PLAN2ADAPT

Guidelines for
Climate Information Tools

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List of Acronyms

AR4 / AR5	Assessment Report 4 / 5 (IPCC)
ARM	Adaptive Resource Management Ltd
CMIP	Coupled Model Intercomparison Project (multi-model climate data source)
GCM	Global Climate Model
GIS	Geographic Information System
IPCC	Intergovernmental Panel on Climate Change
NARCCAP	North American Regional Climate Change Assessment Program
NGO	Non-government organization
PCIC	Pacific Climate Impacts Consortium
RAC	Regional Adaptation Collaborative
RCM	Regional Climate Model
UKCIP	UK Climate Impacts Programme
WCRP	World Climate Research Programme

Plan2Adapt: Guidelines for Climate Information Tools

Table of Contents

1. Introduction

This guidebook has two purposes. Part 1 describes the Plan2Adapt Climate Information Tool – referred to as Plan2Adapt throughout this document - created by the Pacific Climate Impacts Consortium (PCIC) at the University of Victoria, and explains how this web-based tool has been developed and used to provide climate information to local users in British Columbia. The second part of the guidebook describes other similar climate information tools and provides advice on how such tools can be designed and applied effectively anywhere. Our focus is on applications in Canada, so we refer to data sources relevant to the Canadian context, but the principles and procedures apply equally in other jurisdictions.

Over the coming century, climate change is expected to significantly affect ecosystems and human activity. Increases in temperature, changes in precipitation and storm patterns will directly affect flooding, coastal erosion, crop production, water supply and infrastructure. However, the impacts of climate change are not easy to predict. There is high confidence that climates all across Canada will change in the coming decades, but the details in any given locality are uncertain, particularly with respect to changes in variability and extreme events. Furthermore, the impacts of climate change will depend on local conditions, capacities, and decisions: the nature of drainage patterns, infrastructure capacity and maintenance, land use planning and development, and the health of ecosystems already stressed by other pressures, among other factors.

At the local level, many planning decisions about land use, ecosystem conservation, infrastructure investment, and design of long-lived systems may need to consider long-term future climate changes. These factors are mostly *not* built into current standards or practices. Currently, awareness of the scope of future climate change and the potential impacts on current practices is generally low. Locally relevant, future climate projections and plausible impacts information can help increase awareness and provide reference points for local planners and decision makers.

Climate projections derived from models of global climate are not easy for non-specialists to interpret. In particular, it is often difficult to anticipate the difference that small changes in climate might make to local conditions, and to recognize the scope of uncertainty and the range of possible future conditions that might occur. Climate data can be provided in a variety of numerical formats for different time periods, but none of these are particularly informative for users who are not accustomed to analysis of quantitative climate data. This points to the value of a generalized, web-based climate information tool that will translate climate modeling data into visual representations and summaries that are more relevant and informative to a wide range of local non-specialist climate information users. Plan2Adapt has been developed to meet this need.

PART 1: Plan2Adapt

2. Development of the Plan2Adapt Website

The development of the Plan2Adapt climate information website began in early 2008, at the initiative of CitySpaces Consulting and PCIC (see Appendix 1 for key participants). The concept was to develop an introductory information tool aimed primarily at land use planners and local governments, in order to help them visualize climate changes, impacts and related uncertainties in British Columbia. The main purpose of the tool was to raise awareness of climate change and its potential implications at the local level, rather than to serve as a source for detailed technical analysis or planning specific projects. The initial background work was largely unfunded, although both Natural Resources Canada and the B.C. Ministry of Environment supported subsequent refinement of the basic prototype.

The concept drew inspiration from the pioneering efforts of the UK Climate Impacts Programme (UKCIP), described below in section 7 of this document, and from early guidelines for local climate adaptation prepared by the University of Washington's Climate Impacts Group (Snover et. al. 2007). The tool also followed up on the recent release of a national study of climate impacts in Canada that focused on the need for local adaptation (Lemmen et. al. 2008). An international review of other website tools undertaken at the time by PCIC revealed that there were no other sites directly comparable in function and audience to that proposed for Plan2Adapt, increasing the amount of original effort required to develop the site.

The development of the website involved several rounds of consultations with climate adaptation experts and land use planners from across B.C. The consultations took the form of workshops or focus groups to engage users in applying and interpreting the information from draft tool and website mock-ups and to respond to specific feedback questions. These sessions were critical in providing guidance to website developers on the kinds of information desired and the preferred formats for display and user interaction, and led to many modifications in the original draft materials. The Plan2Adapt tool was promoted to land use planners at provincial conferences in 2008 and 2009, and launched for public use in mid 2009.

PCIC recognized that climate change would affect different regions of the province differently, particularly in light of B.C.'s large size and extreme geographical diversity. So the tool had to be able to respond interactively to regionally specific information requirements, and to diverse sectoral interests, in order that local officials responsible for resource management, infrastructure, planning and development would be better able to adapt their plans to meet changing anticipated conditions.

