PROJECTIONS & DECISION SUPPORT

CLIMATE CHANGE

Stationarity Is Dead: Whither Water Management?

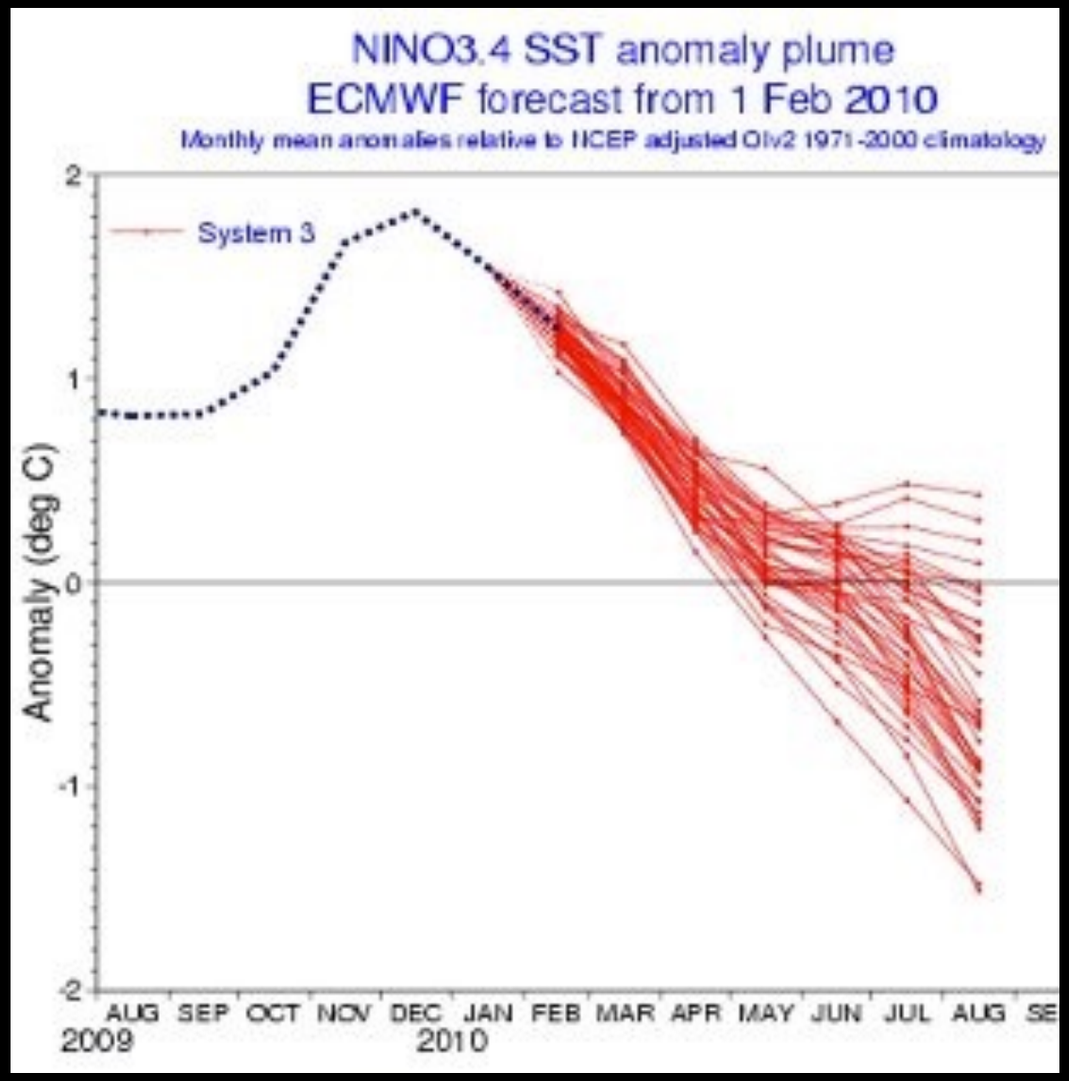
Climate change undermines a basic assumption that historically has facilitated management of water supplies, demands, and risks.

