Presenting and communicating uncertainty

We now consider how to choose *what* messages about uncertainty we shouuld communicate to decision makers and give advice on *how* to communicate those messages effectively.

Deciding what to communicate

The analysis of uncertainty is often complex. Presenting this in its entirety could overwhelm the recipient and may mean they do not take away the key messages. We need to choose carefully which messages about uncertainty to communicate to decision makers – ensuring they receive enough information to understand the key points, without receiving so much that it clouds the central issue.

You should also consider the onward communication of your message to ensure that when your work is passed on to others its core message and integrity are maintained.

What decision is the uncertainty informing?

What is the decision?

When deciding what uncertainty to communicate you need to consider what results are most appropriate in the context of the question being asked. At this point you should refer to the first section of this guidance: Asking the right question.

Consider what uncertainty is relevant to the decision maker. In the example 'what is the likelihood that this policy would save more than £x?', a maximum to minimum range may be less relevant to the decision maker, and instead you should focus your communication on the 'likelihood' and the key drivers that affect it.

How influential is the uncertainty analysis?

If there is a major risk that has not been included in the analysis, then this may be greatest uncertainty

Understand what role the uncertainty has in the decision. How are your results likely to affect the decision being made?

In some circumstances the uncertainty will be the key driver in the decision, for example if the uncertainty is large enough to indicate the result of a policy could be successful or unsuccessful. In this case the uncertainty analysis is very influential, and a more detailed explanation is likely to be required.

If quality assurance has been very limited then presenting any measure of uncertainty may be misleading. In such circumstances where the greatest source of uncertainty is the potential for error, then this should be the most prominent message that is conveyed to the decision maker. This may be in the form of an analytical assurance statement that highlights areas of concern.

	In other cases, the uncertainty could be less important, for example your analysis might suggest that the cost of a project is uncertain, but in all cases the benefits outweigh the costs. In this case the uncertainty is less influential and may require less detailed communication.
Don't let uncertainty undermine confidence in the analysis	Most decision makers want certainty. This can make communicating uncertainty a difficult task. Decision makers can react adversely when faced with uncertainty, leading them to lose confidence in analysis. When uncertainty is large, decision makers may feel that the analysis is of no use. A useful phrase to remember is "all models are wrong, but some are useful". All analysis will be uncertain because every model is a simplification of reality. However, that does not stop them from being useful, models allow us to understand a system and uncertain results can help identify important features of that system. If uncertainty means that a straightforward conclusion is not possible, focus your communication on what the uncertainty analysis can tell you. This may be the key factor that drives overall uncertainty or a greater understanding of how features of a system interact.

What is the key message?

If most uncertainty is quantified, then present this prominently	If most of the overall uncertainty has been quantified, and you are confident that there are no unknowns which are likely to have a major impact on the results then this should be the most prominent message. Discussion of the unquantified uncertainties and risks should be included but should be positioned so that it doesn't reduce confidence in the main results when this is not appropriate.
If little is quantified, then it may be better to present no quantification at all	If there are substantial unquantified uncertainties, then presenting the uncertainty that has been quantified without this important context will give a misleading impression of precision and underestimate the uncertainty. Do not present a range with incomplete coverage if you know that there are substantial uncertainties that are not accounted for in that range.
Is there a major risk that has not been included?	If the largest source of uncertainty is the potential for a risk outside of the analysis to be realised, then this should be the most prominently displayed message.
If quality assurance has been very limited, you should	If quality assurance has been very limited, then presenting *any* measure of uncertainty may be misleading. When the greatest source of uncertainty is the potential for error, then this should be

probably lead with this	the most prominent message that you convey to the decision maker. This may be in the form of an analytical assurance statement that highlights areas of concern.
Front load the important caveats and explain why they matter.	Think about how caveats are presented. A long list is unhelpful, but two or three upfront that have the most impact on the results are likely to be more helpful and easily understood. You should explain what the caveats mean for decision makers who want to use the analysis, rather than simply setting out what they are.