The key challenge in the development of the Plan2Adapt tool was to ensure accurate but comprehensible communication of scientific information to a lay audience. This task is not straightforward, and while Plan2Adapt developers adopted a suitable vocabulary

level and writing style early on, there were many revisions suggested by users to reduce the use of technical acronyms, simplify data presentation and explain key terms and graphic labels. Users recommended the choice of graphic representations of the data (both maps and graphs), and identified the need for explanatory text in conveying basic information.

In late 2009, with additional co-funding support from Natural Resources Canada (part of the B.C. Regional Adaptation Collaborative program or B.C. RAC), PCIC extended its consultation and site review to include users in other sectors, including forestry and water resource management. Adaptation planners and project leaders in the B.C. RAC used the Plan2Adapt site to build awareness and to introduce climate change concepts to local practitioners. The Plan2Adapt site was originally intended as a "gateway" to provide access to additional climate adaptation information such as case studies, of which the regional tool would only be part. However, the other functions were later removed due to a proliferation of climate adaptation information on other websites administered by B.C. organizations (e.g. Fraser Basin Council, Smartgrowth BC, Columbia Basin Trust and others). The Plan2Adapt site was simplified and streamlined in order to provide clear summary information quickly. The site is now aimed more at the general public and local governments who may lack extensive technical resources or expertise on staff, to enable them to gain an appreciation of basic climate change concepts and implications for their local area.

3. Using Plan2Adapt

Plan2Adapt provides users with simple maps, plots, and tables of climate change projections for variables like precipitation, seasonal temperature, snowfall or frost-free days for British Columbia as a whole and, in its original format, for each of the Regional Districts in B.C. The projections originally applied to Plan2Adapt were derived from 15 different Global Climate Models (GCMs), each run under two global greenhouse gas emission scenarios, A2 and B1, for a total of 30 projections. The estimates of future emissions come from scenarios developed by the Intergovernmental Panel on Climate Change (IPCC) (Nakicenovic and Swart, 2000). We discuss some of the details of the application of scenarios and the construction of Plan2Adapt in section 6 below. These are only 2 of several dozen scenarios defined by the scientific panel, and other possible emission outcomes would lead to different climate projections. By the end of the 21st century, these scenarios describe an atmospheric concentration of greenhouse gases of approximately 850 ppm (A2) and 600 ppm (B1), expressed as carbon dioxide (CO2) equivalent. Plan2Adapt summarises all of the projections from the different GCMs in simple graphical formats that can be used in presentations, reports, and to facilitate discussion of adaptation planning at the local level.

The Region & Time menu (Figure 1) is the interface through which users select the period of future climate for displaying the projections, the seasons of the year and region of interest. Once users have made their selection in the Region & Time menu

and clicked “Continue”, Plan2Adapt will display climate change projections for a number of variables according to user specifications. The climate change projections for the desired future time period and region are summarised in a table for quick reference. Clicking on the “Notes” tab enables the user to learn more about how the projections for each variable were produced, how the maps were generated, and how the future time periods were selected.

Figure 1: Region & Time Settings menu

The summary table (Figure 2) displays both a range and ensemble median for some climate variables. These values are represented as the absolute difference (temperature) or percentage difference (precipitation) of the projected value, as simulated by the models, from the climate conditions for the period of 1961-1990.

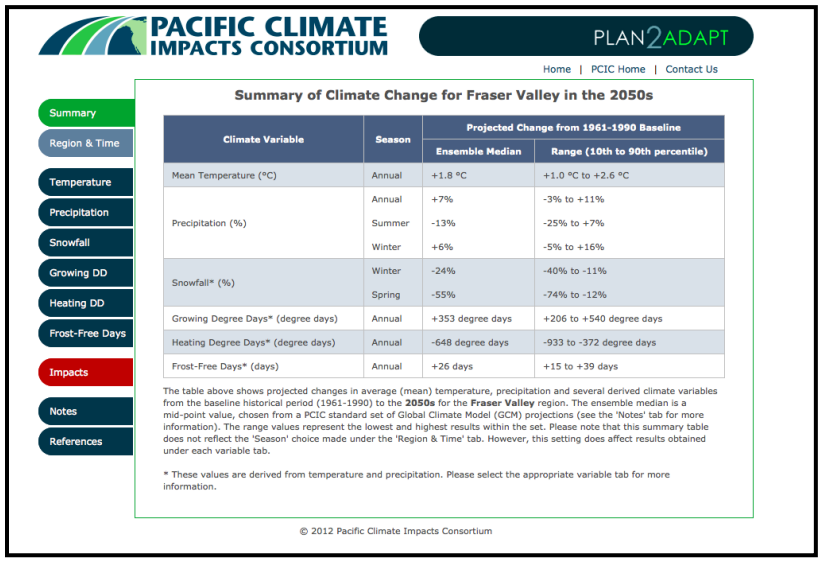

Figure 2: Summary of Climate Variables for Selected Conditions

The range indicates the range of projections produced by the 15 GCMs used in Plan2Adapt for both A2 and B1 emission scenarios. Because we cannot say which model's projection will be closest to future conditions and because each is plausible, it is important to consider the range of projections, rather than relying upon a single projection from a single model. Note also that future emissions may be considered to be higher or lower than in the scenarios chosen, leading to different projected outcomes. The ensemble median is the median value out of the 30 projections used by PCIC.