P. C. D. Milly,[1]* Julio Betancourt,[2] Malin Falkenmark,[3] Robert M. Hirsch,[4] Zbigniew W. Kundzewicz,[5] Dennis P. Lettenmaier,[6] Ronald J. Stouffer[7]

Science 2008

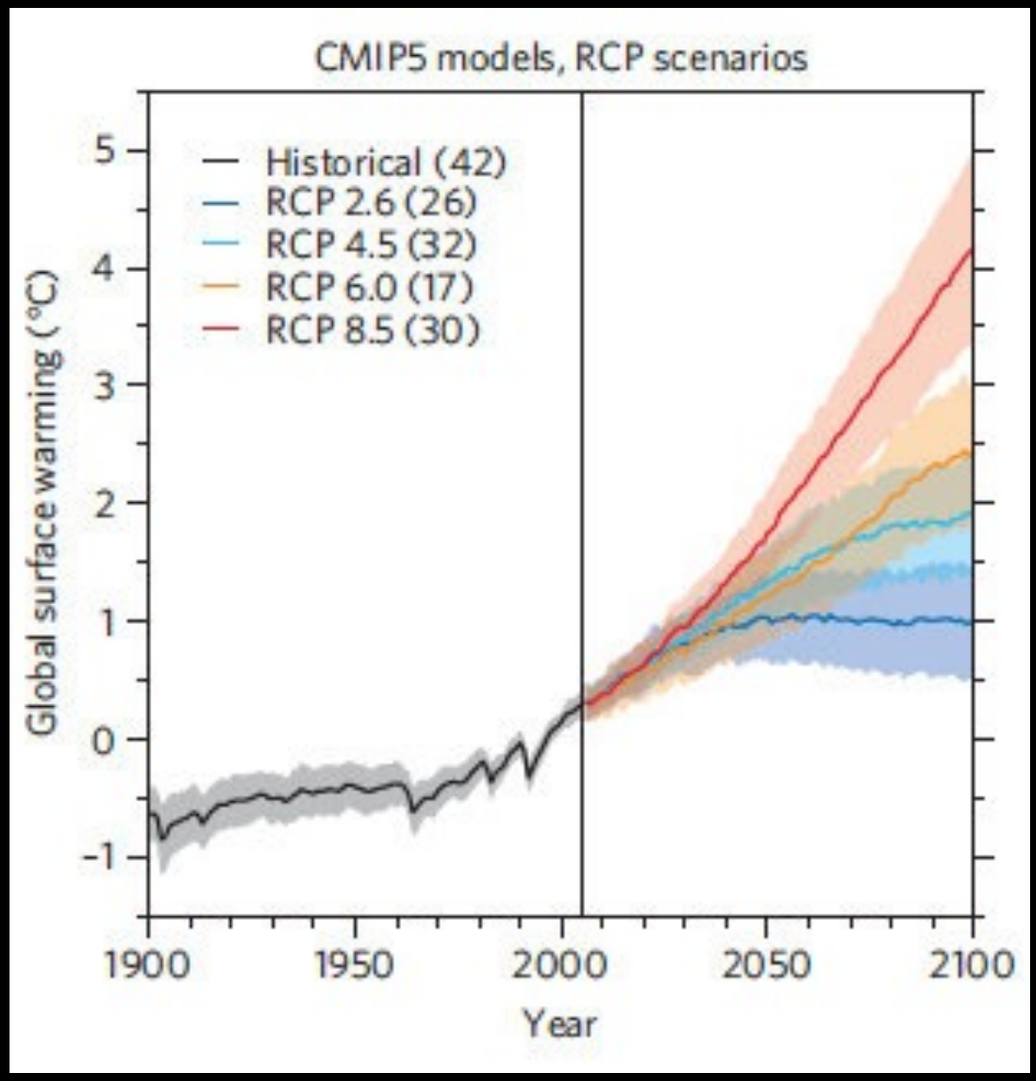
PREDICTION

"PROBABILISTIC STATEMENT THAT SOMETHING WILL HAPPEN IN THE FUTURE BASED ON WHAT IS KNOWN TODAY"



PROJECTION

"PROBABILISTIC STATEMENT THAT IT IS POSSIBLE THAT SOMETHING WILL HAPPEN IN THE FUTURE" GIVEN BOUNDARY CONDITION SCENARIOS



MacCracken 2001

SCENARIOS

Set of plausible **storylines**.

"Futures that could be" that capture key uncertainties

Not probabilistic, don't average over!