Understanding the audience

Consider the audience when choosing appropriate communication methods	People respond differently to different communication methods. We need to assess the intended audience to understand the best way to share information with them. The audience might be: • Analytical - may respond better to a technical explanation of the uncertainty • Non-analytical - may respond better to non-technical language • Mixed - a combination of both If it is a group or individual you have worked with before tailor the method to what has worked well in the past (or ask them or see how they respond to different formats).
Build relationships with decision makers	A good relationship with your decision maker will help you to choose the right communication approach for them. It will also help you to understand their motivations and the implications of uncertainty for their decisions.
Be conscious of how your analysis may be used in future communication	No matter how carefully you communicate the uncertainty to your immediate client, there is a risk that uncertainty will not be communicated upwards and that only the central numbers will persist, and important caveats will be excluded. This can also occur when writing part of a larger document – you need to ensure the key messages about uncertainty survive the drafting process. A good relationship with colleagues will minimise this risk. Work collaboratively to ensure that colleagues understand why central numbers could be misleading and in which situations it would be inappropriate for them to be communicated on their own. Always ensure that wherever possible you have sight of further communication before it is sent.

Deciding how to communicate uncertainty

Now you have determined what the message is you need to consider how to communicate with your decision makers. Firstly, think about how you will be communicating your results. Will this be via a written report, presentation, or an oral briefing with or without visuals? Any constraints on format may steer you to an approach.

This section considers a range of approaches based on your understanding of the audience and the type of message you need to deliver.

Communication Basics

Assess whether to describe uncertainty in words or attach figures	How something is written has a major impact on how people perceive the uncertainty. Research shows that that analysis is seen as less reliable if the outputs are conveyed only in words. Numbers should be presented within a sentence if possible as this helps give context, making them easier to read and understand.
Be careful when using descriptive terms and adhere to an established system is possible	Descriptive terms such as 'low risk' or 'very likely' can be interpreted very differently by different people . If possible, it is best to attach a numerical probability and use these words in support. An exception to this is where there is an established system that your audience is used to for attaching terminology to probabilities, one that can be assumed to be well-understood by the intended audience. For example: • According to the IPCC (Intergovernmental Panel on Climate Change), "very likely" means 90-100% probability. • According to NICE (National Institute for Health and Care Excellence), probabilities of between 1 in 100 and 1 in 10 are referred to as "common".
Use positive and negative framing	Presenting the likelihood of success may be perceived differently to presenting the corresponding likelihood of failure. Present the information both ways to avoid bias (e.g. "there is an 80% chance of success and a 20% chance of failure"). By adding in the chance of failure, you remind the reader that it exists and how large it is, which may otherwise be overlooked. Visual part-to-whole comparisons can help with this.
Decide how to present your numbers	There is no clear preference for choosing between probabilities and fractions (e.g. 10% probability, or 1 out of 10). Given this, the usual preferences of the audience or the 'norm' within the organisation may be best followed. If using fractions, keep the denominator constant (e.g. "1 in 100 vs. 2 in 100", rather than "1 in 100 vs. 1 in 50") and as small as possible while keeping to integers (e.g. "1 in 100" rather than "10 in 1,000"), rounding if appropriate.

Be clear on the specifics and applicability	Saying a '10% chance of rain' is meaningless unless you also state the time period – e.g. in the next hour, or at some point tomorrow – and location. If the outputs are only intended for use within a specific frame (for example, a specific area or to a particular group of the population), then make sure this is clearly stated alongside the outputs.
Use an appropriate level of precision	Consider the overall uncertainty in the numbers you have calculated. Round them appropriately to avoid spurious accuracy (e.g. perhaps 40% rather than 38.7% if the overall uncertainty is greater than one percentage point).
Use ranges wherever possible	Presenting a single figure is best avoided as it can give a misleading impression of precision (e.g. "between 1,200 and 1,800", rather than "1,500"). Commissioners may request a 'best estimate' for ease of onward use, but you must consider the risks in providing this. Try to understand how they intend to use the analysis, so you can provide something that meets their needs while also acknowledging the uncertainty.
Consider whether to include a 'best estimate' within the range	Stating a range may be perceived as a uniform distribution across the range. Conversely, stating a range around a best estimate may be perceived as a triangular distribution (or Normal with analytical audiences). Consider which of these best reflects the actual uncertainty when deciding what to present.
Choose appropriate confidence/prediction intervals and be clear	Don't simply use 95% confidence intervals by default. Think about what the outputs are going to be used for (see section 1), and discuss the level of risk and uncertainty that the decision maker wants to plan for – this might not be 5%. Be clear what confidence level you are using and ensure your audience understands what this means (avoiding precise statistical definitions if it will increase comprehension).

