Valuing risk of non-delivery of environmental outcomes

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Introduction

- Benefit estimation is based on outcomes (quality or quantity change in environmental good)
- For benefit assessments informing environmental *ex-ante* CBA, outcomes are typically assumed to be certain
- In practice, this is clearly not always the case

Delivery uncertainty: a definition

Decision makers face *delivery uncertainty* arising from

a lack of knowledge to make accurate ex-ante predictions about the expected change in environmental conditions from which benefits arise and are evaluated

Delivery uncertainty: 'sources'

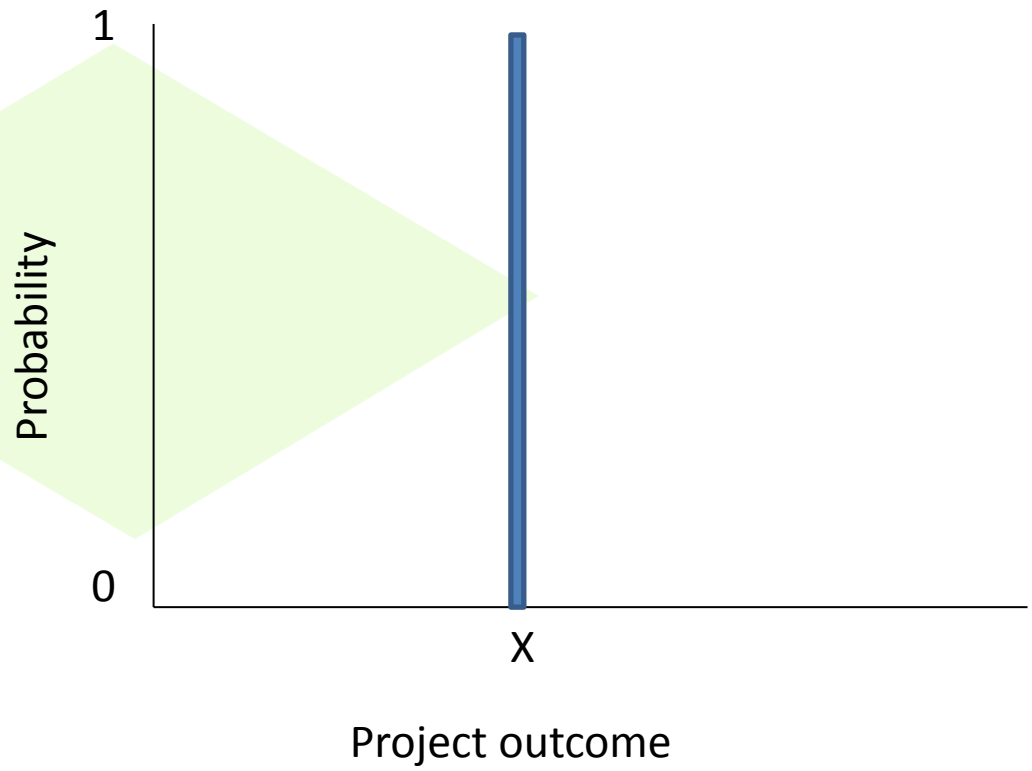
Uncertainty can be associated with

- future changes to the political, social and economic environment
- the influence of external environmental factors on future supply and demand (e.g. climate change)
- the models and predictions based on current scientific knowledge used to project future outcomes

If probabilities can be assigned to outcomes, they can be described in terms of o*utcome-related risk*