Clicking on one of the variable tabs on the left side of the table allows access to maps and plots of projections for that variable. For instance, clicking on the "Temperature" tab will bring users to the window displaying Future Temperature Projections for their region and time period of interest.

From this display, users can select either high-resolution maps or graphical plots of the range of projected changes in that variable for the selected time period. On the high-resolution maps, users are able to zoom in on the map by using the scaling feature (the "+/-" bar located in the upper left corner). Additionally, users are able to select certain map overlays – such as the location of municipalities or forestry districts – and change the opacity of the climate variable by clicking on the "+" signs located on the right-hand side of the maps.

The maps only display results from one GCM for simplicity, and it is not possible to select any other GCMs. However, by glancing at the "Range" bar located on the right side of the map space, users can see where the displayed GCM projection falls within the range of projections from the other 29 ensemble members (see Figure 3). Another way of visualizing the range of potential change that might be seen for a particular climate parameter is to select the graph plot image instead of the map.

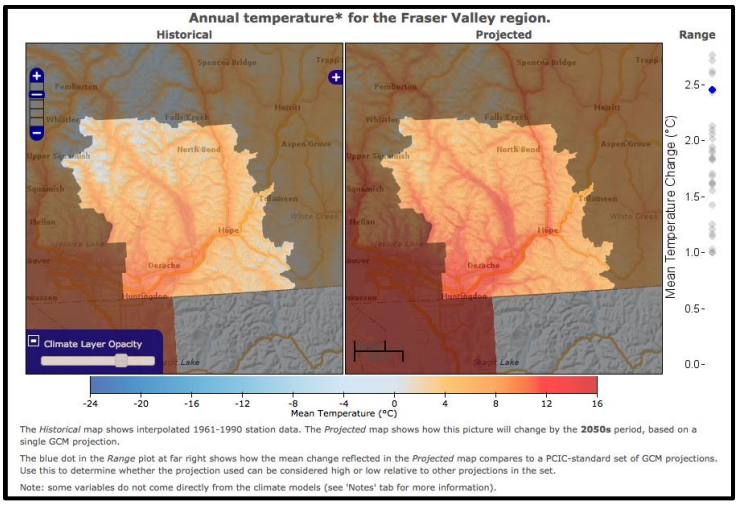

Figure 3: Map display for projected temperature

A map display and graph plot showing the range of climate model projections are reproduced for each climate variable represented on the selection tabs in the Summary table (example in Figure 3). The range of features allows users to focus on climate variables of greatest interest to them. In all cases, the display values are long-term averages for the 30-year time slice and geographic location selected, and actual year-to-year conditions will of course fluctuate.

PCIC has recently upgraded the site to add more detail under the Climate Impacts tab. Section 5 of this guidebook describes the impacts features in greater detail, including how the impacts rules were formed, language choice, and the user consultation process for constructing the impacts.

Limitations of Plan2Adapt

Plan2Adapt provides easily understood maps, plots, and tables of synthesized climate projections for each defined geographic region of B.C., for variables such as rainfall or frost-free days for various future periods. The site now also provides simple impact information and brief discussions of the implications of such impacts for various sectors and areas, like temperature impacts on road maintenance. Such information may be useful in a variety of applications – from holding discussions with various members of a community about the potential impacts of local climate change to rapid climate risk assessments. However, if a land use planner or utility is facing a more complex decision such as a land use or infrastructure development project, or a strategic plan or climate risk assessment, that user will probably need more specific and detailed information than the Plan2Adapt tool can provide.

If climate impacts are of crucial importance for planning decisions, users may want customized data outputs that allow them to examine the model runs in different ways in relation to specific contextual factors and thresholds linked to issues such as infrastructure conditions, environmental hazards, and decision constraints. In these instances, PCIC recommends their Regional Analysis Tool. The Regional Analysis Tool provides access to the same 15 GCMs and 2 emissions scenarios that are used in the Plan2Adapt website, as well as others, and also has the following features that are not available in Plan2Adapt:

- The ability to download the underlying data associated with each projection from each GCM for a variety of climate variables.
- The ability to generate maps and plots for each GCM individually or as aggregates of models for specific climate variables and regions of interest.

The Regional Analysis Tool does NOT contain any information related to climate impacts or potential repercussions for sectors or infrastructure. Users may contact PCIC directly to obtain data for additional climate variables, or for customized climate model downscaling or data interpretation.

4. How Plan2Adapt Has Been Used in British Columbia

An interview survey of Plan2Adapt users on Vancouver Island and the Lower Mainland was undertaken using referrals from site managers and known users. With limited time and resources, approximately 40 users were approached, and 12 felt that they used the site enough to agree to an interview. Respondents included local government staff, NGO staff, consultants and researchers in approximately equal proportions. These are representative of Plan2Adapt's known users, but because we did not formally sample from an identifiable user base, we do not attempt to draw statistical inferences. The sample provided interesting and quick feedback that suggested some consistencies in use patterns.