Graphs and visualisation

Graphs can be an excellent way of communicating the quantified elements of uncertainty	Graphs and visualisations are an excellent way of communicating the outputs of analysis, and many graph types allow you to communicate uncertainty within the graphic (provided the uncertainty has been quantified). Unquantified uncertainties cannot generally be included in graphs, so will need to be communicated through other means. Some types of graph are not particularly well suited to displaying quantified uncertainty:

Some graph types cannot be used to show uncertainty clearly

Some simple graphs
Pie charts, donut charts, stacked charts

These should generally be avoided, except for specific datasets , because people find it difficult compare the angles or sizes of different sections . This is true for analysis in general, but particularly for uncertainty as they show only a single value for each data point.

Most complex graphs
Heat and Choropleth maps, Treemaps, Sankey diagrams

As a general rule, it can be difficult to communicate uncertainty in very information dense visualisations such as those above. There is not space to include the necessary extra information among the colours of heatmaps, the densely packed rectangles of Treemaps or the detailed flow lines of Sankey diagram.

Decide what level of detail to include on uncertainty

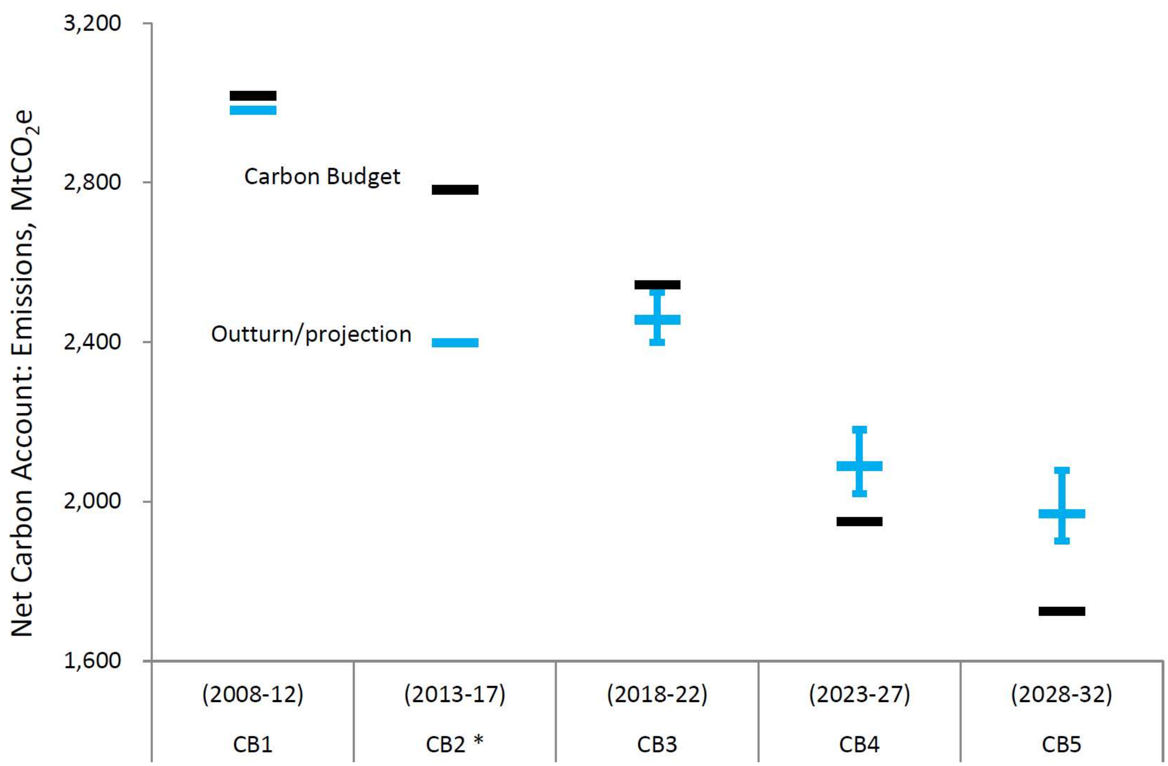
You may have the full understanding of the underlying probability distribution, or just a range within which we expect the result to fall. You may choose to only include the uncertainty due to a single dominant uncertainty, or the outputs from a range of scenarios.