Decision **alternatives**

A framework for addressing **low probability events**

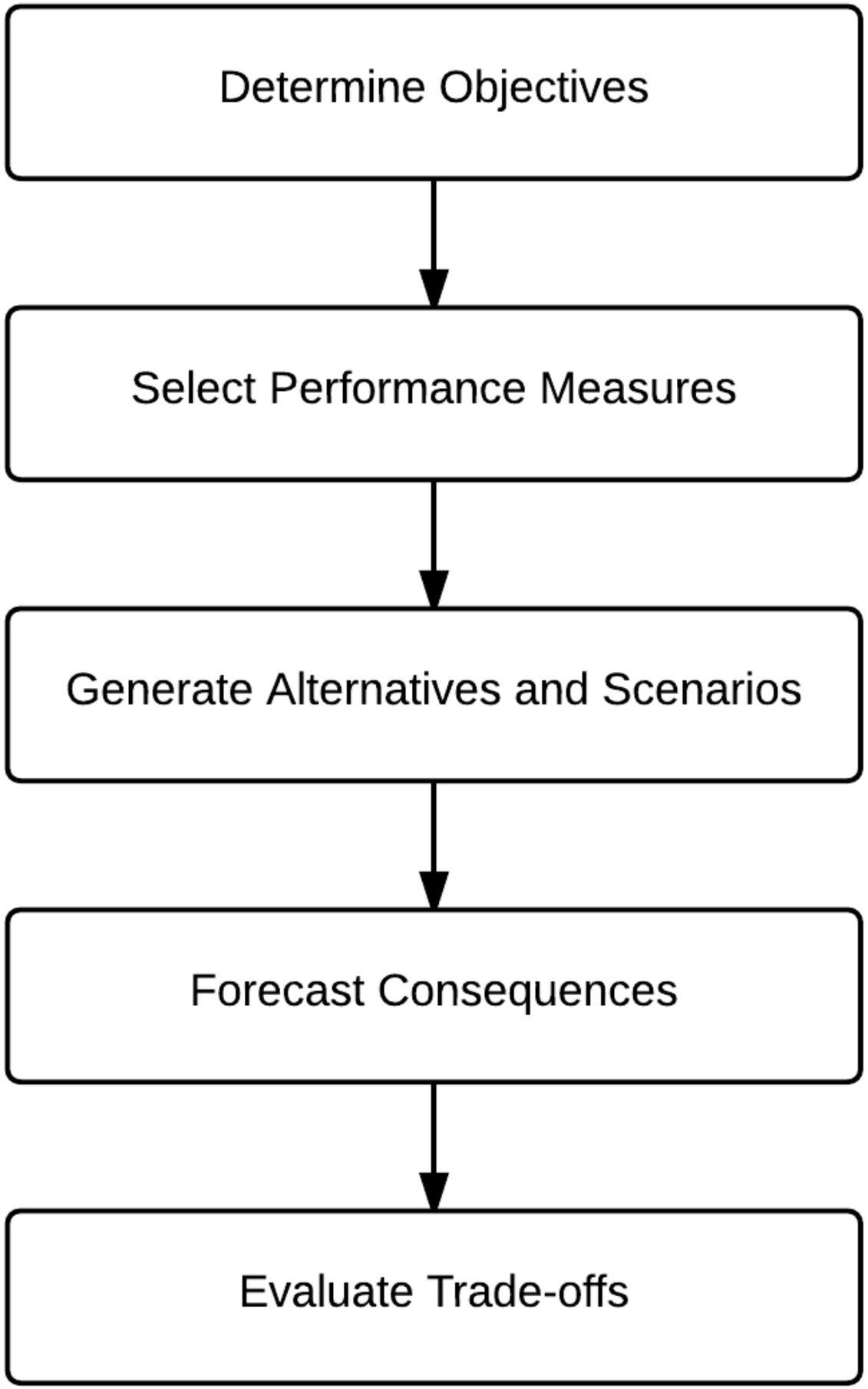
war games, unknown unknowns, & black swans

Not probabilistic, can't average over

DECISION SUPPORT

- Creating well-structured, transparent, and collaborative decision processes involving researchers and stakeholders is as important to effective decision-making as having good scientific information and tools
- Enable decision-makers to apply complex information to decisions,
- Consider uncertainties
- Assess a wide range of possible human responses
- Engage institutions and individuals who are potentially affected

STRUCTURED DECISION MAKING



CONSEQUENCE TABLE

Alternatives

Attribute	Units	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alter
		Name 1	Name 2	Name 3	Name 4	Name 5	Nam
Unit Energy Cost	$/MWh	149	114	110	124	108	
GHG Emissions	kilotons/yr CO2e	31	8	8	16	8	
Local Air Emissions	tons/yr (PM10)	16	17	21	9	24	
Land Area	m2 (000)	29.7	16.8	4.6	19.6	3.1	
Aquatic Area	m2 (000)	8	24	-	35	20	
Construction Jobs	Person-years	75	119	105	96	119	
Permanent Jobs	FT equivalent	49	81	83	76	84	
Noise	Weighted Average Scale (0=Best, 10=Worst)	6.7	3.1	3.7	3.6	3.9	
Visual Impacts	Weighted Average Scale (0=Best, 10=Worst)	1.5	2.2	2.8	1.4	2.2	
Food Harvesting Areas	Weighted Average Scale (0=Best, 10=Worst)	1.5	0.9	0.5	1.4	0.2	
Sustainability / Innovation	Weighted Average Scale (10=Best, 0=Worst)	-	0.3	0.5	0.7	0.3	
Sustainability / Innovation	% Dependable Peak Provided By Renewables	12%	22%	23%	12%	25%	