Users reported that they found the site clear and simple to access and use. They primarily used it for communicating basic climate science information in the context of local planning and decision-making. They used both map and graphical representations of future climate parameters to convey this information, although there was a slight preference for the graphical representation for its clarity on the range of model results. Users frequently reproduced the graphics and summary table from Plan2Adapt. They were generally not concerned with the representation of uncertainty in future climate projections, partly because they were aware of high uncertainty levels in projections of future conditions, and partly because the climate data are only one of many information inputs to decision making – and typically not the most important one. In the view of these users, the main advantages of the site are its visual clarity and simplicity, and the visual representations of future climate data that it presents for different regions of the province. Several of the respondents emphasized that while there has been broad professional recognition of the significance of climate change among local officials and planners in the past several years, they were still dealing with skeptics amongst decision makers and the general public. So the clarity of the visual representations of climate projections was an important tool for communicating the issues and potential impacts.

At the same time, users were aware that the site was not appropriate for providing detailed analysis of climate parameters for planning and design decisions. They were also aware that Plan2Adapt could not provide information dealing with changes in the frequency and intensity of extreme weather events and climate variability. Average seasonal precipitation changes matter less, across several sectors, than the frequency and duration of extreme events. Some respondents requested additional support for effectively communicating likely changes in the nature of extreme weather events as a result of climate change.

Interviewees also indicated that the Plan2Adapt website served as an entry point for them to contact PCIC to obtain more information to use in their local climate adaptation planning. The effectiveness of Plan2Adapt as a gateway site, introducing climate science concepts and impacts in B.C., is indicated by the fact that while almost all of the potential interviewees approached for this survey were aware of Plan2Adapt, most of

them no longer used the site and had moved on to more detailed analytical tools in their climate adaptation work.

5. Representing Climate Impacts: Recent Upgrade to Plan2Adapt

In late 2011, Adaptive Resource Management Ltd (ARM) was engaged to support PCIC in the development of website upgrades that improved the quality and detail of climate impacts information and added GIS data overlays to the map interface. These enhancements was released on the public site in May 2012.

In addition to maps, plots and data describing future climate projections, Plan2Adapt now also invites users to explore broad climate impacts. Describing impacts is more difficult because the impacts of greatest concern to users (e.g. extent of flooding, sea level and storm surge, or the frequency and intensity of drought) are not only difficult to project, but also depend on the specifics of local context (e.g. infrastructure investments, water supply, preparedness).

To support requests for information on potential local impacts of climate change, PCIC enhanced its impacts tab to add more detail and differentiate potential impacts by sector of interest. In order to generate the required information, PCIC and ARM identified the key sectors representing the most climate sensitive B.C. users:

- hydrology
- forestry
- fisheries
- biodiversity
- agriculture
- land use planning
- infrastructure

PCIC invited a group of experts with experience in climate applications in these sectors (see Appendix 2) to join in an exploratory workshop that would identify generic impacts at different levels of climate change. This workshop was designed and facilitated by ARM.

In general, local impacts of climate change are affected by too many local variables to be determined by an automated tool, so in their approach to upgrading the impacts module PCIC took care to listen to the feedback from people experienced in the use of climate science in resource management and local planning. Instead of pointing to specific local impacts resulting from projected climate changes, the new material highlights questions that users of climate information could ask about potential areas of impact, to identify starting points for further local study and community engagement.

Workshop participants were asked to focus their task on identifying management implications of anticipated climate change in their sector. This was broken down into three parts: identifying the primary impact of interest, identifying thresholds at which that impact could be a problem, and then identifying considerations for planning or management organizations to further investigate in their local context. Participants worked in sector groups to approach this task. Different groups chose different approaches: some following each step above in sequence while others started with scenarios of climate impacts and then identified primary and secondary impacts and their related thresholds.

The flow of the workshop was designed to support collaboration, remind people of the climate information available as a starting point, and provide ample opportunity for problem solving and conversation. The workshop kicked off with presentations from climate scientists and web developers to give a sense of what raw data was available to work with in developing thresholds and of the limitations of the programming tools. Facilitators supported each group and encouraged cross-fertilization of ideas and identification of interrelated impacts.

Presentation of Impacts Information

The challenge of presenting impacts is to provide information that serves as a starting point for further research without being interpreted as predictions. In the case of these site upgrades, the management implications highlight key issues that are likely to be exacerbated by future climate conditions specific to the region selected. For example, in the B.C. Southern Interior, facing higher temperatures and lower summer precipitation, water managers will probably want to consider additional reservoir and seasonal storage options, and fisheries managers may find increased stress and declining returns for valuable fish species. Forestry operations may be affected in northern parts of the province by reduced snow cover and shorter winters. By representing these potential sector management implications on the climate information website, as a direct result of the region and timeframe choices made by the user, Plan2Adapt directs users towards a broader conversation about the implications of climate change with local sector experts.