The following table suggests some graph types that can be used for most situations, each of which are described in the following section.

	Single Measure	**Multiple Measure**	**Time Series**	**2-dimensional data**
None	Single point graph, or describe in prose	Bar graph or line graph	Line graph	Scatter graph
A Range	Single point graph with error bars	Bar or line graph with error bars	Line graph with range	Scatter with 2d error bars
Summary Statistics	Single box plot	Series of box plots	?	?
Maximum Detail	Probability Distribution Function (PDF) or Cumulative Distribution Function (CDF)	Multiple PDFs or Violin Plots	Fan chart	?
Uncertainty due to the methodology	Scatter Plot		Spaghetti Plot	Spaghetti Plot
Uncertainty due to alternative scenarios	Describe in prose		Multiple Line Graphs	

Errors bars

Error bars are a simple way to illustrate a range around a data point	Error bars can be added to bar graphs, line graphs and scatter graphs to illustrate a range around a central estimate, within which we expect the value to lie with a given probability.
Choose an appropriate probability level based on the context	As referred to previously, consider the situation and decide on an appropriate level to display. E.g., don't apply 95% confidence/prediction intervals by default. State what probability the error bars represent, and describe in prose how the viewer should 'read' the error bar.
Be clear about what the error bars represent	
Error bars can be applied to series of data points	Error bars can be added easily to a data series or time series. However, if the data are continuous (e.g. a time series) then consider whether showing multiple line graphs would be clearer than a single line graph with error bars.
2-dimensional error bars can be used where necessary	If the output data are 2-dimensional, then you can apply error bars in 2 dimensions. Be careful to ensure that the resulting graph does not become illegible due to clutter.



Example: ***Actual and projected performance against carbon budgets.*** *For future emissions, vertical bars show uncertainty in the projections and indicate 95% confidence intervals for the uncertainties that have been modelled.*

Box plots

Box plots can convey more information about possible outcomes than a range alone

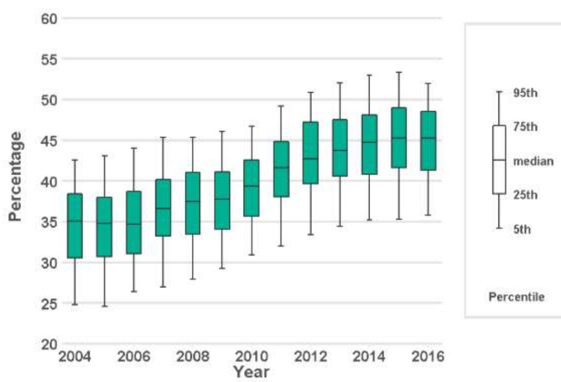
Box plots can help the audience understand the underlying distribution of possible outcomes in more detail than just a range. Typically they show the median, interquartile range, maximum and minimum values for the range of possible outcomes. This can be particularly useful when the underlying distribution is skewed or non-normal.

A series of box plots can be used to compare distributions

Box plots can be arranged in parallel to show the distributions for a range of measures, and can help compare the different shapes.

Think about whether the audience will be familiar with the format

Box plots may not be widely understood by non-analysts, so think carefully about whether the added information will be effective, or whether a simple range would be sufficient. A labelled example can be used to help the audience interpret the format.