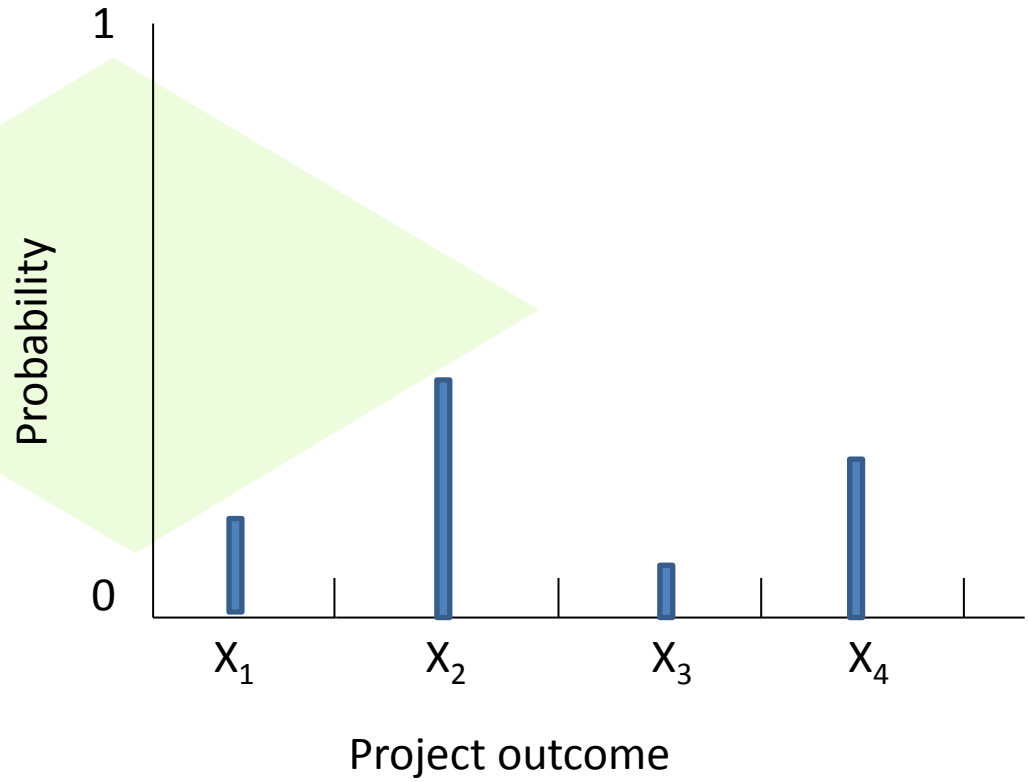
Outcomes and probabilities

- Project outcomes are certain



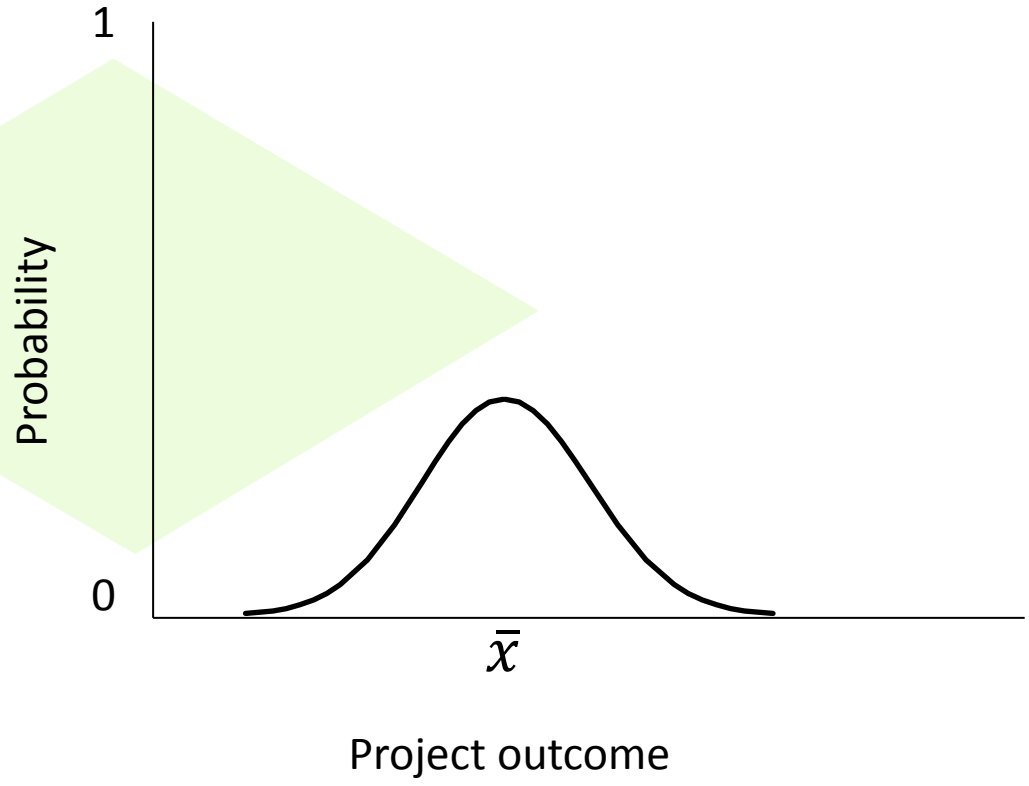
Outcomes and probabilities

- Project outcomes as defined in X are discrete



Outcomes and probabilities

- Project outcomes X vary around a mean $\bar{x}$ with variance σ

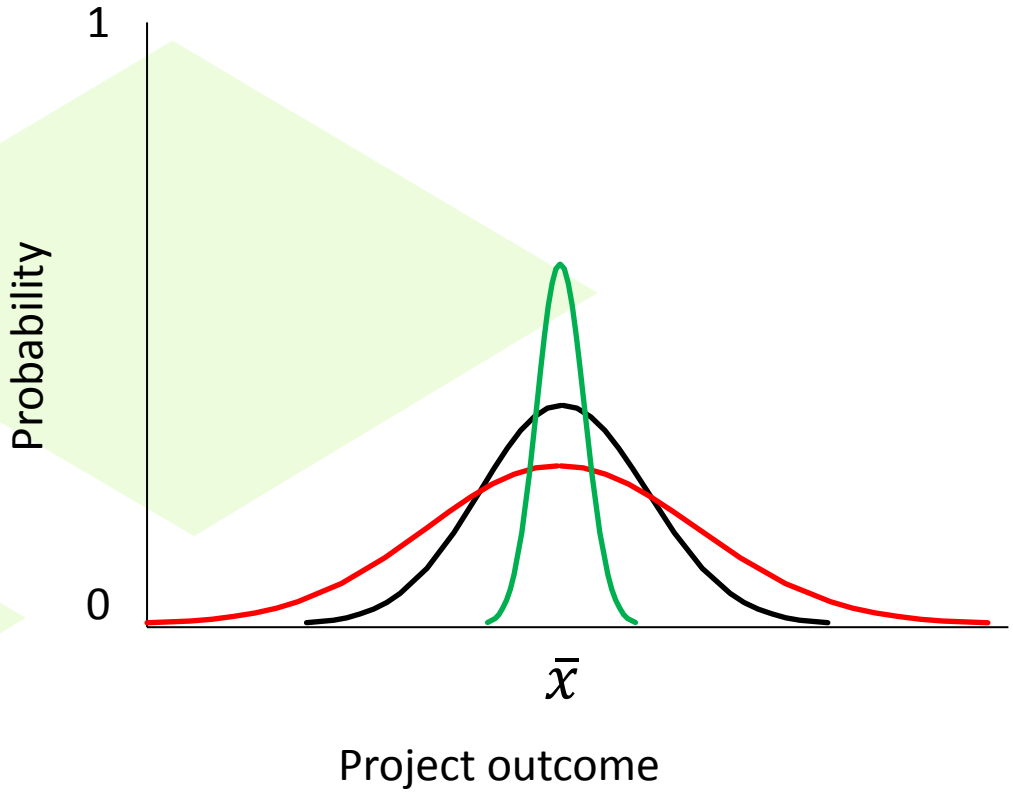


Considerations of outcome-related risk in CBA

- Sensitivity analysis
  - Impact of changes in expected outcomes on decision criteria
  - Monte Carlo simulations
- But: benefits and costs are derived assuming risk neutrality of individuals
- Individuals tend to be risk averse

Outcomes and probabilities

- Project outcomes X vary around a mean $\bar{x}$ with variance σ



Considerations of outcome-related risk in CBA

- Ignoring outcome-related risk may result in overestimated benefits

- Conclusions drawn from *ex-ante* CBA may then not reflect an efficient allocation of resources

Case Study: Soil carbon sequestration

- Assess benefits of a **soil carbon sequestration programme** in Scotland using a choice experiment
- Land use and management change can result in carbon to be stored/retained in soils → contribution to ***net emission reduction***
- 'Scientific' uncertainties regarding outcomes (emission reduction potentials) are (so far) pretty high → ***risk of failure*** to achieve net emission reduction
- Co-effects: ***biodiversity***, ***rural viability***

Measures for increasing soil carbon stocks in agricultural soils a
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Measure	Potential soil carbon sequestration rate (t C ha^{-1} $year^{-1}$)	Estimated uncertainty (%)
Cropland		
Zero-tillage	0.4; 0.3 ± 0.1	>50%; 0 to 0.7
Reduced-tillage	<0.4	≫50%
Set-aside	<0.4	≫50%
Perennial grasses and permanent crops	0.6	>50%
Deep-rooting crops	0.6	>50%
Animal manure	0.4; 1.5 ± 0.1	>50%; −0.7 to 3.2
Crop residues	0.7; 0.2 ± 0.1	>50%; −0.3 to 0.3
Sewage sludge	0.3	>50%
Composting	0.4	≫50%

