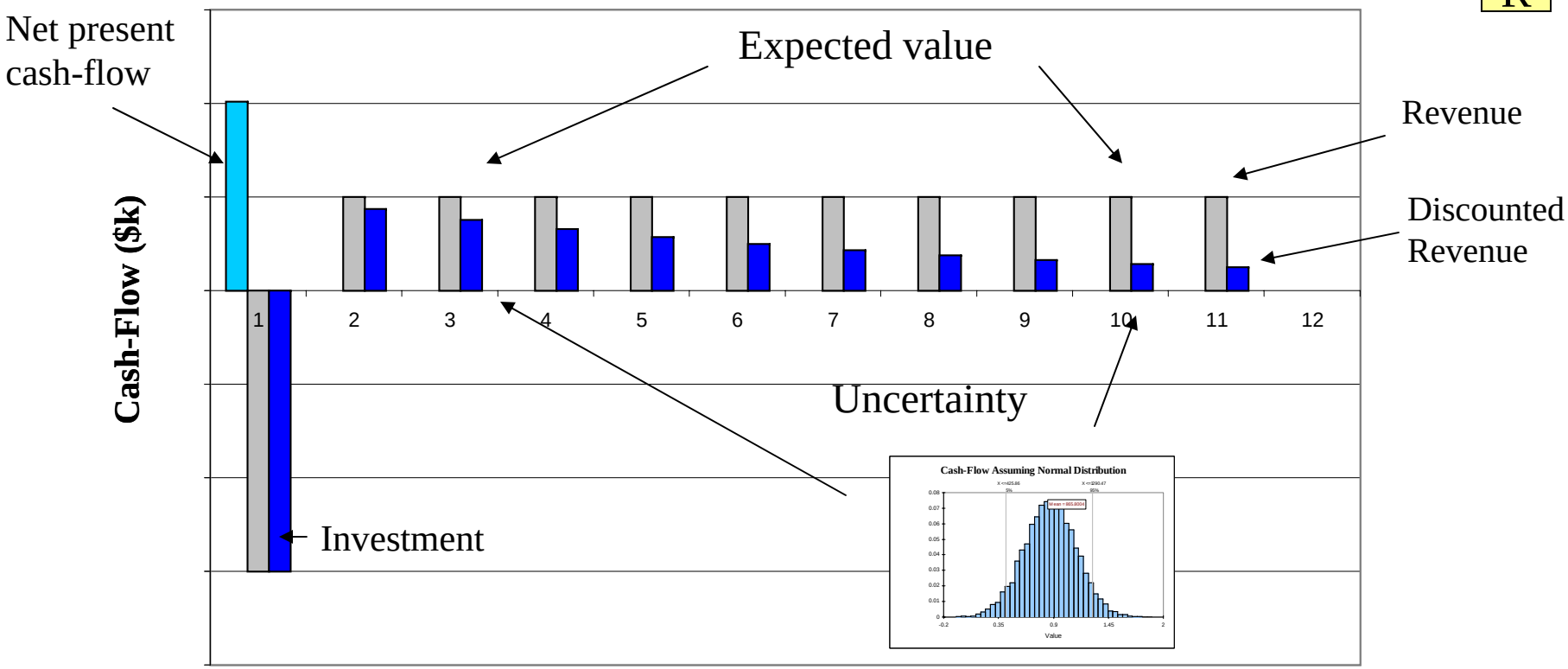
Structural considerations

Simple discounted cash flow techniques can be used to value some assets – though can miss much of the value due to uncertainty*

A Simple Example of a Net Present Value Calculation

Assumptions: Discount Rate (r)= 15%, All-Equity Financed)

V
R



*Due to the ability to flexibly respond to the resolution of uncertainty over time. See appendix for more complex methods, including real options

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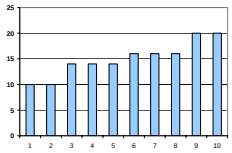
Note: Attribute A is $s

Structural considerations

Individual assets can be combined to form a portfolio – that can improve the owner's risk-reward position

V
R
C

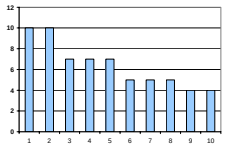
Share



Attribute A

X% Asset 1

+



Attribute A

100-X% Asset 2

Can be extended to N assets

As before:

Asset N (e.g. stock, generator, or R&D activity)

Attribute A (e.g. $, carbon or R&D outcome)

is characterized by

- An **expected value** for each year ($<a_i>$)
- **Uncertainty** about the expected value for each year (σ (a_i))

But now:

- **Correlation of outcomes** (corr (A(1), A(2))) also important*

* It is actually the lack of correlation that is important

Risk and Return

Portfolios of assets generally do better than expected for a given risk tolerance – and vice versa. ➔ Diversity is generally good

- Outcomes of different assets or R&D activities are rarely perfectly correlated – In practice, investing in many things offsets the risk to some degree
- Intuitively this is why financial planners often recommend that retirement portfolios hold a mixture of stocks and bonds. It is also why
  - It can make sense to carry out R&D for different technologies
  - It can make sense to carry out multiple R&D projects to achieve a specific goal
  - Adding wind to a portfolio of traditional assets can reduce portfolio risk
  - Wind developers may:
    - Obtain debt for multiple projects,
    - Invest equity in multiple projects, and
    - Buy turbines in advance for multiple projects
- In this section we explore – both quantitatively and qualitatively – the value of diversity in more detail

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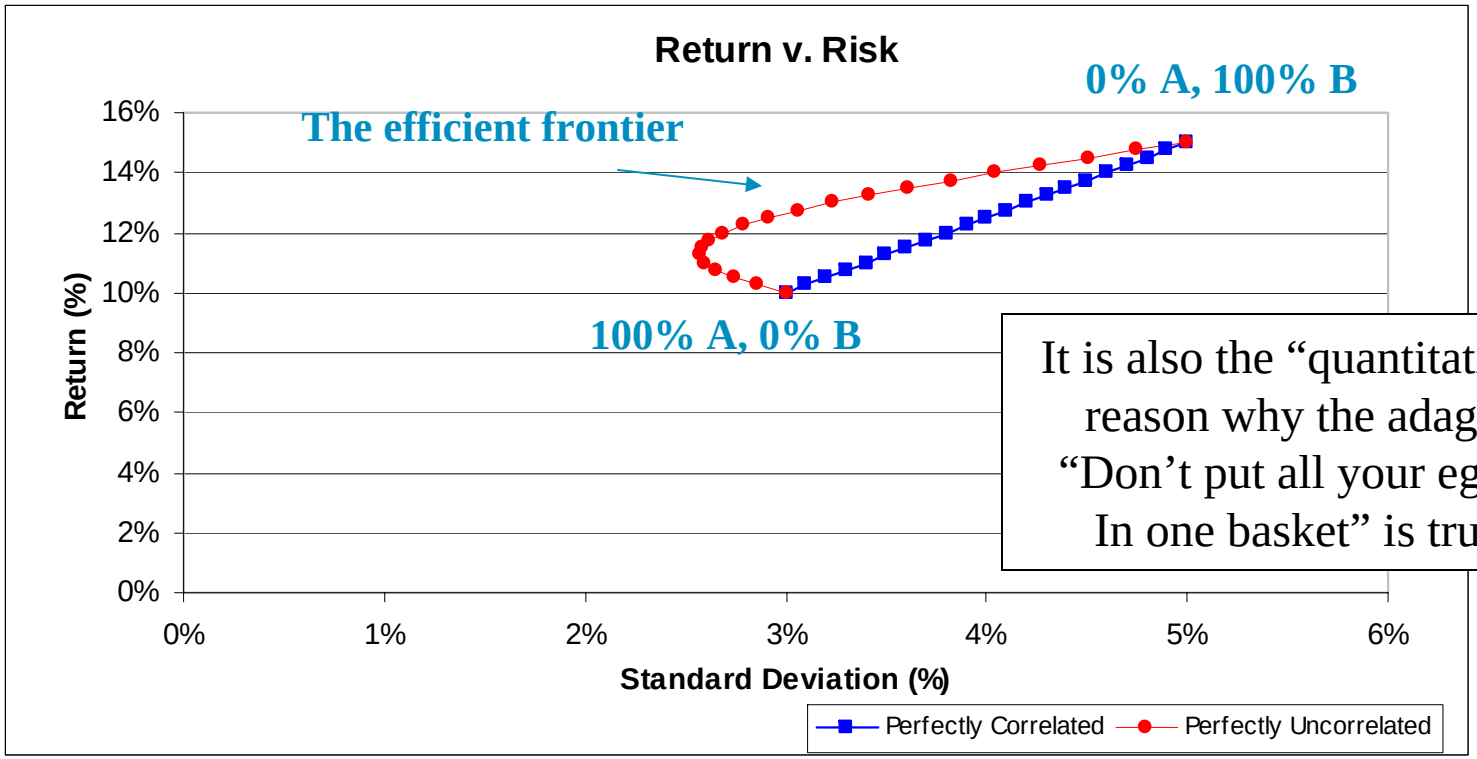
Risk and Return

When returns (or benefits) do not move in lock-step there is — on average – a better return for a given risk – or vice versa

V
R
C

- When assets are uncorrelated the risk for a given return can be reduced; a rare example of a "free lunch"*
- While basically statistics, this insight won a Nobel prize and tells you why investing in an S&P 500 index fund is smarter than you might think



It is also the "quantitative" reason why the adage "Don't put all your eggs In one basket" is true

* Shimon Awerbuch uses this "free lunch" analogy when discussing electric supply portfolios