Example: ***Deaths in the usual place of residence.*** *The graph depicts the percentage of individual that die in their usual place of residence. Box plots are used to show the variation between different Clinical Commissioning Groups, and district and local authorities. A labelled box plot is presented to explain what the ranges mean.*

Probability density functions (PDFs)

PDFs show complete information on the quantified uncertainty

A probability density function can be used to give complete information on the range of possible outcomes, and the likelihood of each for a given estimate.

Think about whether the audience needs this much

While presenting complete information may seem ideal, it may be more information than the audience actually needs. Would a prose description of the mean and range be sufficient?

information

If the PDF is approximately normal, then there may be little value in displaying it, as the essential features can be described in a few words.

PDFs can be useful when the distribution of outcomes is multimodal, or otherwise complex

The distribution could be multimodal – for example the marks for students passing a university module may have a peak for a number who don't study very hard, and a peak for those who worked really hard. In this case it could be misleading to present the mean, so a graphical illustration of the distribution may be more effective.

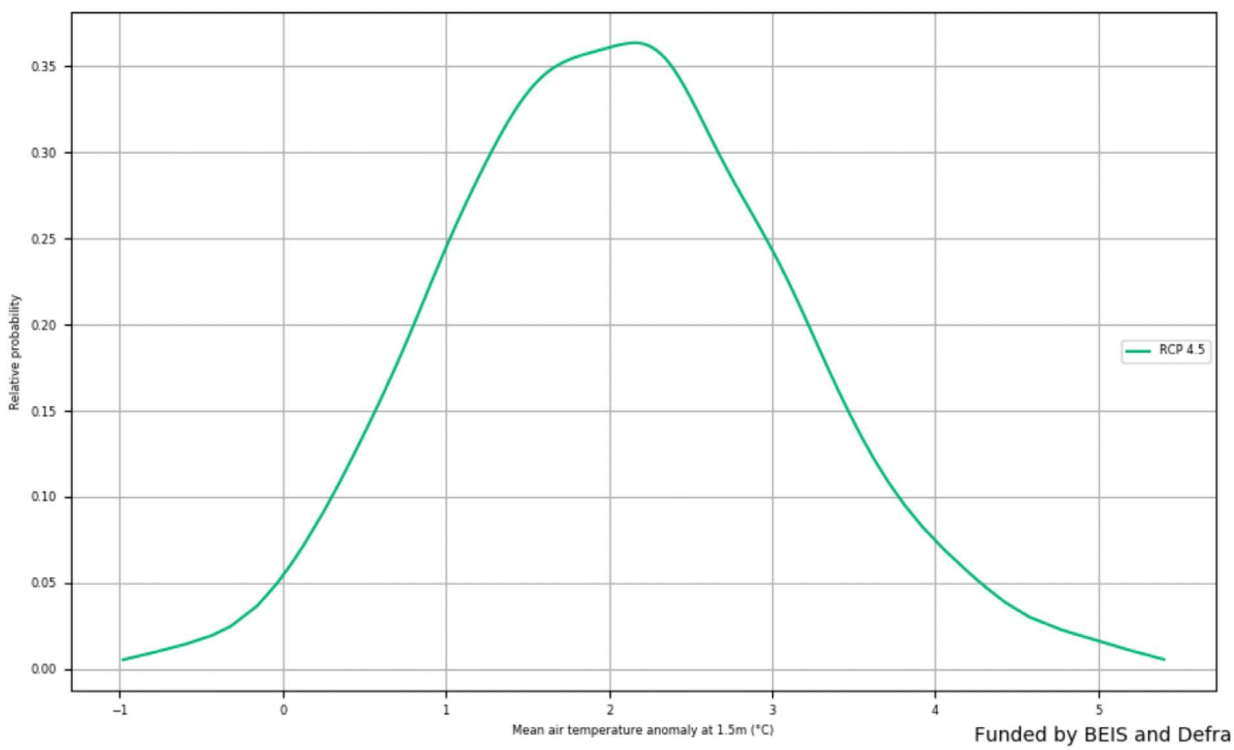
Labelling can be used to highlight the key features

It may aid clarity to draw the reader's attention to important features, such as the mode.