This site upgrade links the impacts to the projection data, and makes the impacts and conclusions regionally sensitive in context. In a geographically diverse province like B.C., this means ensuring factors such as glacier melt, sea level rise, and hydrological regime, are tailored to the relevant regional summaries.

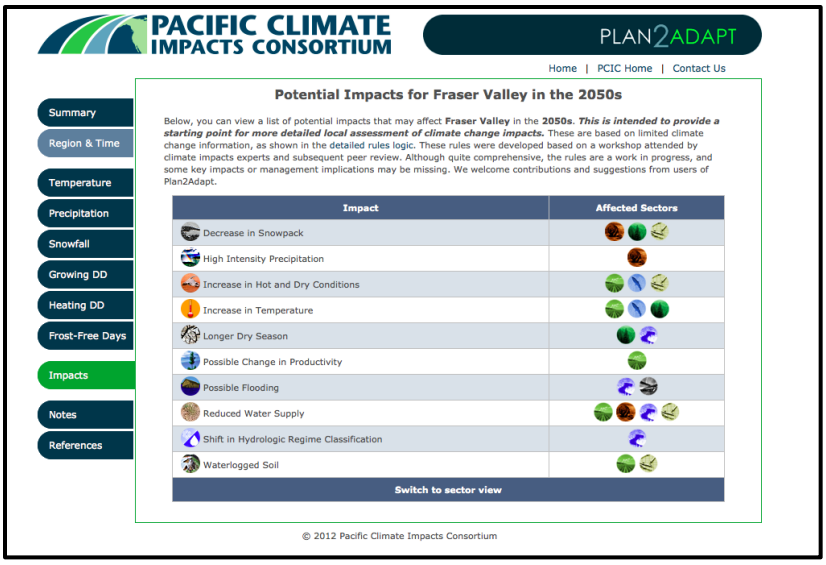

Figure 4: Updated Impacts Tab

The workshop outputs described impacts by sector, with some cross-referencing between sectors where impacts were related, to transfer to the website. To capture the relationships between the sectors and impacts, information is layered through the use of icons and hyperlinks. The new Impacts Summary table can be displayed either by category of impacts valid for the selected region (see Figure 4) or by sector of interest. In either case, the same information is presented. Clicking on any icon in an impacts line (either impact or sector) will reveal a list of management implications linked to that impact in all sectors relevant to the selected region / time slice.

The website upgrades also mean that users can now present results not only by Regional District, but also by regional Health Authority, or by ecoprovince (classified according to British Columbia's Ecoregion classification system), as well as by provincial government resource management regions. The geographic area selected will form the base map for the display of historical and future climate conditions, and for the calculation of regional average changes in key climate parameters on the summary table.

Improved features on the base maps (Figure 5) include adjustable scales (zooming), and additional information layers that can be optionally added (municipal boundaries, forest management unit boundaries, biogeoclimatic zones, land cover, parks and glaciers).

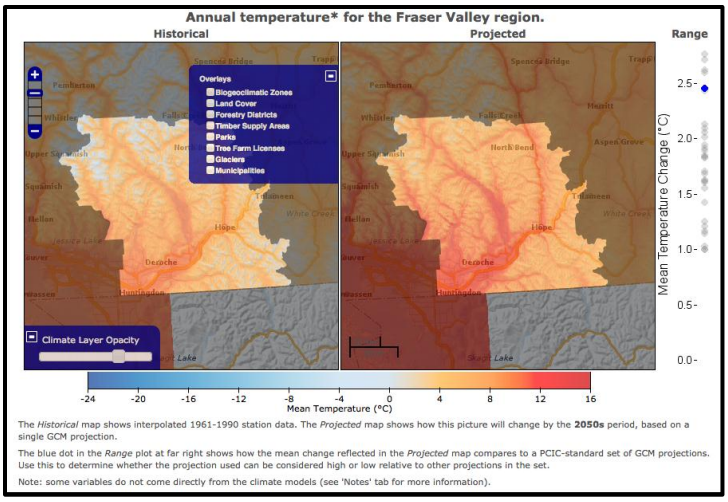

Figure 5: Geographical overlays on thematic maps

The updated Plan2Adapt display provides impact descriptions and maps that allow users to focus on sectors or geographical characteristics of greatest relevance. The presentation highlights natural resource management sectors, so that users can find a familiar starting point for grounding the climate science in their own local knowledge and experience.

PCIC's experience demonstrates the need for regular updating of the site to provide the most recent climate science and to ensure consistency with new research findings, as well as to respond to user feedback. In the future, PCIC expects to update the climate data used in Plan2Adapt. The site currently uses data from the World Climate Research Program's Coupled Model Intercomparison Project phase 3 (CMIP3). This will be upgraded to reflect the latest adjusted climate model results and alternative emissions pathways from CMIP5. In addition, the PRISM climatology that is used to provide the historical baseline is currently being updated by PCIC in collaboration with Oregon State University to incorporate a more recent baseline period and a higher spatial resolution. The use of these climate data in constructing an interactive site like Plan2Adapt is discussed in the following sections of this document.