Objective

Performance Measure

Consequences

STAKEHOLDER WORKSHOPS

- Should engage a diverse group of stakeholders
  - Need for multiple points of view when considering complex environmental issues
- Allows people to step away from entrenched positions and identify positive futures
- Biggest trap is the inability of participants to perceive their own assumptions and the potential consequences of being wrong

OBJECTIVES

- Summarize something that matters to the stakeholders (e.g. revenue, comfort)
- Inclusion validates that an objective has value, but stakeholders may disagree on how much
- Not assigned weights
- Desired direction of change (not goal/threshold)
- Context-specific, not statements about universal values

DECISION: TRAVEL TO NYC

OBJECTIVE	
MIN TIME	
MIN COST	
MIN CO2	
MAX COMFORT	

PERFORMANCE MEASURES

- Quantify objectives
  - Natural (e.g. carbon storage MgC/ha)
  - Proxy (e.g. habitat quality)
  - Constructed measures (1-10), defined impact scales
- Natural units, don't have to monetize
- All values for a single performance measure (row) need to be calculated the same way with the same assumptions

REPORTING UNCERTAINTIES

- Difference between common and technical language
- Humans do not innately understand probability
  - But are accustomed to dealing with risk
- Report more than mean, but not piles of stats
  - CI interpreted as equal probability
  - multiple framings: 5% vs 1 in 20
  - low probabilities are ignored, focused on outcome

FRAMING UNCERTAINTIES

- Reference baselines
  - but losses and gains not perceived equally
- Downside reporting: worst plausible case
- If discrete thresholds exist (e.g. legal standard)
  - Exceedance probability, not Y/N

DECISION: TRAVEL TO NYC

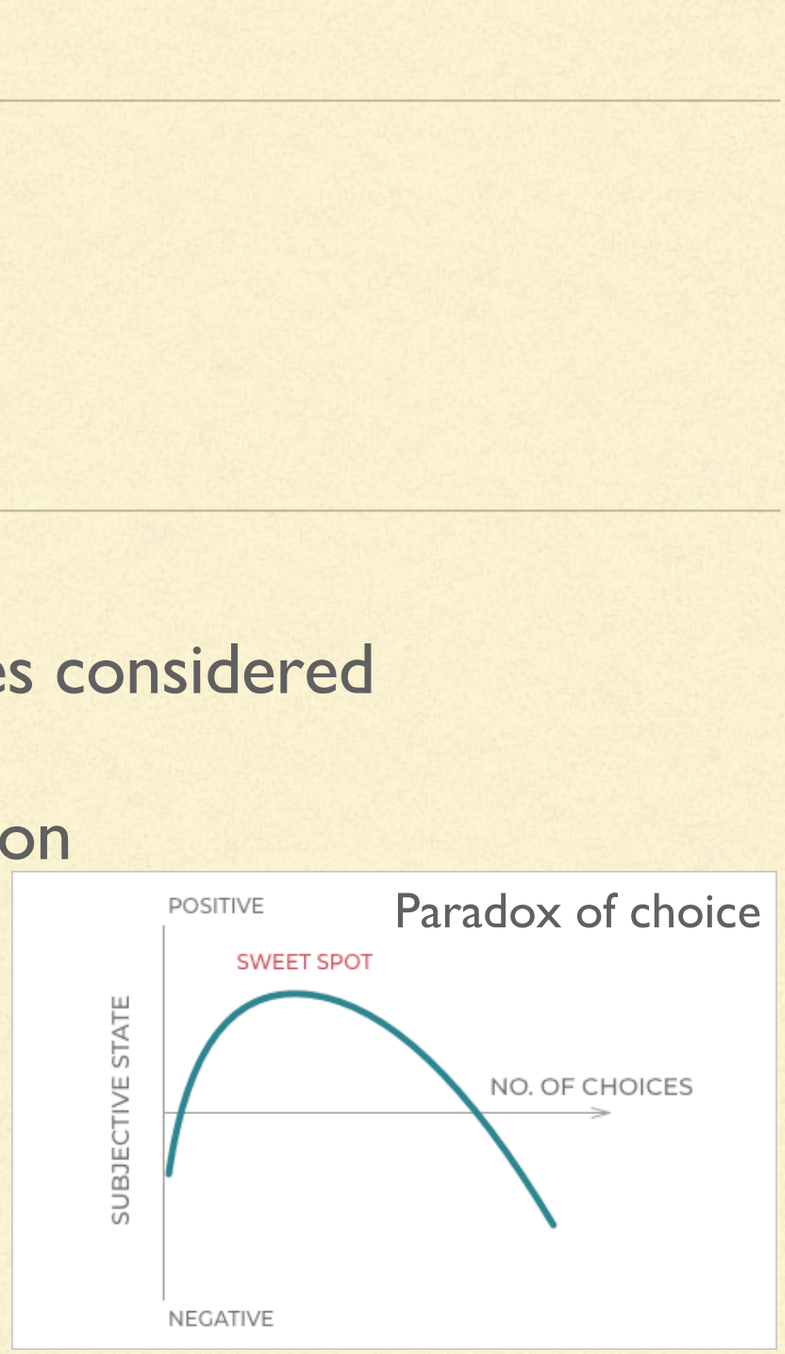
OBJECTIVE	MEAS.
MIN TIME	hr
MIN COST	US$
MIN CO2	lbs
MAX COMFORT	stars (1-5)