Multiple PDFs can be used to show uncertainty across different measures

If we need to communicate a series of PDFs, then multiple functions can be shown to compare the range of possible outcomes across the series.

If there are only 2 or 3 these can be overlaid to make it easy to compare. With more, 'small multiples' are likely to be clearer.



Example: ***Change in Air Temperature for 2080-2099.*** *The graph shows the expected change in air temperature in 2080-99 compared to 1981-2000 for a medium emission scenario.*

Cumulative density functions (CDFs)

A CDF may be more helpful than a PDF if there is a specific threshold of interest to the customer

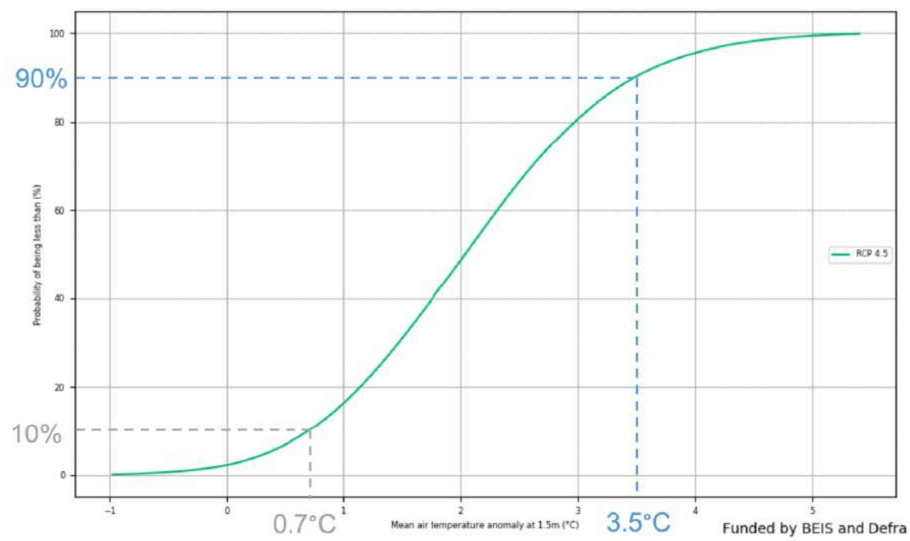
A cumulative density function essentially shows the same information as a probability density function. However a CDF may be more helpful when the audience is primarily concerned with how likely it is that the value will be below (or above) a particular point (rather than the range within which we expect the value to fall). For example, how likely is it that our costs exceed our budget? (rather than what are our costs going to be?

The most likely value is less clear on a CDF

However, features such as the mode are less clear on a CDF (shown by the steepest part of the graph), as they are harder to read by eye.

Labelling can be used to highlight the key features

Drawing gridlines intersecting at key points of the function can help the viewer understand how to 'read' the graph.



Example: ***Change in Air Temperature for 2080-2099.*** *The graph shows the same information as the PDF example above. The grey dotted lines indicated there is a 10% probability of a mean temperature change of less that 0.7C. The blue dotted line indicated that there is a 90% probability of a mean temperature change being less than 3.5C.*