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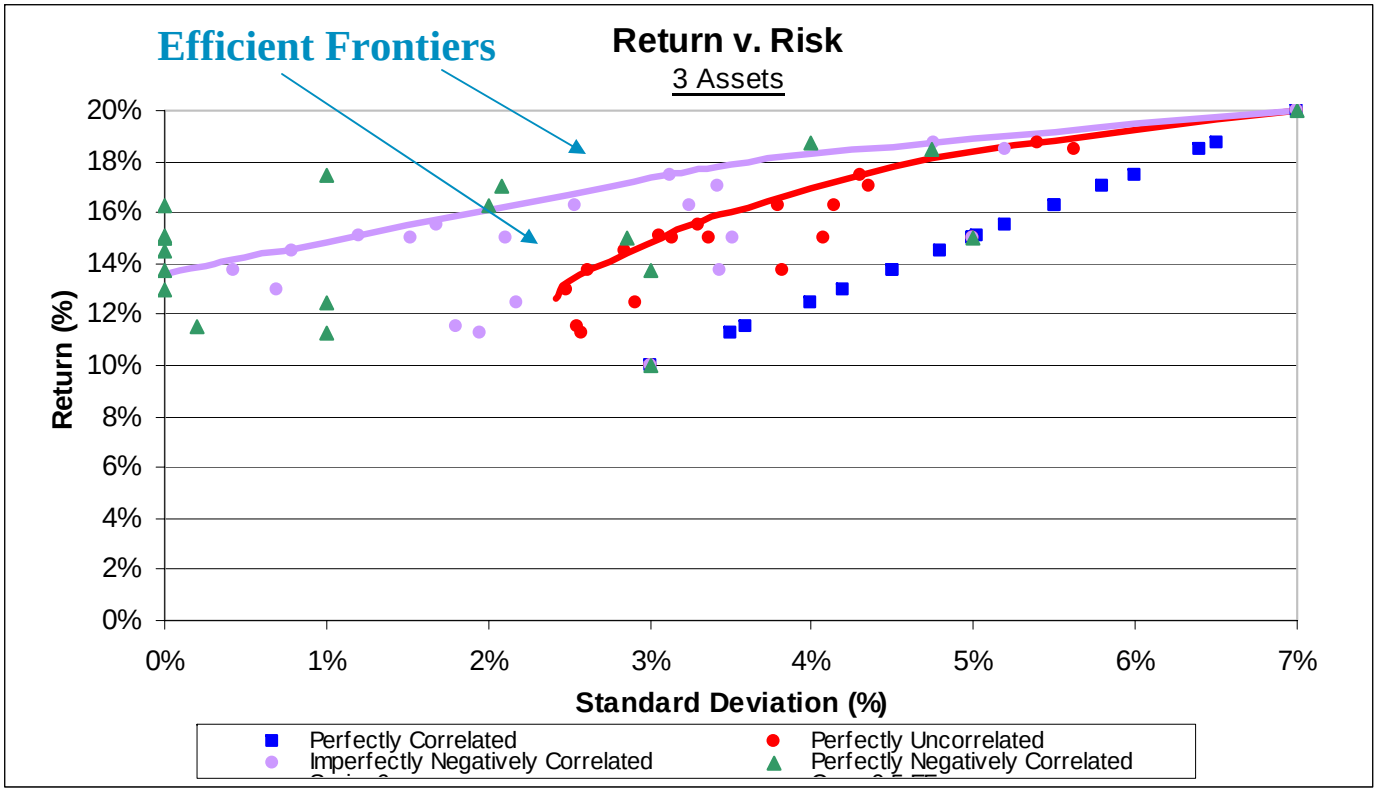
The theory also works for 3 or more assets – but now some mixes are strictly preferred over others – so care should be taken

V
R
C

- Combinations on the "efficient frontier" offer the best mix for risk and return
- Note: In our simple 2 asset example, each possible portfolio is on the EF – not so for 3 assets



* Brought forward from appendix

Risk and Return

The late Dr. Shimon Awerbuch explored the potential extension of this approach to electricity generation portfolios, with an emphasis the value of adding wind*

- Awerbuch's work showed "directionally" the benefit of adding wind to a traditional generation portfolio under certain assumptions – a "free lunch" for generation
  - He recognized that the inherent complexity/non-similarity of attributes associated with generation portfolios (such as differences between peaking and non-peaking units) limits the use of such analysis in determining how much wind to add – since many other factors need to be considered to "optimize" the portfolio
  - This caveat suggests the need to be careful when interpreting the results from other "quantitative" e.g. scoring models - however well they appear to "optimized"
- Once a trial portfolio is selected, it may be possible to get some quantitative sense of the benefits of using wind in place of alternate generation technologies

* The risk of a portfolio of financial instruments, which could include energy instruments, can be estimated using methodologies such as Value at risk (VaR), which refers to maximum loss (for a given confidence interval, e.g., 95th percentile) over a specified time period. Some hedging is possible by combining different contracts with options. Though not the focus of this presentation, it is a very important area of activity in both the financial and energy markets.

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Risk and Return - After Awerbuch

"Return" (Generation Cost)

	2005 ¢/kWh		
	2000	2010	2020
Gas (Old)	5.24	5.46	5.68
Coal (Old)	6.54	6.54	6.54
Nuclear (Old)	6.48	6.48	6.48
Hydro (Old)	5.64	5.64	5.64
Wind (Old)	5.26	5.26	5.26
Gas (New)	3.87	3.77	3.69
Coal (New)	7.78	7.09	6.46
Nuclear (New)	0.00	6.62	5.40
Onshore Wind (New)	5.32	4.12	3.57
Offshore Wind (New)		7.03	7.03

"Risk"

Technology Risk Estimates (Standard Deviation)

	Construction Period */	Fuel	Variable O&M	Fixed O&M
Gas	10.0%	23.0%	20.0%	8.7%
Coal	20.0%	12.8%	20.0%	8.7%
Nuclear	20.0%	9.5%	20.0%	8.7%
Hydro	20.0%	0.0%	20.0%	8.7%
Onshore Wind	5.0%	0.0%	20.0%	8.7%
Offshore Wind	7.5%	0.0%	20.0%	8.7%

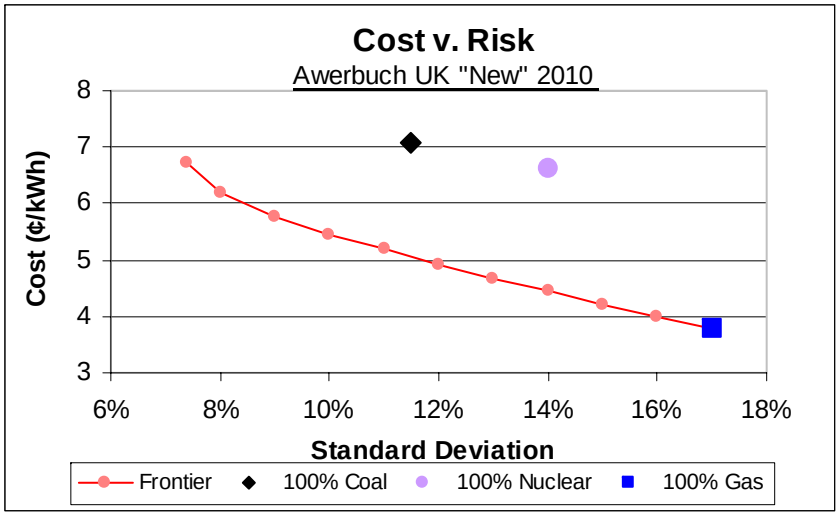
*/ Construction period risk for existing (embedded) technologies is 0.0

Fuel risk, determined from historical fuel price variation, dominates for fossil technologies

Correlation

	Coal	Gas	Nuclear	On Wind	Off Wind
Coal	1.0	0.2	-0.3	0.0	0.0
Gas	0.2	1.0	0.3	0.0	0.0
Nuclear	-0.3	0.3	1.0	0.0	0.0
Onshore Wind	0.0	0.0	0.0	1.0	0.0
Offshore Wind	0.0	0.0	0.0	0.0	1.0

Optimization



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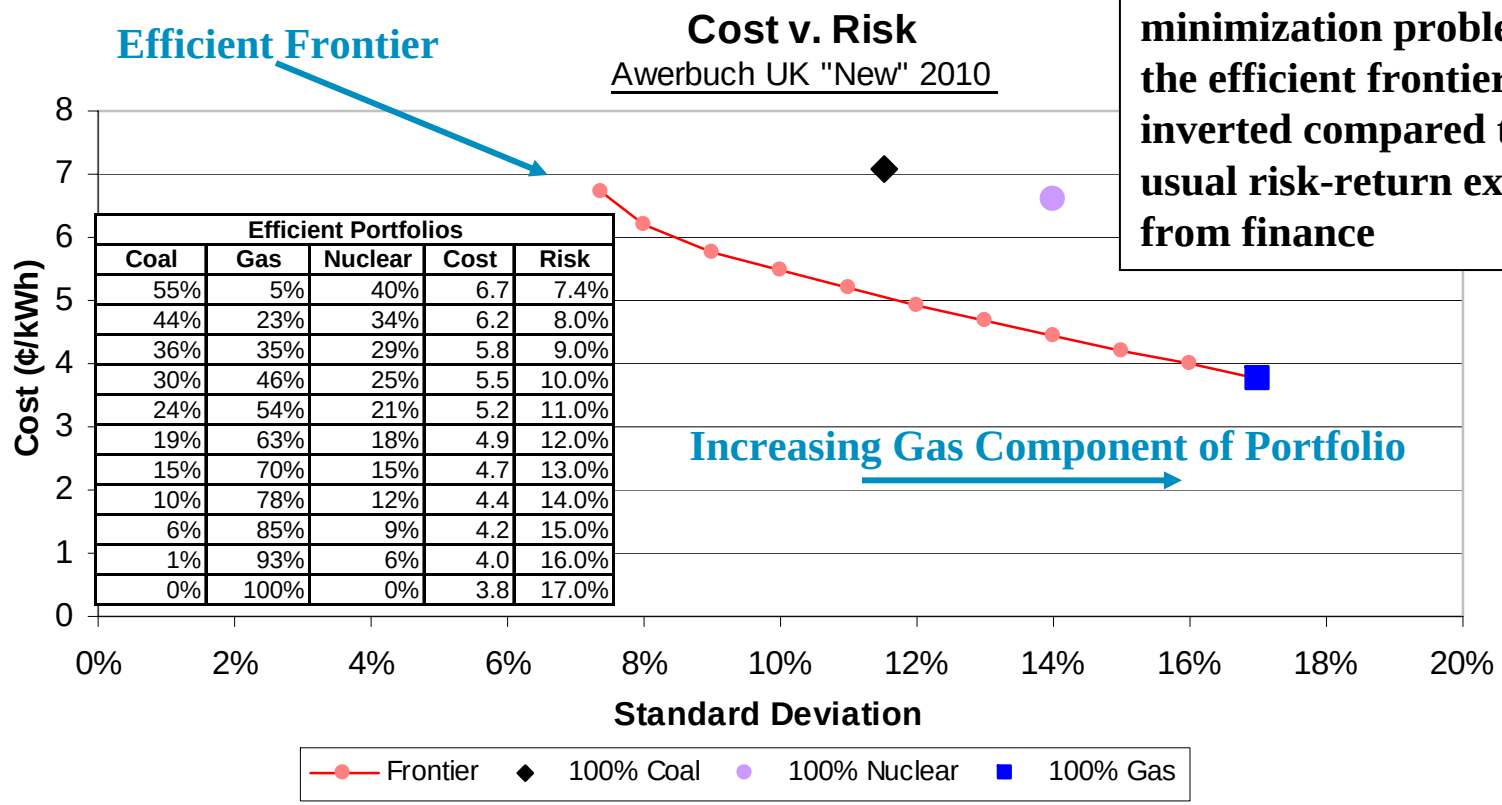
Risk and Return - After Awerbuch