Freibauer et al. 2004, *Geoderma* 122, 1-23

Scientific evidence: uncertainty

CARBON SEQUESTRATION IN ARABLE SOILS IS LIKELY TO INCREASE NITROUS OXIDE EMISSIONS, OFFSETTING REDUCTIONS IN CLIMATE RADIATIVE FORCING

gases methane (CH_4) and nitrous oxide (N_2O). Reduced tillage, enhanced crop residue incorporation, and farmyard manure application each increased soil C-sequestration, increased N_2O emissions, and had little effect on CH_4 uptake. Over 20 years, increases in N_2O emissions, which were converted into CO_2-equivalent emissions with 100-year global warming potential multipliers, offset 75–310% of the carbon sequestered, depending on the scenario. Quantification of these types of biogeochemical interactions must be incorporated into assessment frameworks and trading mechanisms to accurately evaluate the value of agricultural systems in strategies for climate protection.

Li et al. 2005, *Climatic Change* 72, 321-338

Scientific evidence: uncertainty

Soil carbon sequestration to mitigate climate change: a critical re-examination to identify the true and the false

depending on the alternative fate of the residue. Increases in SOC from reduced tillage now appear to be much smaller than previously claimed, at least in temperate regions, and in some situations increased N_2O emission may negate any increase in stored C. The climate change benefit of increased SOC from enhanced

Powlson et al. 2011, *European Journal of Soil Science* 62, 42–55

Introducing ‘risk of outcomes’ to survey respondents

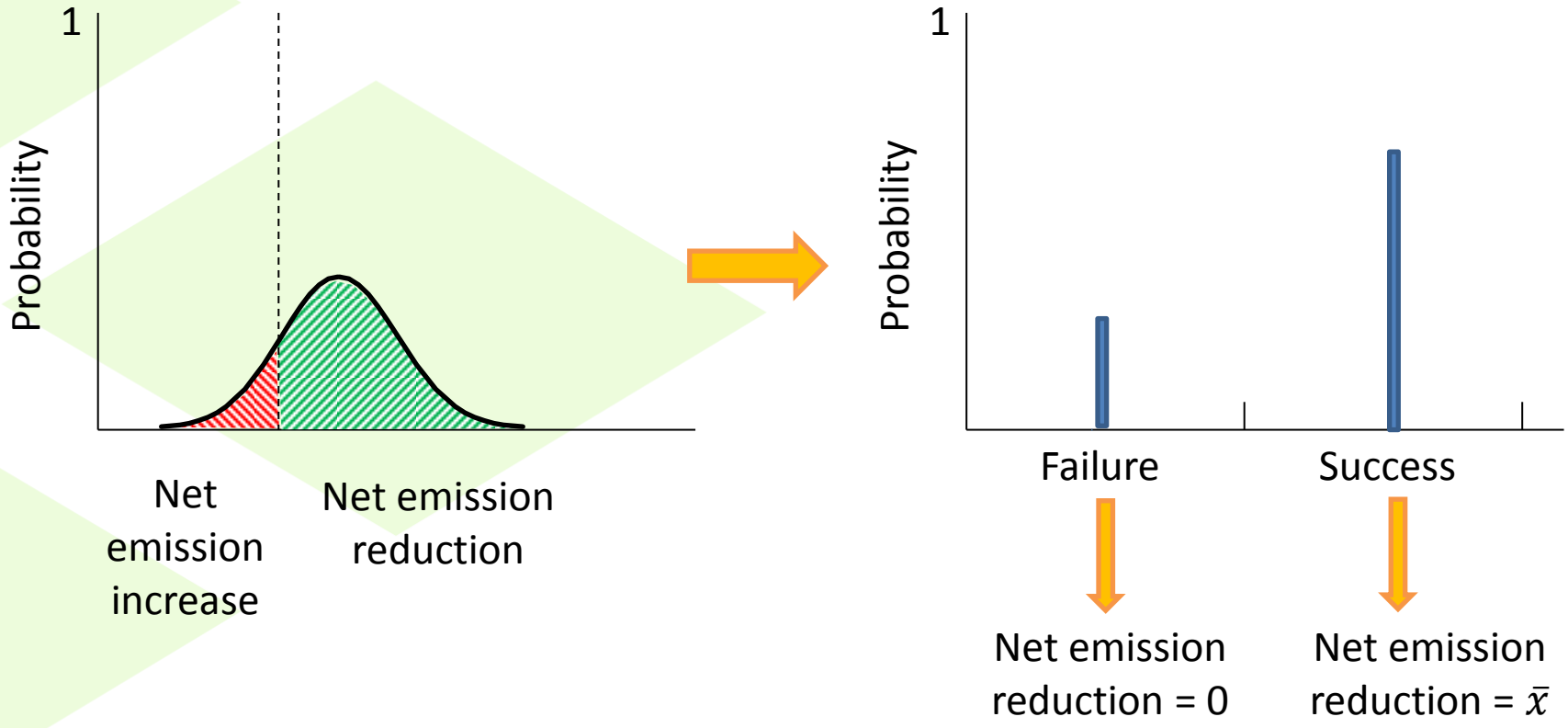
Risk is part of our lives: especially when we plan ahead for a long time and when things are complex. This also applies to a soil carbon programme … I’d now like you to choose from … policy options that consider that there is a chance that the programme ***fails to reduce overall greenhouse gases emissions****…*