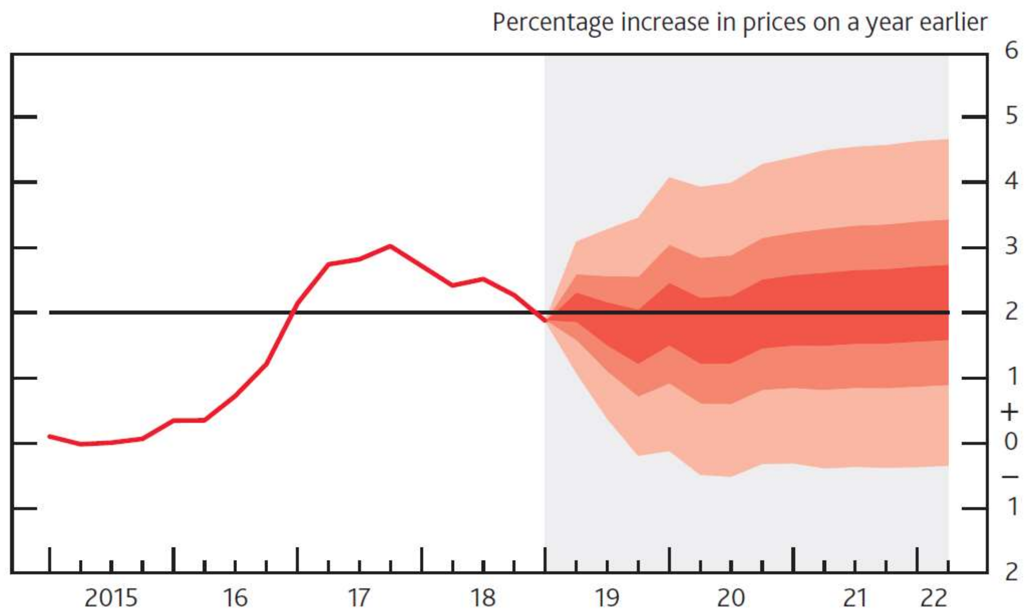
Fan Charts

Fan charts can show how uncertainty changes over time

Fan charts can be used to show a series of different prediction intervals for time-series projections (e.g. 30%, 60% and 90% at the same time). This is essentially plotting selected points from a time-dependent PDF.

Avoid including the mode

Often a central 'best estimate' is not included, to avoid the viewer focussing on a single estimate and undermining the importance of the uncertainty



Example: ***CPI inflation projection.*** *The graph depicts probability of various outcomes for CPI inflation in the future. The fan charts are constructed so that outturns of inflation are also expected to lie within darkest central band and each pair of the lighter red areas on 30 occasions. In any particular quarter of the forecast period, inflation is therefore expected to lie somewhere within the fans on 90 out of 100 occasions. And on the remaining 10 out of 100 occasions inflation can fall anywhere outside the red area of the fan chart (grey area).*

Multiple Line Charts

Multiple line charts can be clearer than a series of error bars

Alternative scenarios can be illustrated with multiple line graphs

Give equal prominence to each scenario

Try to have an even number of scenarios

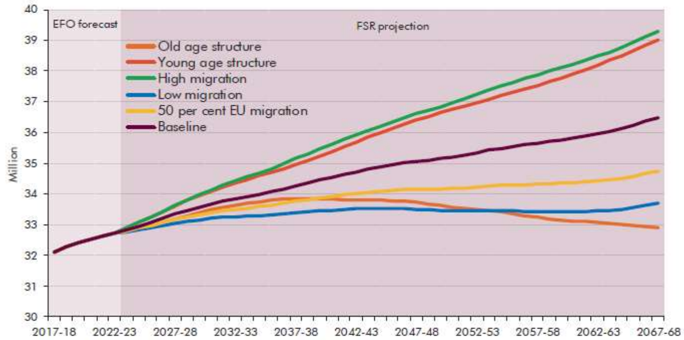
Multiple line charts with time series data to show a quantified range around a 'most likely' projection (essentially a series of error bars).

With scenario analysis, a series of line charts can be used to show the projections from each scenario.

Generally with scenario analysis each scenario should be presented with equal prominence, to avoid suggesting that one is more likely than another (unless analysis has been carried out to quantify the likelihoods of each).

Try to include an even number of scenarios, to avoid having a middle option that may be misinterpreted as the 'most likely' scenario.

Chart 3.4: Employment projections (16+ population)



Source: OBR

*Example: **Employment Projections.** The graph presents future employment levels for different demographic scenarios. Each scenario is represented by a separate line plot. The graph does not attempt to show the probability of each scenario occurring.*

Tornado Diagrams

Tornado diagrams can be used to show the *sources* of uncertainty

Tornado diagrams are different to most other graphs discussed here. They are not used to show the outputs of the analysis, but to show how different sources of uncertainty contribute to the overall uncertainty.