Using Awerbuch's approach, "efficient" portfolios can be identified for conventional generation technologies (based on levelized generation cost and associated risk)

- Costs and risks are based on a UK example for new capacity, where costs include carbon allowances – results are directional

V
R
C

Note: Since this is a cost minimization problem, the efficient frontier is inverted compared to the usual risk-return example from finance



Efficient Portfolios				
Coal	Gas	Nuclear	Cost	Risk
55%	5%	40%	6.7	7.4%
44%	23%	34%	6.2	8.0%
36%	35%	29%	5.8	9.0%
30%	46%	25%	5.5	10.0%
24%	54%	21%	5.2	11.0%
19%	63%	18%	4.9	12.0%
15%	70%	15%	4.7	13.0%
10%	78%	12%	4.4	14.0%
6%	85%	9%	4.2	15.0%
1%	93%	6%	4.0	16.0%
0%	100%	0%	3.8	17.0%

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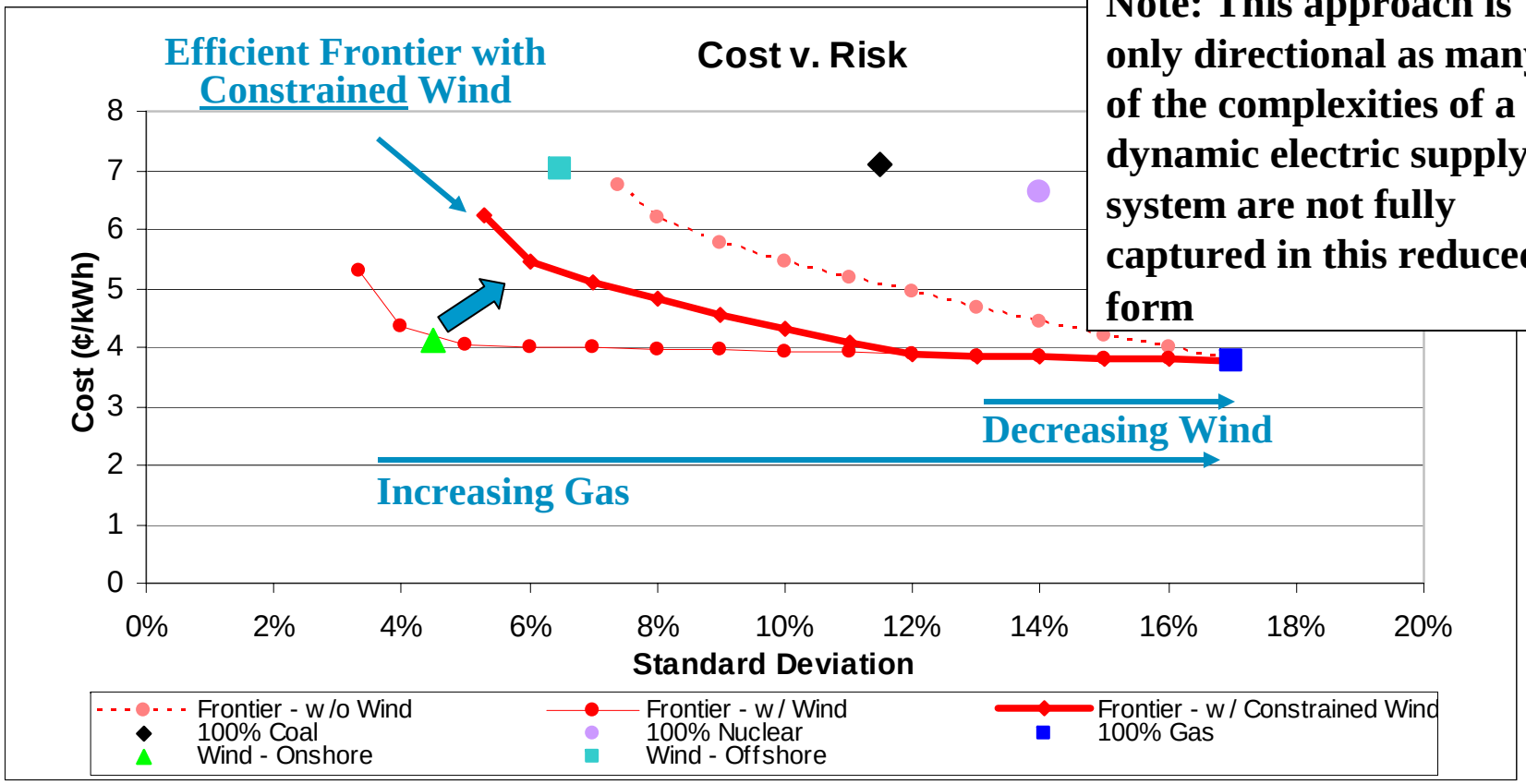
Risk and Return – After Awerbuch

The addition of Wind to the generation mix results in an improved frontier (reducing cost for any given level of risk)

V
R
C

- Impact driven by Wind's lack of correlation with fossil fuel costs
- The addition of a constraint can set upper limit



Note: This approach is only directional as many of the complexities of a dynamic electric supply system are not fully captured in this reduced form

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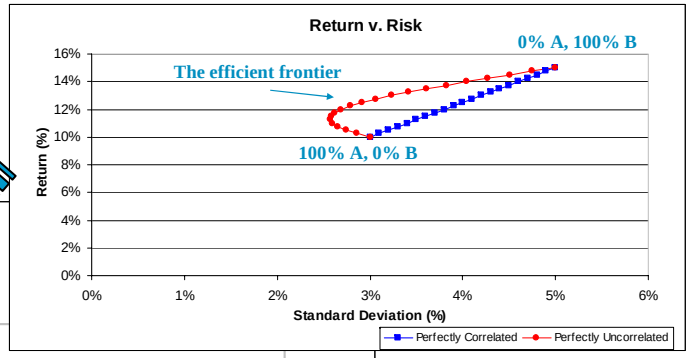
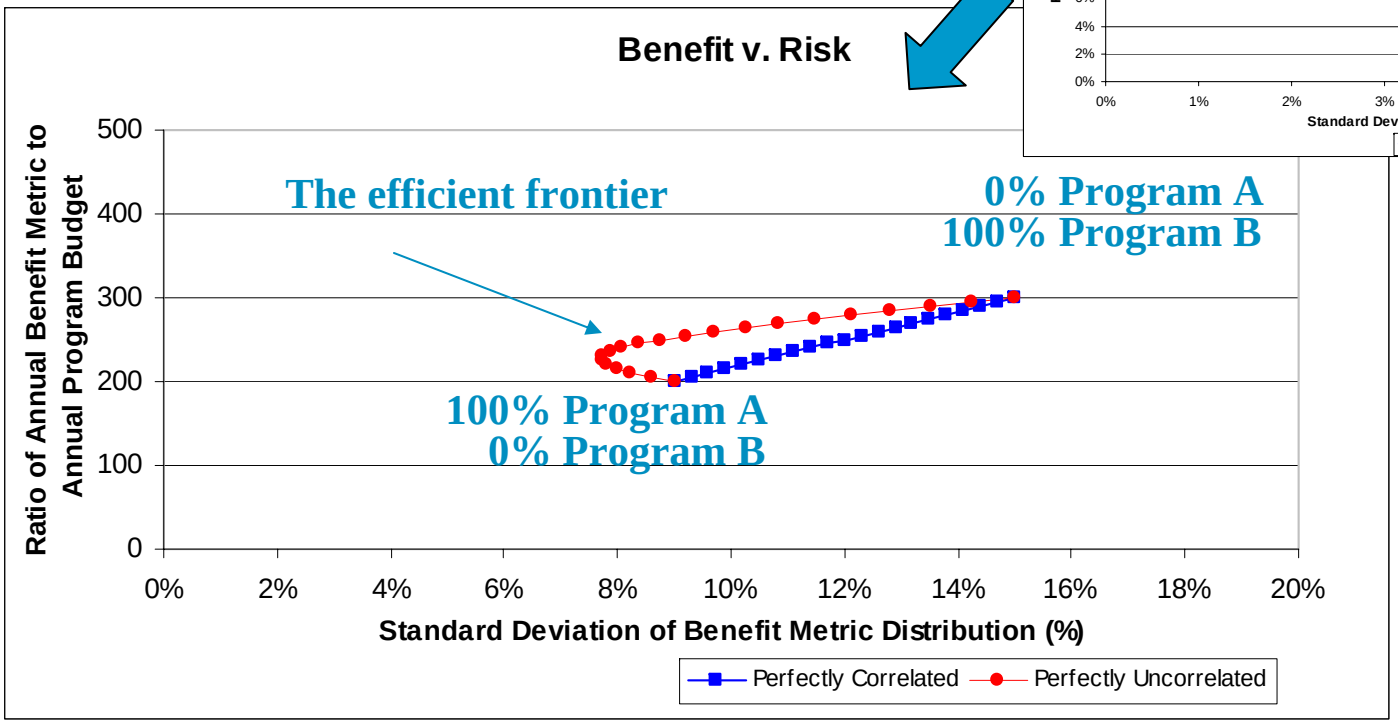
Risk and Return: Applicable to R&D?