ALTERNATIVES

- Any decision is only as good as the set of alternatives considered
- Search for win-win alternatives: iterative, hybridization
- How many?
  - Initial: computational, financial, time limits
  - Stakeholders: 4-12
  - Decision: 3-4

Even numbers reduce anchoring on middle

- Unbiased, informative names



ALTERNATIVE CRITERIA

- Address the same problem
- Evaluated over the same time
- Same level of detail
- Same assumptions and performance metrics
- Mutually exclusive (not a la carte)
- Able to drive forecast models

MANAGING RISK / UNCERTAINTY

- Precautionary Alternatives
  - but can't be precautionary for all objectives
- Robust Alternatives
- Adaptive Alternatives
  - Iterative forecasting
- All come with a cost!

DECISION: TRAVEL TO NYC

OBJECTIVE	MEAS.	CAR	CARPOOL	BUS	TRAIN	PLANE
MIN TIME	hr					
MIN COST	US$					
MIN CO2	lbs					
MAX COMFORT	stars (1-5)					

ESTIMATING CONSEQUENCES

- Ecological Forecasting!
- First pass: Expert elicitation, literature, Fermi estimation
- Focus on terms that affect the outcome of the decision
  - Uncertainty analysis
  - Reducible vs irreducible uncertainties

DECISION: TRAVEL TO NYC

		Alternatives				
OBJECTIVE	MEAS.	CAR	CARPOOL	BUS	TRAIN	PLANE
MIN TIME	hr	8.5	8.5	9.5	9.5	4.25
MIN COST	US$	107	26	80	166	195
MIN CO2	lbs	240	60	15	110	125
MAX COMFORT	Stars (1-5)	3	3	3	3.5	3.5