Typical choice card

	Policy option A	Policy option B	Current policy
Living conditions for **farmland birds**	No Change	Improvement	No Change
Regular staff **employed in farming**	Slight Decline	No Change	No Change
Overall annual **greenhouse gas emissions**	reduced by 6%	reduced by 8%	No Change
Risk of failure to reduce emissions	30%	60%	No Risk
Cost to you per year	£10	£25	£0
I prefer	❑	❑	❑

N=648 (face-to face interviews), Scotland-wide quota based sampling

A great simplification: binary lottery



Modelling outcome-related risk

- Direct utility from risk
- Expected Utility Theory (EUT)
- Prospect Theory: non-linear probability weighting (overweighting of low probabilities and underweighting of high probabilities)

Glenk, K. & S. Colombo (2011): *Modelling outcome-related risk in choice experiments*. 18th Annual Conference of the European Association of Environmental and Resource Economists, Rome, June 29th – July 2nd

‘Basic’ model

- **No** probability weighting, only direct utility from risk:

$$\text{AD:}\quad V = \beta_0 + \beta_{ER} X_{ER} + \beta_{RISK} X_{RISK} + \sum_k \beta_k X_k$$

'Basic' model: results

	coef.	*t-stat.*
β_0	2.55	9.05
β_{BIRD}	0.33	5.12
β_{FARM}	-0.30	-4.66
β_{COST}	-0.01	-13.90
β_{ER}	0.14	7.13
β_{RISK}	-1.87	-9.64
σ_{PO}	2.89	10.73
LogL	-1330.27	
Adj. ρ^2	0.239	

- Error component logit model
- Risk of failure has a highly significant and negative influence on utility
- **Respondents 'value' risk of non-delivery of outcomes**

Expected Utility Theory models

- Constant marginal utility over outcomes (risk neutral behaviour):

$$\text{LEU}: \quad E(V) = \beta_0 + \beta_{ER}\left(\left(1 - p_{RISK}\right)X_{ER}\right) + \sum_k \beta_k X_k$$

- Diminishing marginal utility over outcomes (risk averse behaviour):

$$\text{NLEU}: \quad E(V) = \beta_0 + \beta_{ER}\left[\frac{\left(1 - p_{RISK}\right)X_{ER}^{\,1-r}}{1-r}\right] + \sum_k \beta_k X_k \qquad r \neq 1$$

- $r = 0$ indicates risk neutrality; $1-r < 1$ indicates risk aversion

EUT: results

	LEU		NLEU	
	coef.	*t-stat.*	*coef.*	*t-stat.*
β_0	1.93	7.14	1.37	4.25
β_{BIRD}	0.32	5.00	0.324	5.06
β_{FARM}	-0.30	-4.73	-0.3	-4.62
β_{COST}	-0.01	-13.88	-0.01	-13.84
β_{ER}	0.23	10.63	0.40	11.35
r			0.58	7.30
σ_{PO}	2.87	10.72	2.89	10.73
LogL	-1343.32		-1333.28	
Adj. ρ^2	0.232		0.237	