Could a similar approach be applied directly to a portfolio of R&D programs and technologies, and associated benefits? Some issues

V
R
C

- Limited risk and uncertainty information to apply such a technique
- Correlation among program outcomes may be difficult to estimate
- Does risk-reward relationship makes sense?
- Are public funded R&D investments risk-neutral? (Social discount rates are 3% to 1.5%) & impact of this





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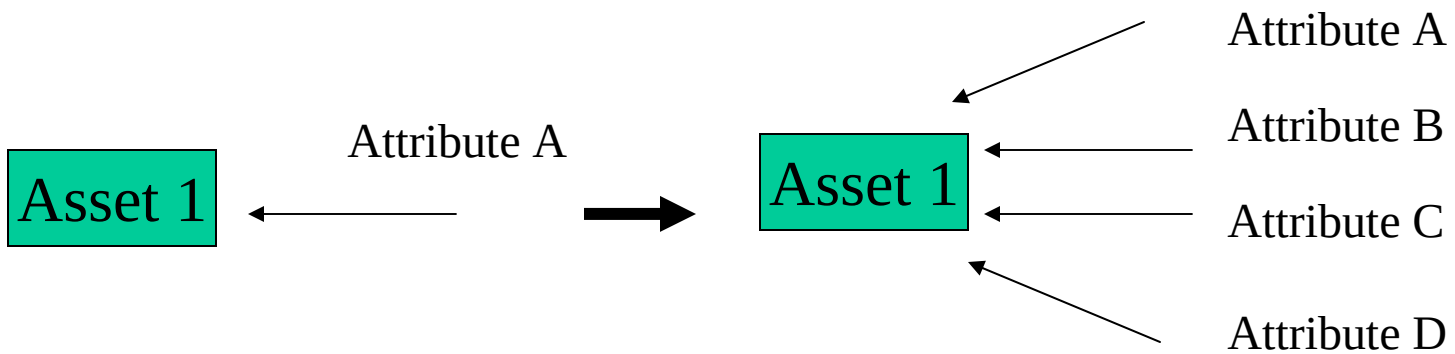
Structural considerations

Complicating this situation – assets often generate multiple attributes (that are often not easily compared) - and which can be given different weights

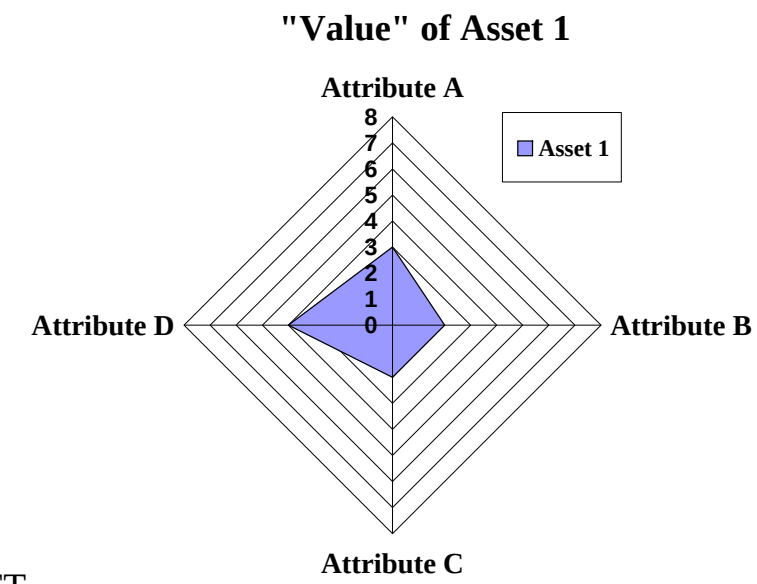
V
R



What is the value of an asset with many attributes?

More informative to represent without trying to "condense" to a single parameter

As before there will be uncertainty (or risk) about the values of these attributes (σ (A_i), σ (B_i), σ (C_i), and σ (D_i))



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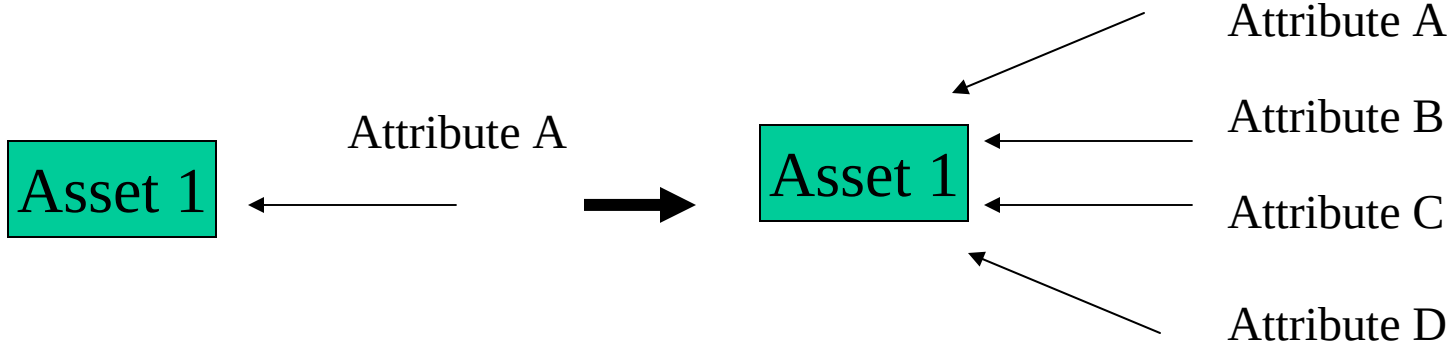
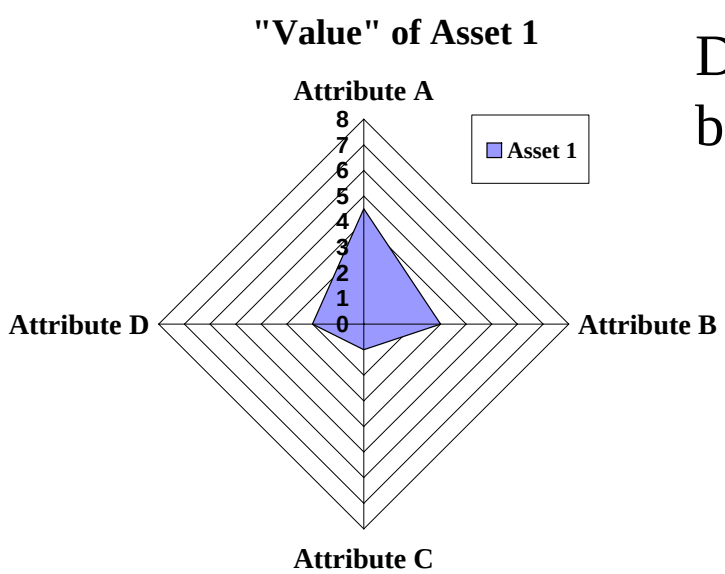
Structural considerations

Different weights to different attributes can lead to very different outcomes

V
R

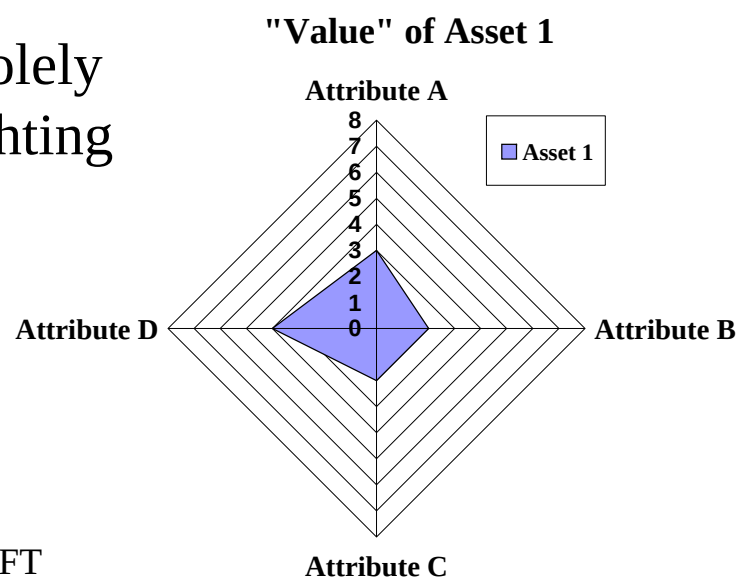
Information is lost if collapse to single value