Consequences

TRADE-OFFS

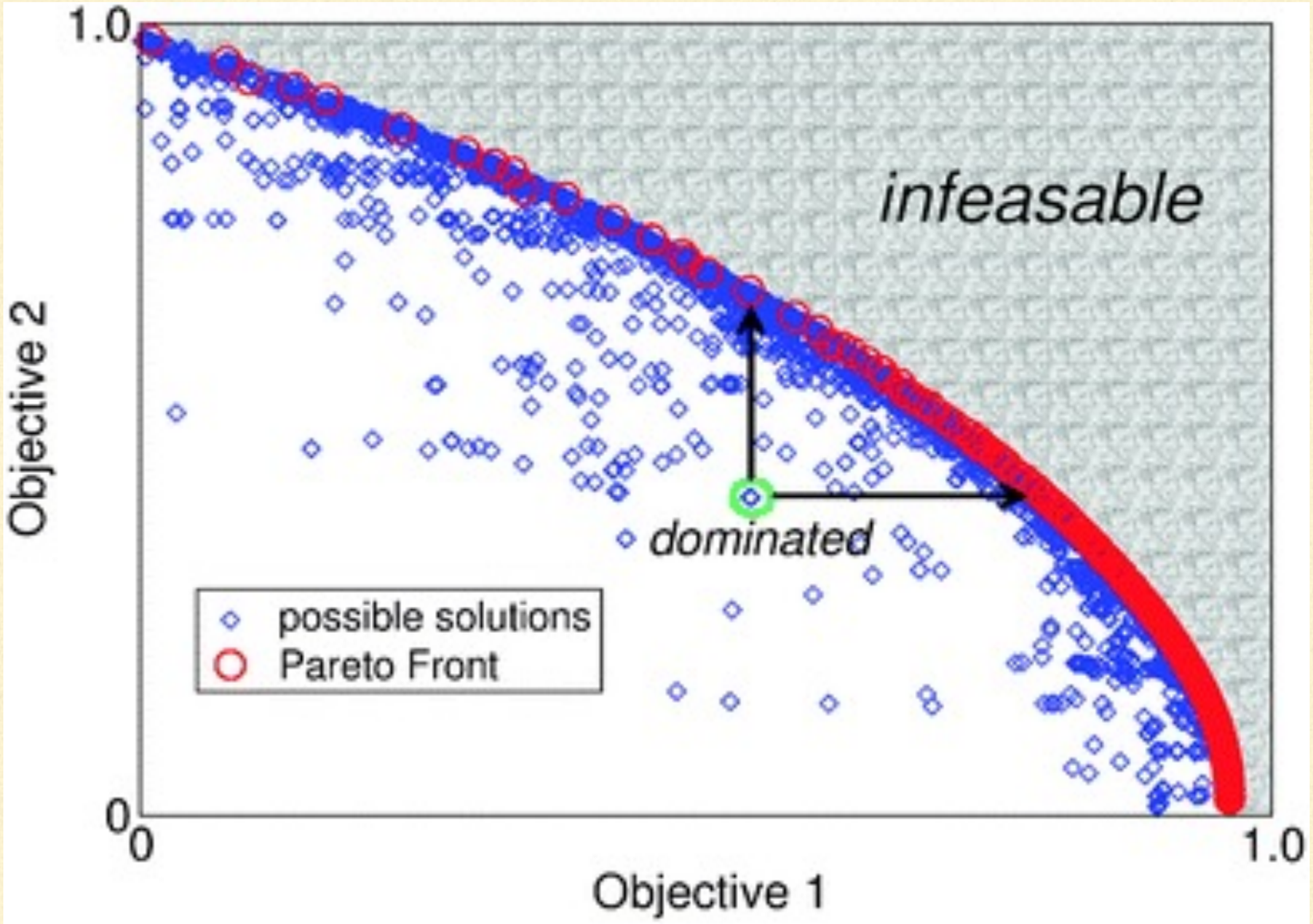
OBJECTIVE
no weights, values

- If no clear winner, goal is to eliminate **dominated** Alternatives and **insensitive** Performance Measures
- Refine understanding of key trade-offs
- Strictly vs practically dominated
  - Not based on CI!! diff in risk = value
- By hand for small n (*pairwise*)
- No regrets actions

Dominated

OBJ.	MEAS	CAR	CARPOOL
MIN TIME	hr	8.5	8.5
MIN COST	US$	107	26
MIN CO2	lbs	240	60
MAX COMFORT	Stars (1-5)	3	3

PARETO OPTIMIZATION



DECISION: TRAVEL TO NYC

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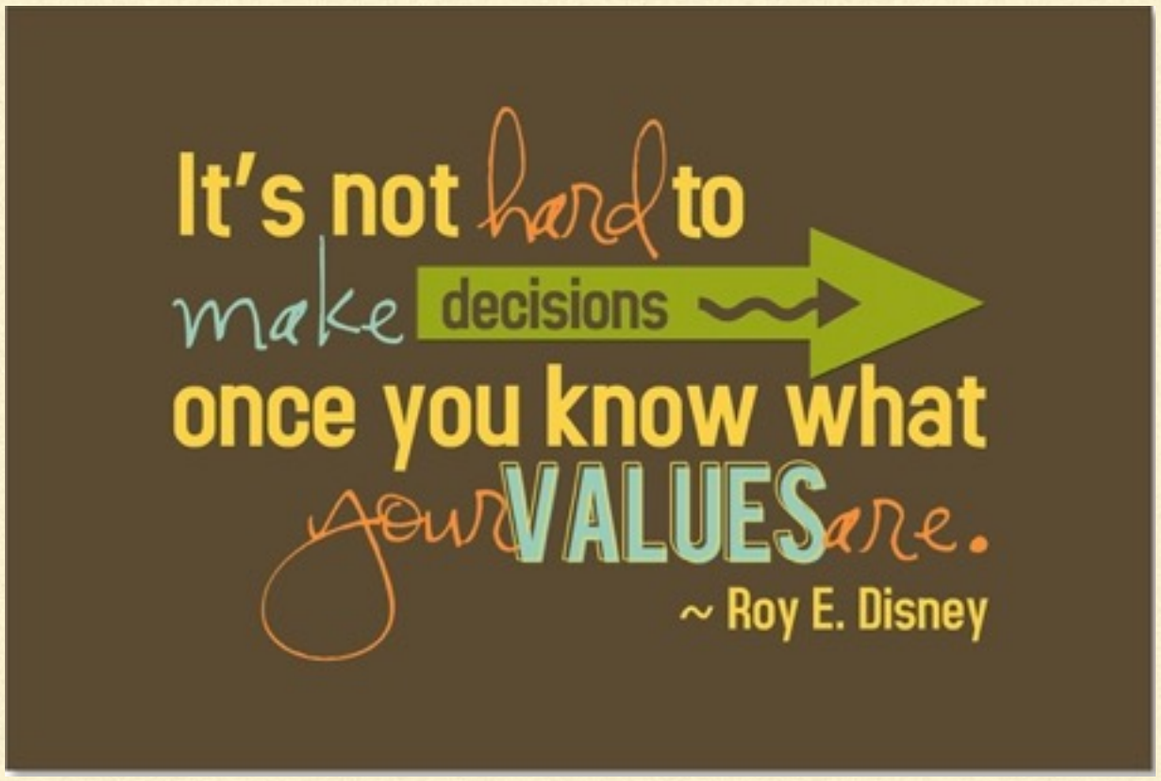
Job of analyst is to ID core trade-offs, not make the decision