- NLEU better model fit than LEU
- **1- 0.58 < 1 indicates risk aversion**

WTP estimates

	CS1 ER: 2% - 4% R: 0% - 10%	CS2 ER: 2% - 4% R: 0% - 30%	CS3 ER: 2% - 6% R: 0% - 30%	CS4 ER: 4% - 6% R: 10% - 30%	CS5 ER: 6% - 8% R: 30% - 60%
LEU	36.9	18.4	50.7	13.8	-23.1
NLEU	25.9	-8.1	13.0	-12.8	-52.0
AD	9.4	-28.1	0.1	-9.3	-28.0

Values in £ per person and year

Limitations and issues

- Introducing risk as a binary lottery ‘success-failure’ was a concept that was well comprehended by respondents. However, this is a very simplified picture of reality
- Other ways to represent/communicate outcome-related could be explored
- Choices over risky prospects fail to be invariant to the framing of prospects (Tversky & Kahneman 1981): ‘chance of success’ instead of ‘risk of failure’?
- This approach is mainly useful if risk/uncertainty of outcomes can be influenced when policy is implemented – else, need different approach, e.g. include information on outcome risk in scenario/policy description

Conclusions – case study

- **When delivery of outcomes can be described in probabilistic terms, outcome-related risk should be incorporated in SP studies**
- Analysts and decision makers are offered a more realistic assessment of how benefits change with risk
- WTP for reducing outcome-related risk can be substantial
- WTP to reduce outcome-related risk can be a signal for policy makers to invest more into reducing it e.g. via more research
- Incorporating outcome-related risk may enhance scenario credibility and hence reliability of benefit estimates

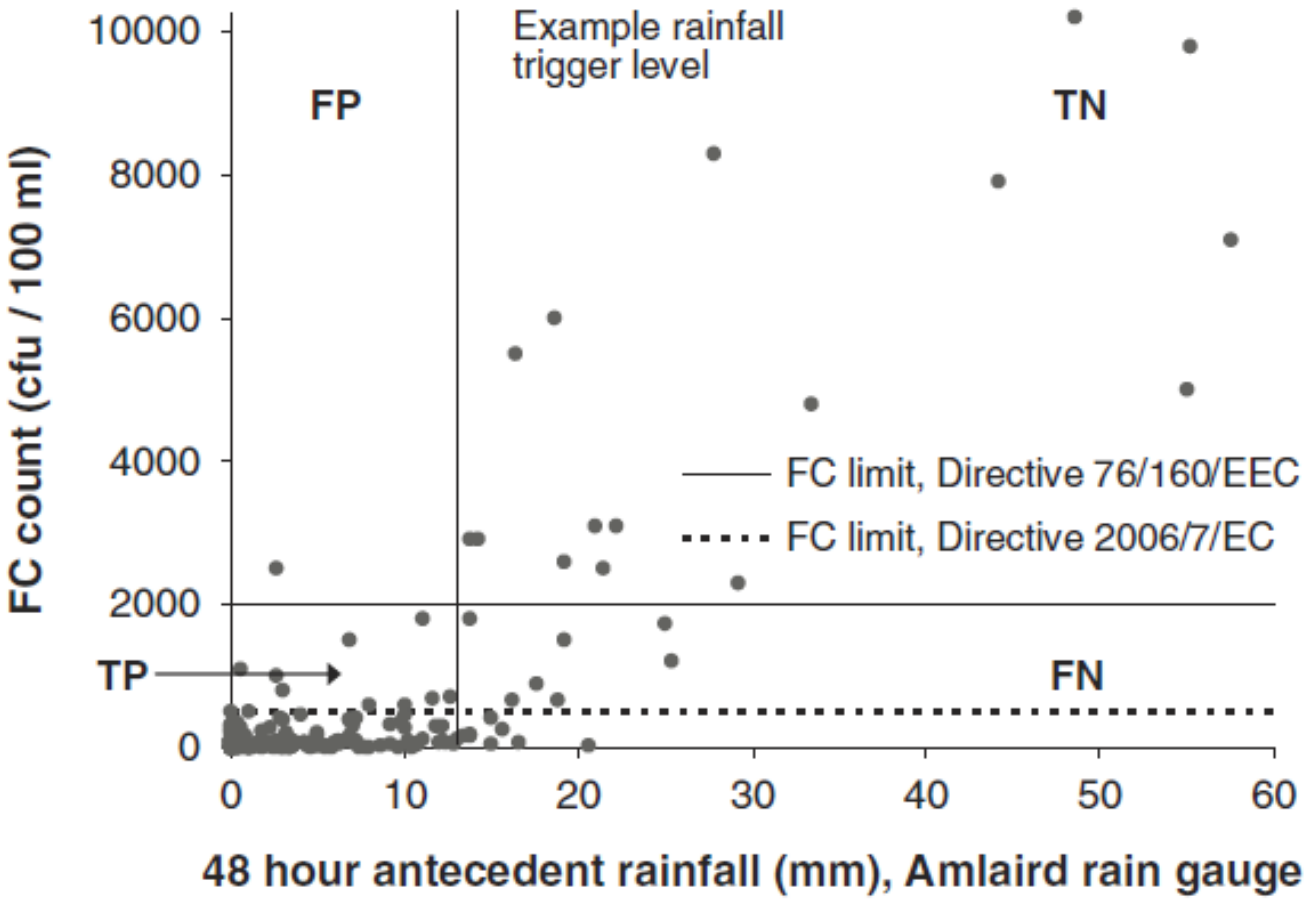
Relevance for DHW?