Differ solely by weighting

OR



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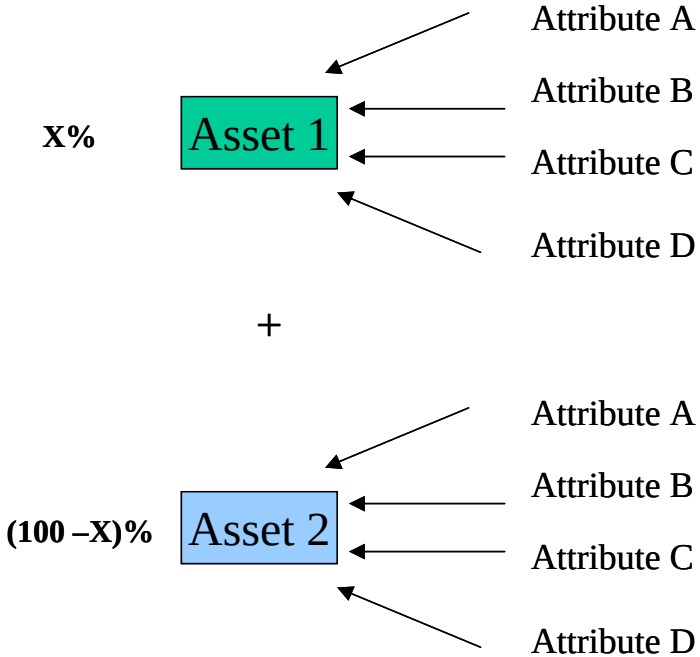
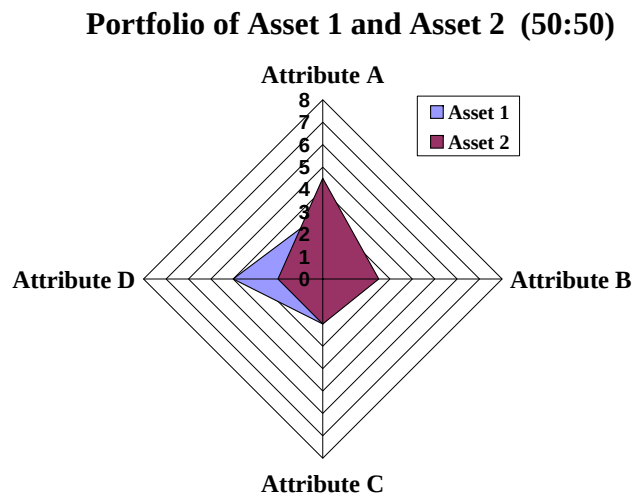
Structural considerations

Combining assets with multiple attributes into a portfolio leads to a more complicated problem

V
R
C





Lack of correlation of attributes needs to be considered as well as attribute values and uncertainty of those values

Could have N assets with n attributes

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Multi-attribute Analysis

DOE estimates, where possible, the economic and other benefits of their R&D and deployment Program (GPRA benefits)

GPRA Benefits

Economic Benefits

- **Reduction in gas prices**, percent
- **Annual consumer savings**, $bn/yr

Environmental Benefits

- **Avoided carbon emissions,** MMTCE/year

Security Benefits

- **Avoided oil imports**, million barrels/day
- **MPG improvement - Efficiency** (%)
- **Transportation fuel diversity improvement** (%)

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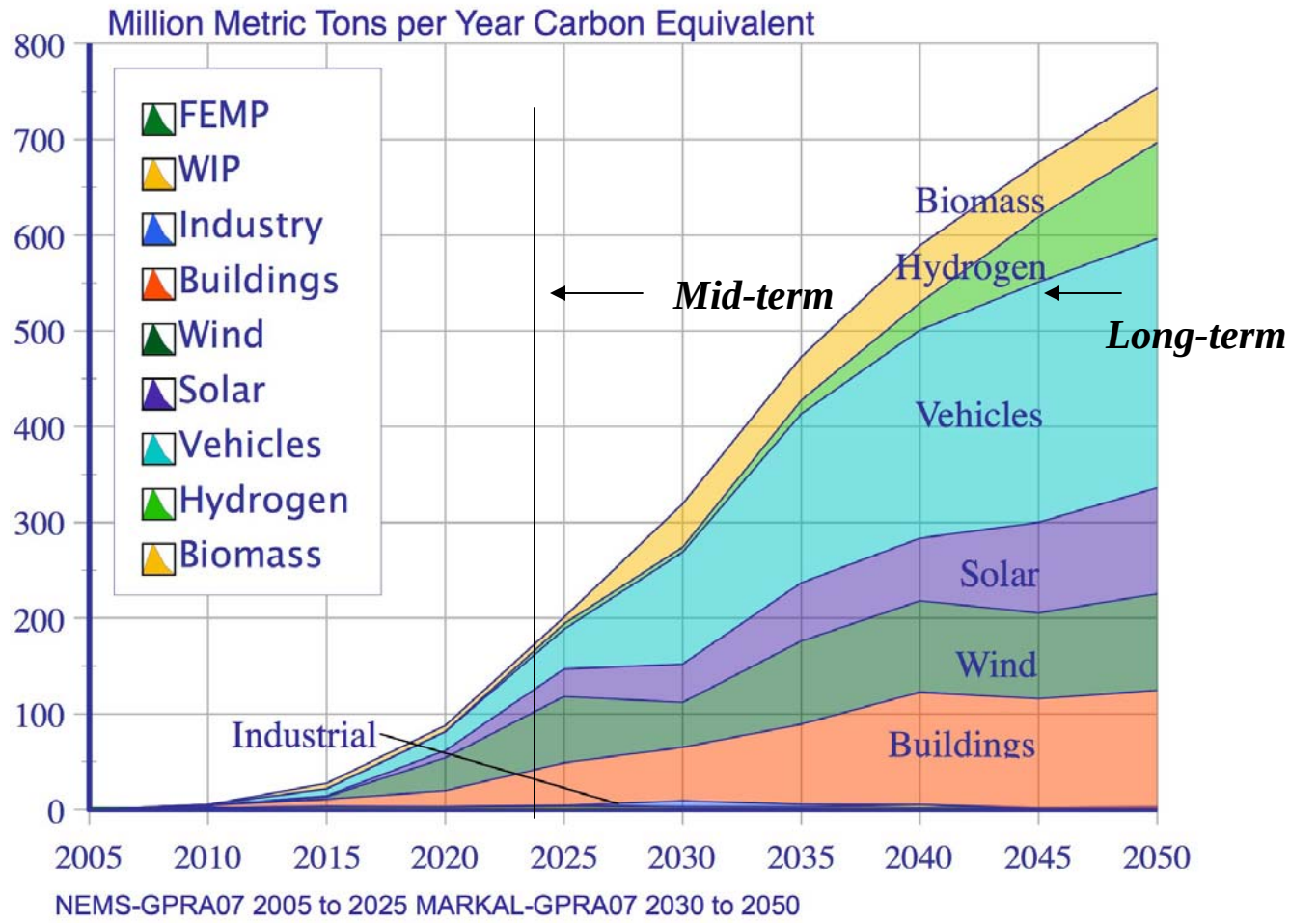
Single Attribute
Multi-Asset

A single attribute can be represented for multiple for program e.g. carbon reduction

Illustrative

V
R
C



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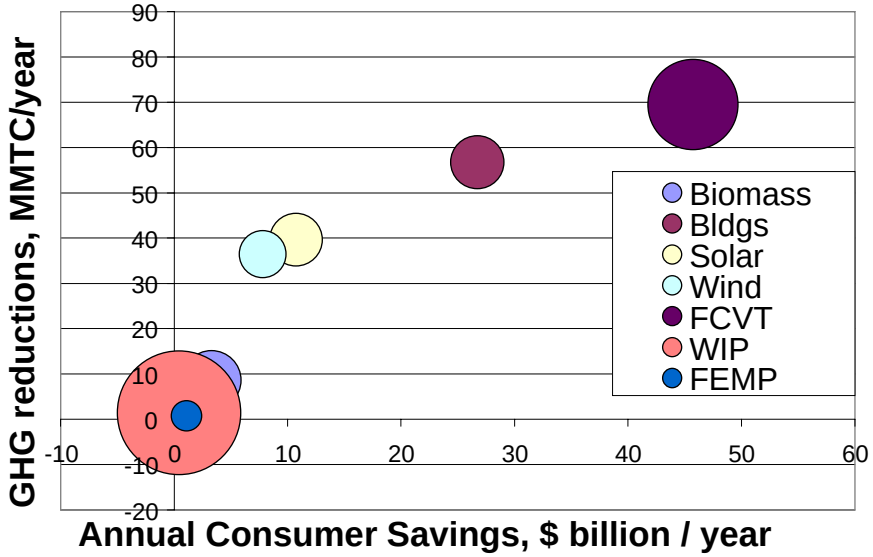
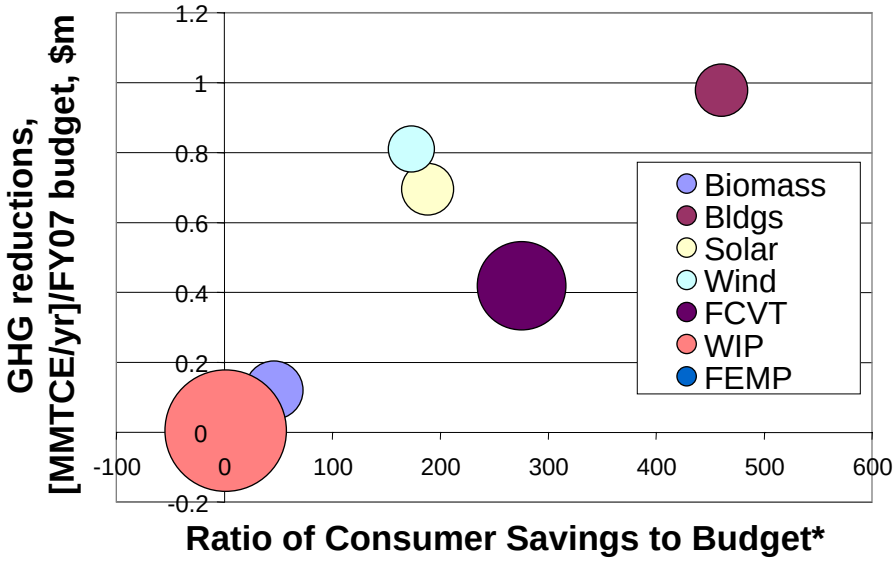
Multi-attribute Analysis
- 2 or 3 Attributes -

Environmental and economic benefits for different programs can be considered together

V
R
C

Illustrative





Circle diameter proportional to Program funding

* This is only a rough measure of "value"; could be refined to cover complete flow of benefits generated and R&D costs incurred, discounted as appropriate (e.g. using a social discount rate of 1.5% to 3%).