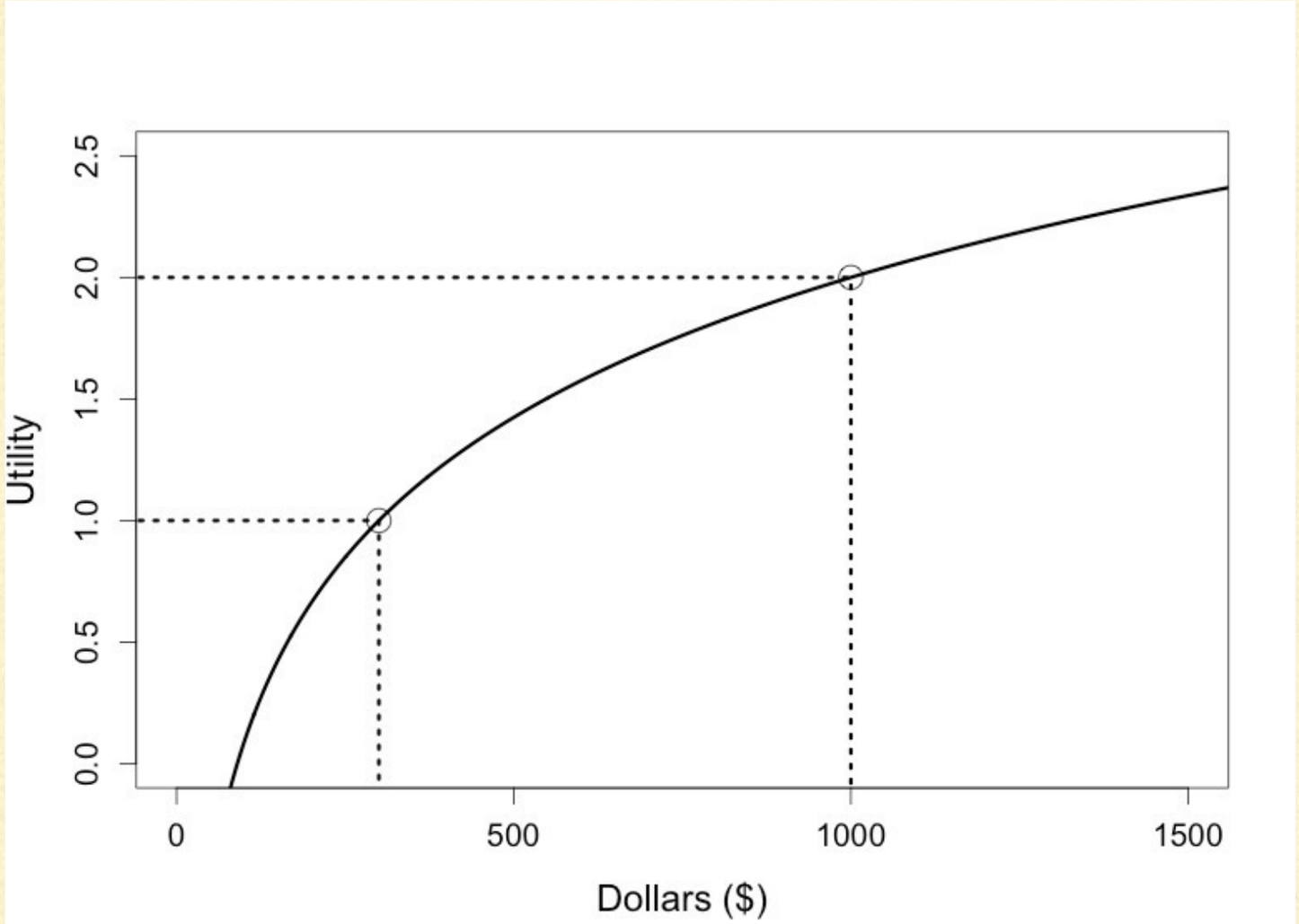
VALUES

- Consequence table organizes information
- Decisions are about values
  - beliefs
  - priorities & preferences
  - tolerance for risk
  - time discount