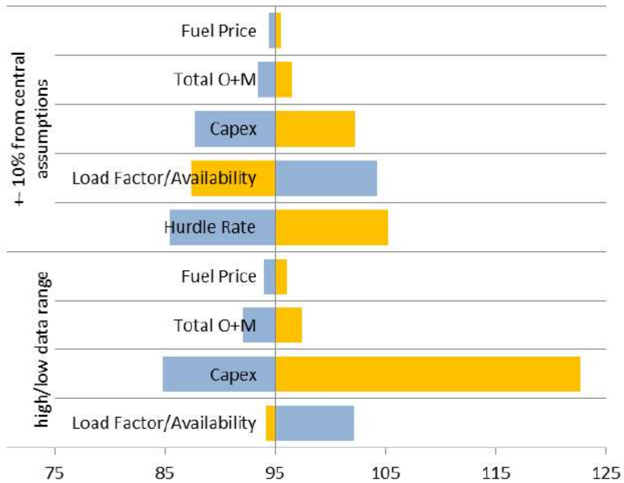
Tornado diagrams depict sensitivity of a result to changes in selected variables. They show the effect on the output of varying each variable at a time, keeping other input variables at their assumed values.

Can help communicate the reasons for uncertainty, and identify further need for analysis

If the level of uncertainty is unpalatable to the customers, then this format can be useful to help focus work on reducing the level of uncertainty in key parameters.

Tornado diagrams can be misleading in complex models

One limitation of the format is that only one parameter is changed at a time. There are some situations where the uncertainty due to one variable may appear small initially but becomes much more prominent if a second variable takes on a slightly different value (e.g. think of a workflow model with a bottleneck. A tornado diagram might show the bottleneck parameter to be the overwhelming uncertainty. However, if this parameter is increased slightly then the bottleneck may move elsewhere, completely changing the picture)



Example: ***Nuclear Levelized Cost of Electricity.*** *The graph presents the change in the levelized cost of nuclear electricity (£/MWh) that would result from changes in input parameters. Impacts are shown from both 10% upward or downward movement in central estimates and from predetermined parameters ranges (high/low data range). Yellow bars represent an increase in the parameter, blue bar represent a decrease in the parameter.*

Infographics

Infographics can be useful for public facing communications

Infographics are graphic visual representations of information, data or knowledge intended to present information quickly and clearly. They can improve people's understanding by using graphics to enhance peoples' ability to see patterns and trends.

Graphics can grab attention and make messages more accessible

When done well they will grab the reader's attention from become a very powerful way of communicating key messages. Designing a good infographic may be worthwhile if your audience is less confident with data and analysis.

However, watch out for common pitfalls and follow best practice for the design

Like all graphs and visualisation you should ensure the information is presented clearly and truthfully. With infographics there is additional the risk that visual design elements detract from the key message. Consider the final audience for the information to determine if an infographic is the right choice and follow best practice

Example: ***Reoffending Behaviour After Receiving Treatment.*** *The infographic uses people icons rather than a bar chart to show the number of reoffenders in a sample. An uncertainty in the form of confidence intervals is included in the infographic*

Interactive Tools

Interactive tools can be used to immerse your reader on complex matters

An interactive tool can help make analysis more accessible to non-specialists. They can create an immersive experience that is easier for them to understand and is highly memorable.

Focus on specific messages

Consider the overall message and where the uncertainties lie. Which aspects will the audience be interested in and what do they need to know? Use this understanding to bring focus to which interactive elements to create.

The interactivity will enable your users to manipulate and get a deeper understanding of the message.

Allow reader to adjust a key variable

If a key source of uncertainty is a single variable, then it may be possible to construct a display that can be changed as the user adjusts the value of this variable by moving a slider.

Or, if there are several key assumptions that impact the result a chart may be created that will change depending on the inputs that the user inserts.

Being able to see what would happen if an underlying assumption was to change is a powerful way to demonstrate the level of uncertainty we may have in a given result.

Example: The DECC 2050 Calculator is an award-winning, user-friendly tool that helps users to explore the choices available to meet the 2050 carbon target. Whilst it doesn't explicitly cover the uncertainty in the underlying data it does allow the user to create their own set of policies to try to reach the target. This engaging tool was helpful in demonstrating to users how difficult some of the options are and the relative impact of each choice.