PART 2: General Guidelines and Examples

6. How to Prepare Climate Information Tools like Plan2Adapt

General Considerations

A web tool like Plan2Adapt helps to bridge the communication gap between climate scientists and users of climate information - a significant challenge. Determining how to communicate climate science effectively involves both the clear presentation of scientific information and a clear understanding of the intended audience and their information needs. Of course, these are related concepts. How the science is illustrated depends on assumptions made about the background knowledge and interests of the users, which means that a natural place to start is by identifying key user groups. Once these user groups are identified, it is important to also create opportunities to seek their input so that they can continue to provide guidance about what they will find most useful. It is important also to keep in mind that a climate science tool will only be useful with ongoing review, revision and dialogue to respond to the evolution of both climate science and user requirements.

PCIC developed Plan2Adapt at the same time that it was involved with several other projects that involved significant community engagement and communication of climate science. The idea for Plan2Adapt grew out of conversations with interested potential users and the recognition that there were common streams of information to which people in various parts of the province would like access. The strengths of the tool reflect the fact that from its inception there has been ongoing dialogue between potential users, climate scientists and web designers.

One of the lessons from experiences of communicating climate information in a variety of different places is that while credible and reliable climate science is fundamental to generating climate information, climate scientists typically do not frame this information and uncertainty in the same way as those who need to apply it (Kinzig, 2003; Gay and Estrada, 2010). In developing climate information tools, for example, UKCIP found it more effective if information users and climate scientists provided independent feedback on tool structure and content. If they worked together, the input of climate scientists tended to dominate and misdirect efforts towards information that was less intelligible or applicable for users (personal communication R. Street and S. Ferguson, 2011). While they are essential for a successful product, climate scientists often have a limited understanding of decision-making processes, user needs, existing knowledge and how users interpret information (Opitz-Stapleton, 2010).

Defining Your Audience

Defining the audience and objectives of a similar tool is an iterative process. After identifying one or more distinct target audience(s), there is a follow-up process cycling

between assessing what users want to know and already understand about climate science, what information can actually be conveyed using available climate data, and what gaps remain. With an awareness of who the target audiences are, it is easier to identify what information should be conveyed, and how that information should be represented. Alternatively, if the climate information tool is intended to achieve a particular communications or awareness outcome, then identifying the processes and users who are best able to accomplish that outcome is a logical first step.

These questions will be helpful in determining your audience:

- What is the purpose of the intended climate information – for example, to communicate broad changes or provide more detailed information to be used in infrastructure or land use development decisions?
- Who do you want to reach?
- Who has requested information about climate change?

Plan2Adapt was designed to be an entry-level awareness-building tool, and PCIC considers that, while the tool will have broad applicability across B.C. in a variety of local and provincial level organizations, most users are unlikely to be long-term repeat users of the site. The intent is to enable users to become familiar with the site contents of local relevance, and then encourage them to integrate this information into their work on a routine basis and move on to more detailed climate analysis where appropriate. So the primary audience for the Plan2Adapt is mainly new users who are unfamiliar with its contents. This required a site design with intuitive and easily navigated menus. The target audiences are those who will refer to the site early on in a climate resilience or adaptation planning process and use it as a starting point for their own local assessment and planning processes. Recent site upgrades facilitate this learning by making impacts and sectoral management implications more explicit.

Interviews with Plan2Adapt users reveal that those who regularly use the site are using it as part of a program of community engagement, research and/or education, and often in multiple locations. In these cases, the website resources are utilized for facilitated communication and education purposes, primarily as a reliable source of graphical representation of regional data, and integrated with additional local or sectoral contextual information. Since these users have regular interactions with people who are being introduced to the material, they have valuable input into what works with the site and what does not.

Defining Objectives

In the preparation of any climate information tool, developers should be prepared to address the following issues in order to better define the structure and content of the information tool. This list of questions largely echoes the issues that came up in the development of Plan2Adapt, but also in other comparable sites.

- What information do users want?
- How can climate science be used to communicate practical information in response to user requests?
- How will this information be used?
- What climate information is important for decision makers and planners in key sectors to consider?
- What important climate factors may not be widely recognized or considered now?
- How can this information be shared?
- What mechanisms exist for ensuring iterative feedback between potential users and climate information providers, to guarantee that the information product evolves to meet changing user needs and updates in climate science?

The design and content of the tool should support the processes for which the users will apply the climate information. For example, in the case of land use planning, the tool should use information relevant to planning processes (e.g. administrative boundaries consistent with planning jurisdictions; issues sensitive to land use decisions). For introductory information and ease of communication, visual representations of climate data are often the most effective. Plan2Adapt has used two visual formats: regional maps that focus on areas familiar to users, and graphs that represent the range of model results for future conditions. *To ensure that the climate science message is being delivered in a way that can be easily used, it is important to solicit input and feedback from representative user groups.* PCIC has systematically sought feedback from a range of users for the design and content of its site.