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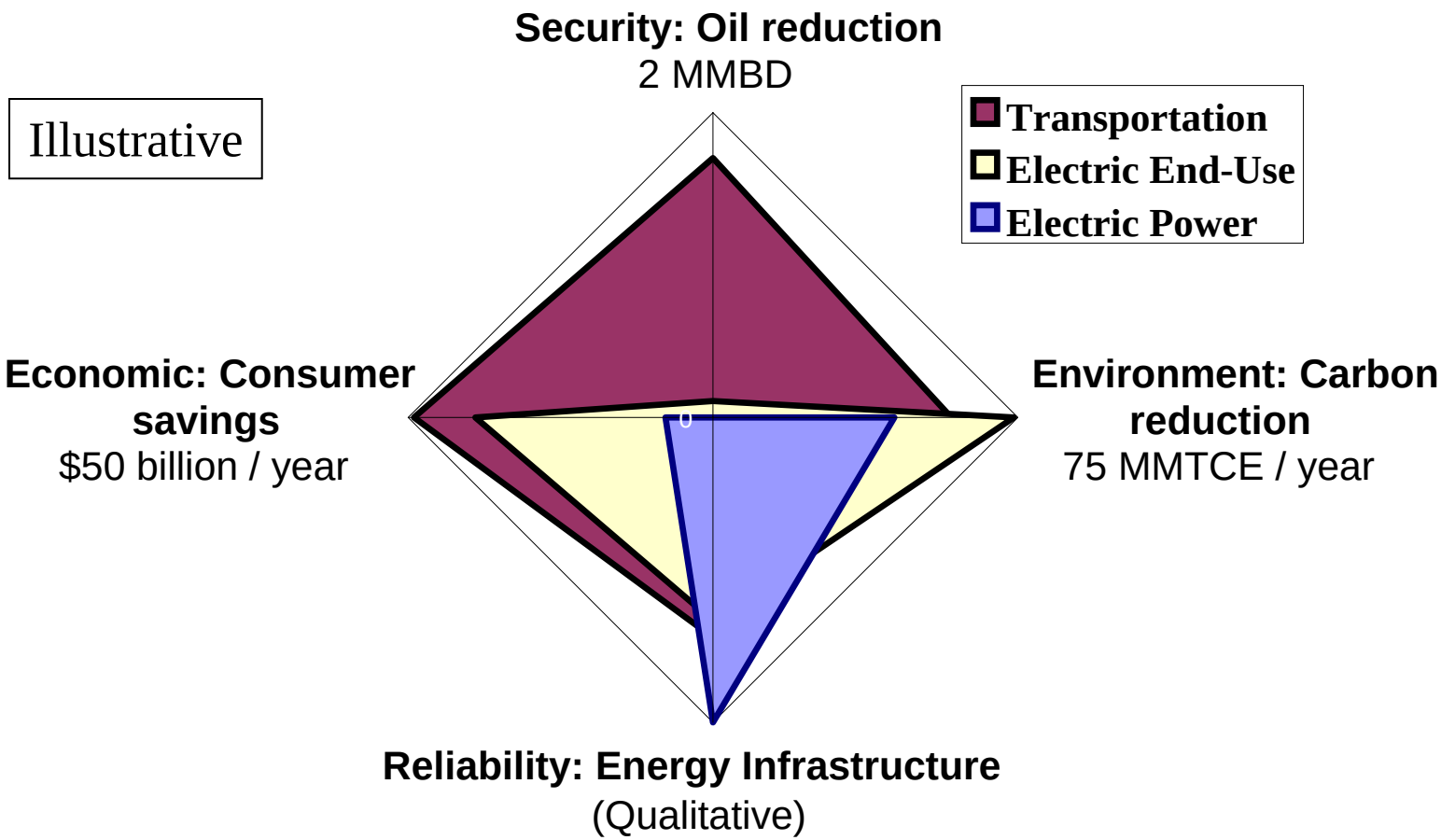
Multi-attribute representation of aggregated programs is also possible*

V
R
C

Illustrative



*Some of these attributes may correspond directly (or indirectly) to strategic goals.

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Scoring Models

- **Scoring models allow N-attributes to be considered** together by combining attributes into single metric using weights*
  - **Advantages**
    - Allows large numbers of factors to be considered – where figures would be unwieldy & this can be important to a decision maker
    - Allows ranking of technologies, projects
    - Allows sensitivity analysis
  - **Disadvantages**
    - Loss of information by collapsing to a single number
    - Can lead to overconfidence that the differences have meaning
    - Not good for representation of "balance"
    - Weighting based on decision maker is inherently subjective and/or arbitrary

* Weighting is not unique to the scoring model approach and can be applied to all earlier figures (and in fact implicitly was)

Structural considerations

Reducing the value of a portfolio – or component assets – to a single numbers loses a lot of information, and care should be taken when interpreting such analysis

Can build optimization models – in principle e.g.

Max [Value **[(x)(Asset [1]) + (1-x)(Asset [2])]]**

where: Asset[N](A,B,C,D]

Subject to:

σ (Portfolio (xA1, (1-x)A2)) <= 10% **(Risk/Uncertainty)**

nA + mC = 100 **(Resource Constraint)**

10A = 5B = 2C = D **(Weighting)**

(Correlation)

	A	**B**	**C**	**D**
A	1	p	q	r
B		1	s	t
C			1	u
D				1

Some use for approximate ranking, scenario analysis and stress testing

Fundamental issues with interpretation

- **Loss of information in representation by a single parameter**
- **Fundamentally different units**
- **Subjective weighting**
- **Poor data (Correlation and other data and data relationships often unknown)**

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Scoring Models

To understand strengths and limitations consider the ranking of different universities

- The Sunday Times (ST) ranks UK universities
- The Sunday Times identifies useful qualitative traits, decides on (relatively arbitrary weights), and then scores the universities
- The traits – or rather attributes - seem fair: Alternative Weights
  - Entrance Requirements (out of 250 points) x 3
  - Research Quality (200) x 0.5
  - Student Satisfaction (1500) x 0.5
  - Teaching Quality (100) x 0.5
  - Peer Assessment x 3
  - Employment Prospects (100) x 3
  - Exam Results (100) x 3
- The weights seem OK, but could easily be different e.g. Exam results might be worth more? Does research quality matter for an undergraduate?
- The scoring is arbitrary e.g. there must be many different ways to measure student satisfaction or employment prospects etc.

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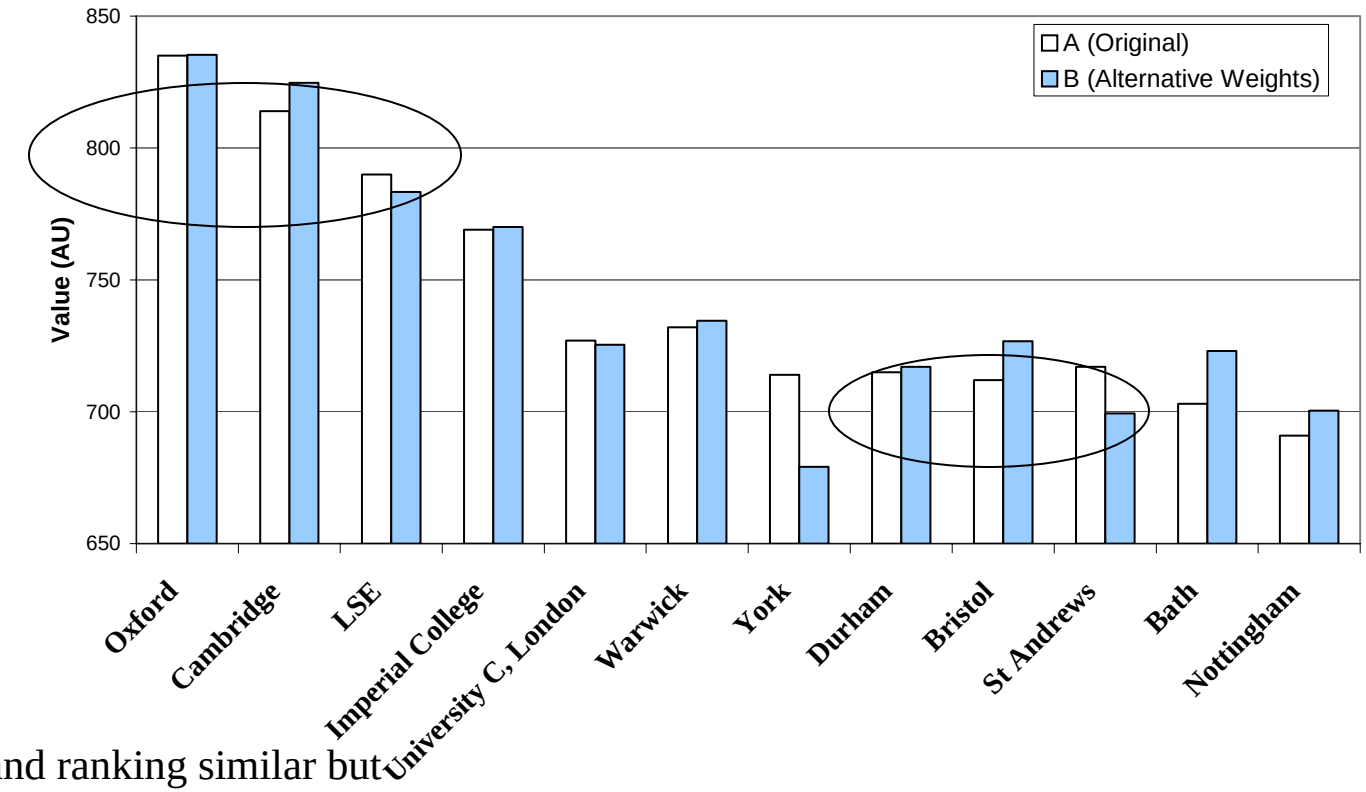
Oxford and Cambridge seem better than Bristol and Durham*

- But Bristol vs. Durham? Or even Oxford vs. Cambridge?
- Need to be very careful on the margin

Relative Value of University Attractiveness



* Scoring and ranking similar but not exactly the same as Sunday Times

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Scoring Models

Q: Given all this, how should one interpret the following?