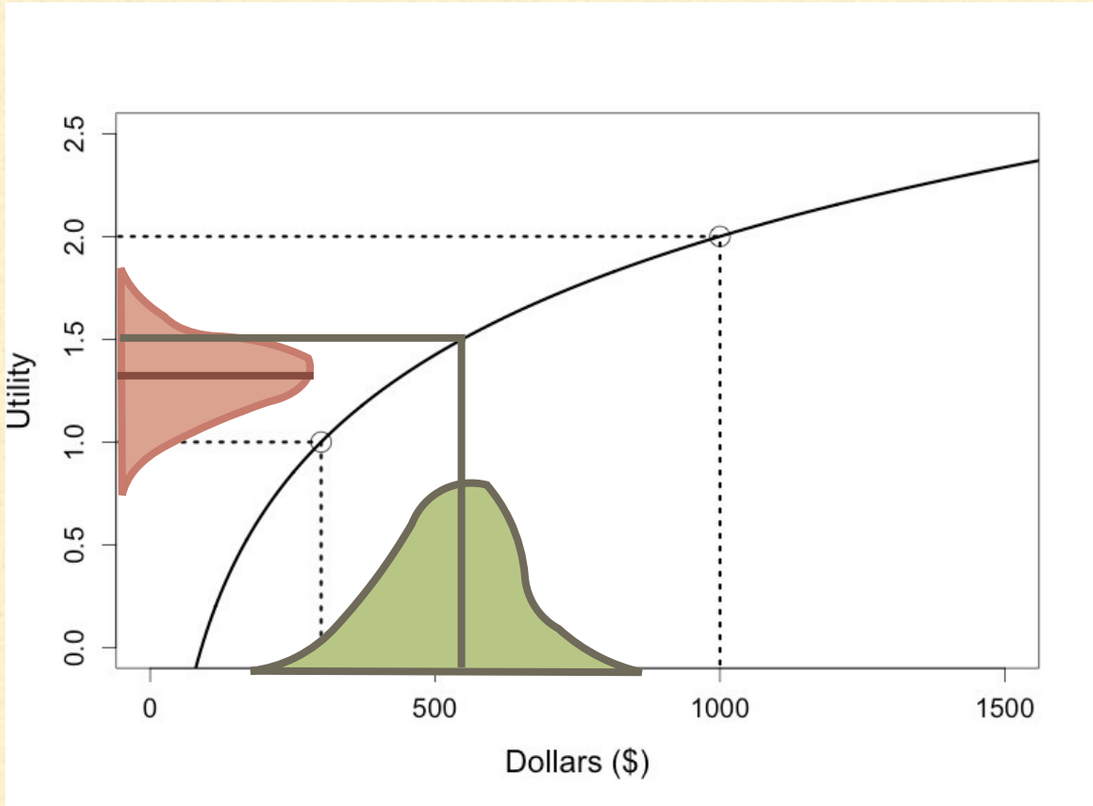
UTILITY

- Cumulative value increases
- Marginal value decreases
- Maximum Willingness to Pay
- Demand = Marginal MWTP
- Eliciting indifference



RISK TOLERANCE

- Losses hurt more than gains
- Concave = risk adverse
- E[U(x)] < U(E[x])
- E[U(x)] declines with increasing uncertainty
- More risk neutral for repeated, low-stakes decisions



WEIGHTING OBJECTIVES

- Only done AT END: post winnowing, data in hand
- Done at individual level: Jensen's Inequality; How trade-offs perceived
- Swing weighting, ranking (best=100) vs Utility
- Sensitivity & Critical value analysis
  - How much would Consequence have to change?
  - Probability of exceeding threshold?

Forecast: how good is good enough? CI? RMSE?

VALUE OF INFORMATION

- "When does the addition of more information contribute to decision-making so that the benefit of obtaining this information exceeds the expense of collecting and processing it?"
- Expected additional benefit from additional information, relative to what could be expected without that information
- Delaying a decision to obtain more information doesn't always lead to different or better decisions

DECISION SUPPORT