Steps to Produce High-Resolution Climate Change Maps

Global climate models (GCMs) and regional climate models (RCMs) generate projections of future climate parameters for a grid on the earth's surface at scales on the order of ~100-300 km (GCMs) or ~10 - 50 km (RCMs). Projected variables, such as temperature or rainfall, from such models are generated as only a single value at a given point in time for each of these large grid squares on the earth's surface. They must be rescaled or "downscaled" in order to be useful for local adaptation planning, which often requires data in a grid of about ~4 - 10 km. A number of downscaling techniques and models exist, so the method chosen depends partially on what information is to be conveyed and how it is to be displayed.

PCIC derived the downscaled projections for British Columbia as a whole, and for smaller-scale regions within B.C., using PRISM datasets as the base for interpolating the coarse-resolution projections from 15 different GCMs (steps described below). PRISM is a dataset of estimated climate variables, such as precipitation, at fine-scale grid resolutions that uses relationships between the variable and characteristics of

terrain such as elevation. In this way, point measurements of observed station data are distributed to a fine-scale geographic grid (~ 4 km), and estimates of the variable can be made for grid cells where no weather stations exist, based on measurements from the surrounding stations (Daly et al. 1994). High-resolution (~ 4 km) PRISM precipitation and temperature datasets derived from historical station data now exist for some of Canada and all of the United States. Other high resolution datasets are available as listed below. Note that in other parts of Canada where elevation differences are less extreme than in British Columbia, it may not be necessary to use elevation-adjusted data.

The following steps describe the process PCIC followed in producing its Plan2Adapt maps. These can serve as a guideline for other organizations who wish to develop similar tools in other regions.

- **Step 1:** PCIC generated high-resolution maps of historical climate variables – temperature and precipitation – using 4km PRISM datasets for British Columbia for the period of 1961-1990, further interpolated to a very high 400m resolution using the ClimateBC downscaling tool. In the climate science community, scientists compare long term average projections for a future period (say 2041-2070) with those from a historical baseline period. PCIC uses the historical period of 1961-1990, because this period serves as a commonly used baseline in other climate studies and because PRISM datasets were available for this period. A variety of other gridded historical datasets are available for Canada including:
    - CANGRID climate data – 50 km resolution (Environment Canada)
    - ANUSPLIN Canadian Forest Service – 10 km resolution (Agriculture and Agri-Food Canada)
    - UDel Regridded Monthly and Annual Global Precipitation and Temperature - ~55 km resolution (University of Delaware)
    - Climatic Research Unit TS 3.0 - ~55 km resolution (Climatic Research Unit at the University of East Anglia)
- **Step 2:** PCIC then downloaded the gridded future projection data for temperature and precipitation variables for 15 GCMs and two emissions scenarios – A2 and B1 – that were assessed in the IPCC Fourth Assessment Report (AR4), and are available through the WCRP CMIP3 Multi-Model Dataset Archive. The 15 GCMs, each with two scenarios, yielded a total of 30 temperature and precipitation projections or ensemble members. Median values of these outputs can be used as a summary, when presented with additional information on the range of results across all 30 ensemble members. For most Plan2Adapt users the focus is on adaptation up to the middle of this century, not on long term climate. In these time scales, the differences in simulated climate values between the two quite different (and mutually exclusive) emissions scenarios are relatively small, so both sets were included in the calculation of median values. Some variables – snowfall, growing

degree days, heating degree days, and frost free days – are derived from the raw data in GCM simulations, analogous to their construction from historical data. Developers will have to download the datasets and extract the variables for the appropriate grid spaces that approximate their location, and then input these on relevant base maps in mapping software. There are a number of software programs available for extracting the variables, but most require experience working with NetCDF data files. Precipitation, temperature and other variables of interest will need to be downloaded to obtain an ensemble of GCM projections (Murdock and Spittlehouse, 2011). IPCC has also produced guidelines for the application of scenario data in climate impact and adaptation assessment. These describe the available data related to observations, emissions scenarios, and GCMs, and provide guidance on how to access, interpret and apply this data (Carter, 2007).

- ***Step 2b:*** Alternatively, a number of projections are now available from RCMs for Canada through the North America Regional Climate Change Assessment Program (NARCCAP). RCMs provide projections at a higher grid resolution of around 50 km, and the projections are better able to capture localized climate processes than the coarser resolution GCMs. For the time being, only 11 RCM projections are available from NARCCAP. The number of RCM based projections remains limited compared to the number of GCM based projections, so it should be recognized that the range of plausible future climate values simulated by RCMs may not be as broad as the span covered by GCM simulations.

- **Step 3**: Many community planners are interested in knowing how different the future climate might be from the historical climate. These differences are represented as anomalies in which either the absolute or percent difference is calculated between the projected variable in a grid cell for a future period (normally expressed as a mean value over several decades e.g. 2041-2070) and GCM simulated data from 1961-1990. The anomalies are calculated by subtracting the historically simulated period from the future projections for the period of interest. Some caution and judgment need to be applied during this step as to whether additional validation and bias correction of the GCM projections needs to be done, especially for precipitation, before the calculated anomalies are draped (added) directly onto the PRISM (or other historical) datasets. This requires consultation with climate scientists familiar with climate scenarios and downscaling.