A: With care

Not to be used for all Activities
Just one way to do it

	Scores	Weight	Project/Activity A				
			A	B	C	D	E
Threshold			Y	N	Y		Y
Impact			1	0			
Needs Assessment	1,3, 5	2		3			
Phase I/II - Mention	1,3, 5	1					
Phase I/II - Scores Link to MYP	(1-5)	1					
Phase I/II - Value to EERE		1					
A "Top 10 priority	1, 3, 5	1		3			
Other Criteria							
Meets one or more strategic goals	1, 3, 5	1		3	3	5	5	1
Adds value to corporate decision	1, 3, 5	1		3	3	5	5	1
Adds value to TD program decision	1, 3, 5	1		3	3	5	5	1
Benefit to Cost	1, 3, 5	1		3	3	5	5	1
Number of Programs Affected	1, 3, 5	1		3	3	5	5	1
Total/Priority				33	0	55	0	11

Strengths

Allows impact of qualitative dimensions to be aggregated and this is important

Weaknesses/Concerns

Arbitrariness of (i) questions
(ii) relative weights
(iii) scoring

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  - How well analysis and/or figures represent these traits can be indicated

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- Portfolio Analysis frameworks and tools, and their application is as much "Art" as "Science". Understanding what these tools can <u>and cannot do</u> should help EERE is their decision making.
- Lack of credible data – or data relationships – can be a significant limiting factor on what analysis can be done

Some Summary Findings

- Some observations
  - Assets often have multiple attributes and these should be represented explicitly where possible
  - Bundles of assets (i.e. portfolios) benefit from lack of correlation between the assets (and potentially)
  - Maximizing the value of a multi-asset, multi-attribute portfolio is not really possible – the question is whether it might be close and/or whether there is benefit from doing sensitivity analysis
  - Great care should be taken when using portfolio analysis for decisions making
    - May be useful for identifying major changes, but not useful or even misleading for where differences are small
    - This is partly due to inherent limitations with multi-attribute analysis
    - Data and the data relationships (or lack thereof) is also critical

Appendix

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Structural considerations*

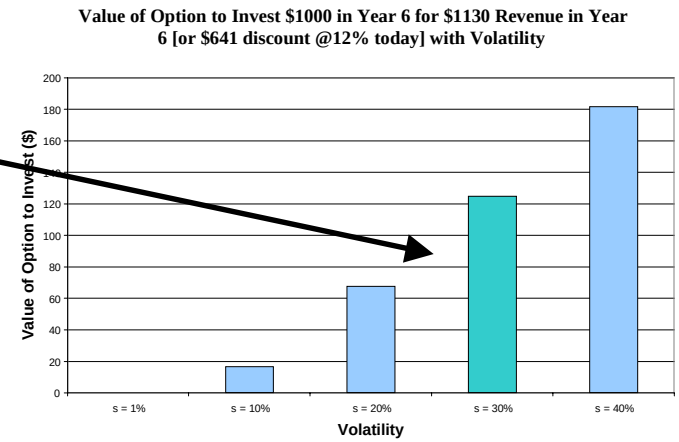
More complicated methods are required where asset's value depends on decisions that are made as the future unfolds (e.g. use of decision tree analysis and/or real options)

V
R

NPV = R&D Cost + Value today of Option to Invest $1000 in Year 6
[in a Project with PV of $1130 in Year 6 [and $641 today]]

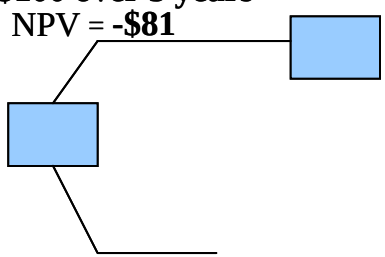
<u>Value of Option</u> c(V, I, τ, t) = $125

Discount rate = 12%
Risk Free Rate = 5%
Volatility σ = 30%



R&D worth doing if costs less than value of option created

R&D Investment $100 over 5 years
NPV = **-$81**



No R&D Investment - Stop

Invest $1000 For Production Plant

PV = [PV(200) over 10 yrs @ 12%]/(1.12)^5
= $1130/(1.12)^5
= $641

Value of option solved here analytically - using Black-Scholes equation.
This is a special case: more complex problems use other approaches, such as Monte Carlo simulations

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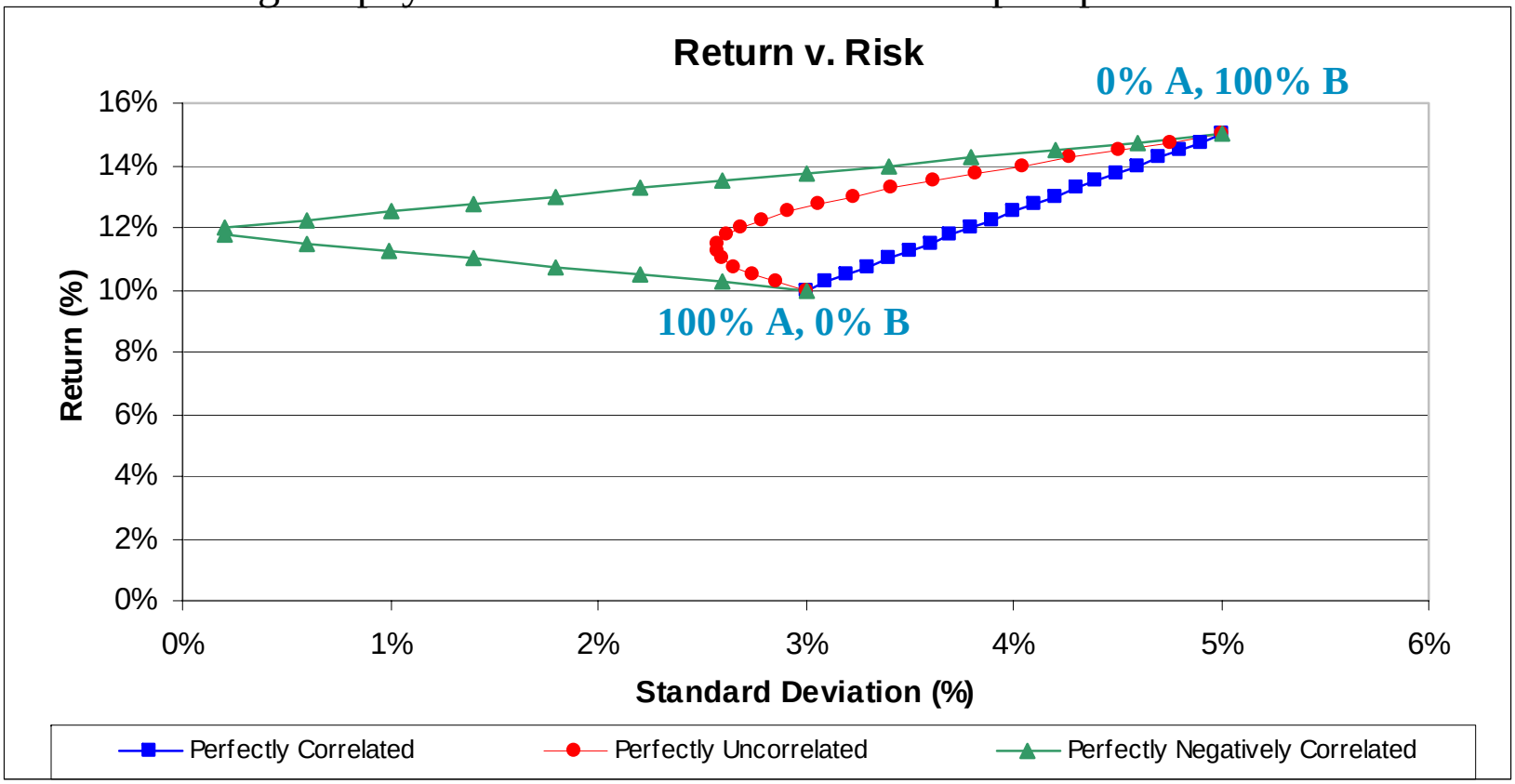
Risk and Return

Negatively correlated assets – where returns are inversely related – offer the greatest benefits and are worth understanding in R&D "success"

- With perfectly negatively correlated assets – which exist only in theory – risk can be eliminated!
- Understanding the physical intuition behind this concept is powerful



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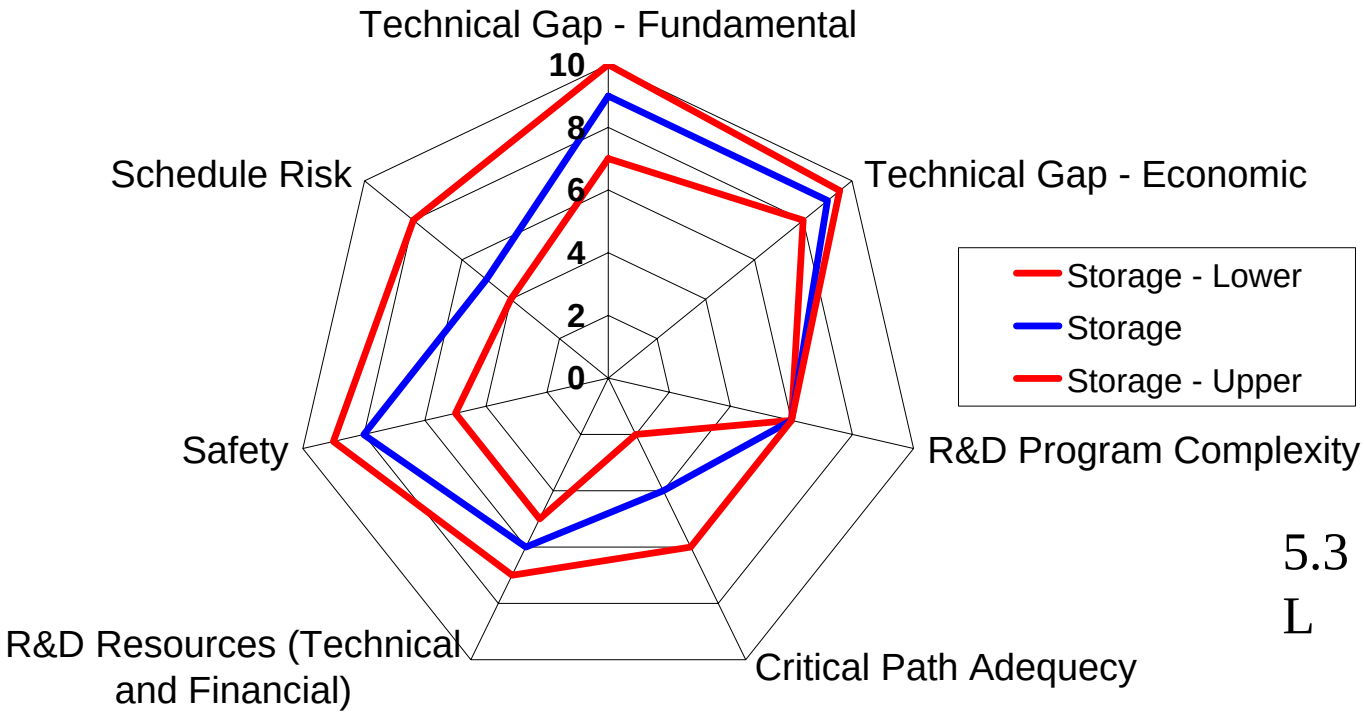
Multi-attribute Analysis
- A lower level example -