- Technology choice – assess costs and benefits:
  - culturable methods
  - rapid methods (qPCR)
  - predictive modeling

Relevance for DHW?

- Culturable methods: *variability* in fecal indicator bacteria density over the course of the day, time and location of sampling *can result in inaccurate beach closings and notifications* (Tim Wade, US EPA)
- 'EU-wide studies have suggested potential *analytical problems with the precision* and inter-laboratory reproducibility of qPCR-based enumeration'
- 'there is *much uncertainty regarding the precision and accuracy of qPCR* for microbial enumeration in the bathing zone'
- Predictive modeling: *how accurate is prediction*?

Predictive modelling



TN: True negative

TP: True positive

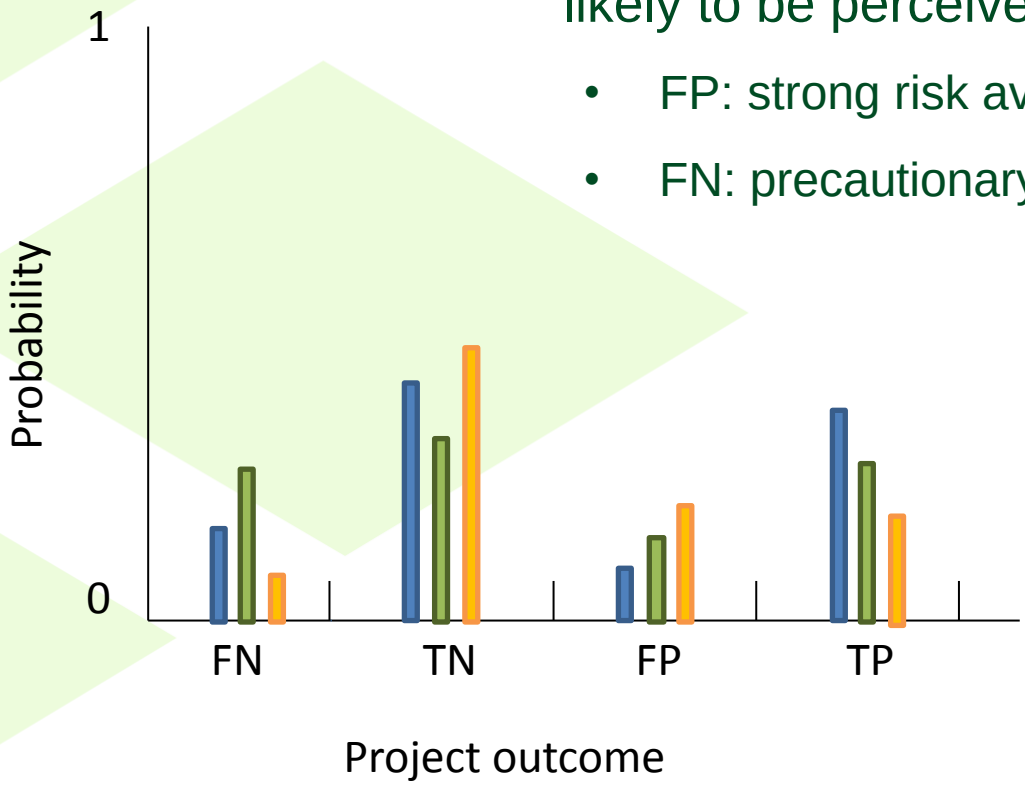
FN: False negative

FP: False Positive

Stidson et al. 2012, *Water and Environment* 26, 7–18

Discrete outcomes?