Uncertainty of estimates of R&D outcomes can also be represented

V
R
C

- Reviewer is asked for best estimate – based on response to question
- Also provides – high/low value that "pretty certain" actual value falls between
  - Technically this might be called the 90% percentile of outcomes



Illustrative

5.3 - 6.7 -7.9
L mean U

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Risk and Return: Applicable to R&D?

Example application - illustrative

- "Return" metric: Annual Consumer Savings in 2030 normalized by FY08 Program Budget (GPRA08 Final) – proxy for an appropriate benefit v. cost ratio*
- Hypothetical standard deviations were estimate (not available in GPRA08 but might be in future as part of risk work)
- Assumes individual program "return" constant along frontier (at various budget mixes)

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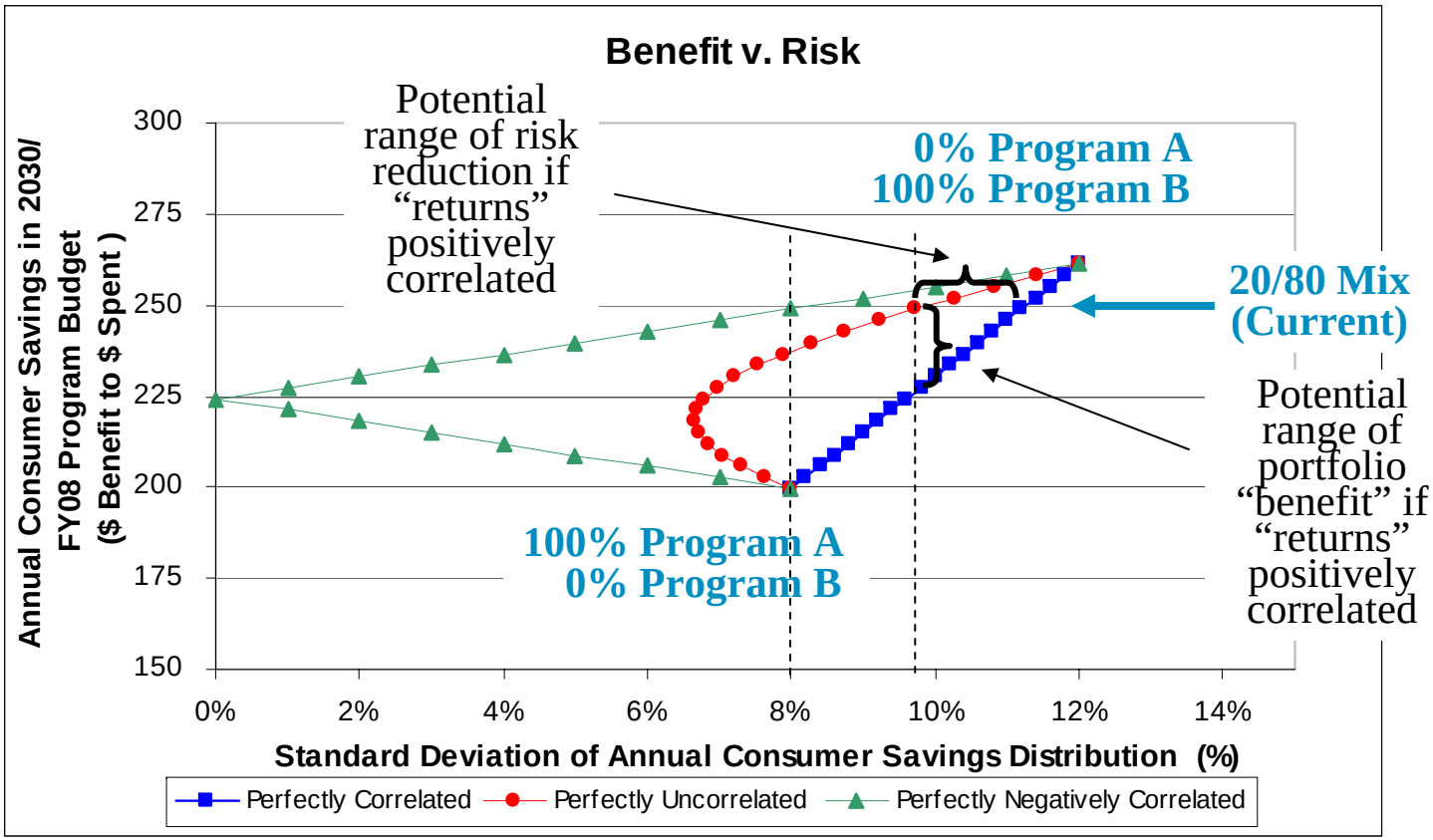

* This can obviously be refined

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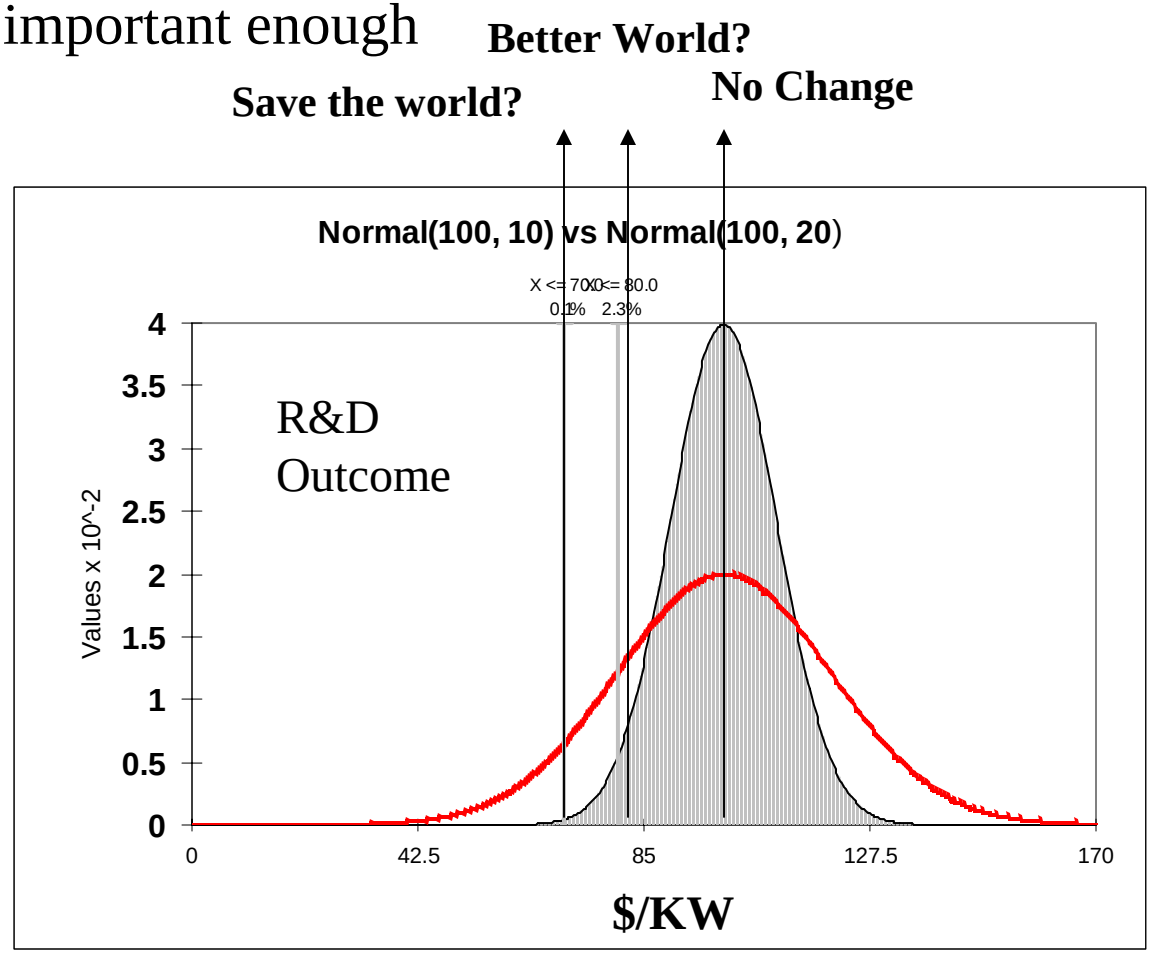
Public Sector R&D and Risk Preference?

Same expected value R&D output but "Riskier" project has much better chance of reaching break-thru goal. So risky is the better project provided outcome/benefit important enough

Partly a question of definition since while R&D outcome riskier in second case, the benefits outcome is less risky and hence strictly preferred

However even of benefit distribution reflected R&D output distribution's shape – riskier distribution may still be preferable [untrue for the private sector]



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