- False positives and false negatives likely to be perceived differently
  - FP: strong risk aversion
  - FN: precautionary – so is it a problem?



TN: True negative

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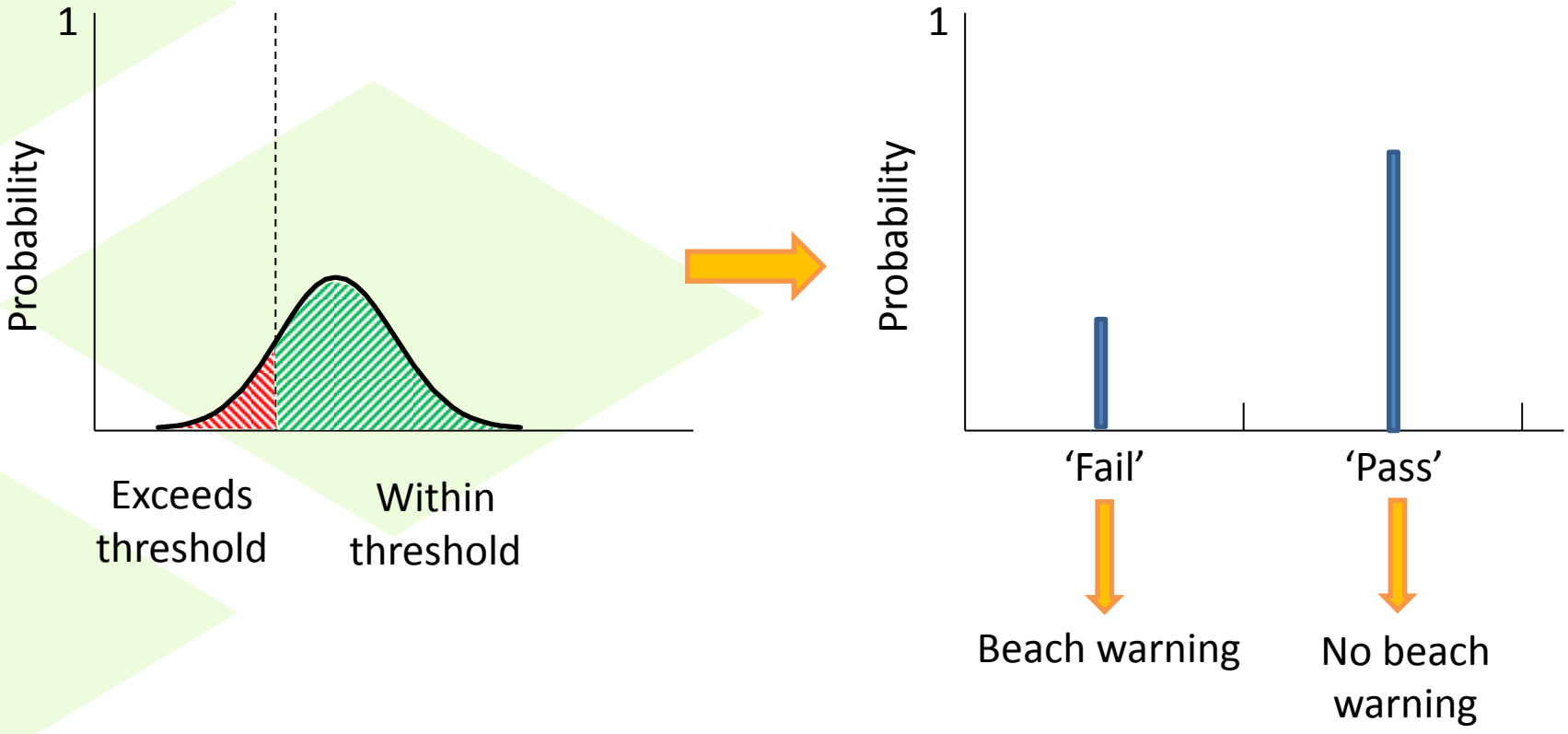
Binary outcomes linked to threshold?



DHW and outcome-related risk

- There is certainly an element of outcome-related risk in this!
- But:
  - What exactly are the outcomes that are to be evaluated, and how are they related to benefits?
    - Outcome = reduction in health risk / illnesses?
      - Need to establish cause-effect
    - Outcome = frequency of beach warnings?
- Whether it makes sense to consider outcome-related risk explicitly in a valuation exercise will depend on the definition of outcomes