- **Step 4:** PCIC then generated the high-resolution projection maps by literally adding the calculated anomaly value from a GCM grid cell onto the variable value in the PRISM historical data grid cells that are approximately represented by that GCM grid cell. For precipitation there is an additional step in that the calculated anomaly is computed from the GCM percent anomaly and then applied to the high-resolution baseline value. One GCM grid cell, at ~ 100 – 300 km resolution, can contain anywhere from ~600 to a couple of thousand PRISM grid cells. An implicit assumption in this step is that changes simulated by GCMs at large scales are also representative of climate changes at much finer resolution. If one of the other gridded historical climate datasets mentioned in Step 1 is used, the resolution of the projection maps will be different. Note that elevation corrected baseline data is

much more relevant in British Columbia than it might be in other parts of Canada where topographic differences are less significant.

- **Step 5:** Graphs were produced by assessing the distribution of all 30 ensemble projections for the various individual climate variables (model outputs and derived variables), and plotting the 10th, 25th, 50th, 75th and 90th percentile values of the distributed data results in each time period.

These are the steps PCIC followed to generate their graphs and high-resolution projection maps. As mentioned previously, a number of different downscaling and mapping techniques exist for generating such maps. Expert judgment is required to select the appropriate method depending on the area and timeframe to be represented and the variables to be displayed.

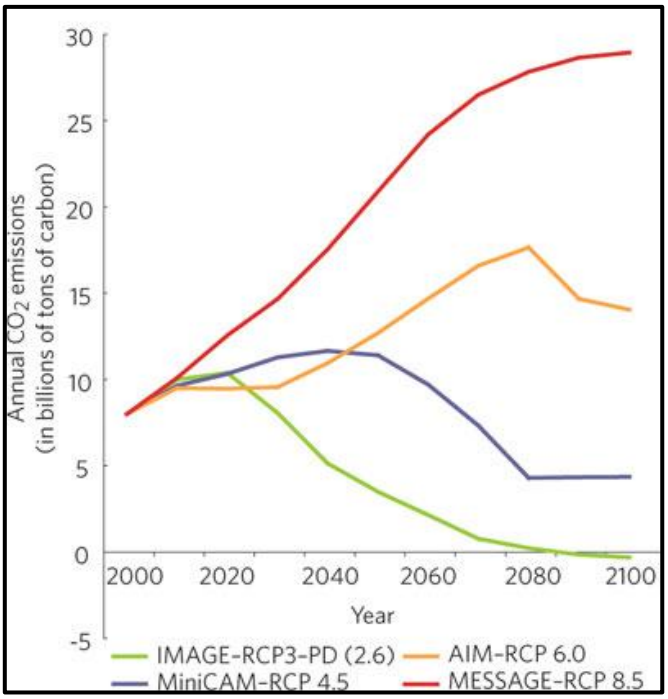

Figure 6: Representative Concentration Pathways Showing Annual Global CO2 Emissions (reproduced from Inman, 2011)

We note that the next generation of GCMs, which are providing results to IPCC's AR5 with new projection datasets, are increasingly being made available through CMIP5. These models use new emission scenarios called representative concentration pathways (RCPs) – see Figure 6. There are four new emissions endpoints that represent different levels of equivalent greenhouse gas emissions that could occur as a result of different policy and growth trends by 2100 (Moss, et. al. 2010). These datasets and RCPs will supersede the datasets that provided results for AR4 over the next few years, and climate information providers (including PCIC) will adopt the new model / RCP combinations as they re-constitute ensemble projections.

7. Representing Climate Projections

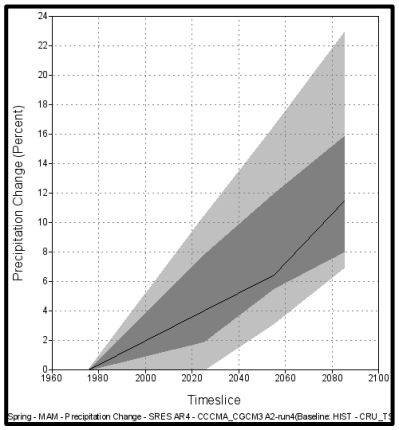

Figure 7: Plan2Adapt plot of potential precipitation changes (percent) for British Columbia showing distribution of results from multiple GCMs

Nobody knows exactly how the climate will change in the future, most simply because we do not know how many people will live on this planet in the next 100 years, how much greenhouse gases we will emit, or how rapidly we will continue to convert forests and grasslands to other uses. Unknown future human actions represent some of the largest uncertainties in projecting future climate. At the same time, each climate model created by the modelling centres simulates climate processes in slightly different ways at different resolutions and represents the complexity of the land-ocean-atmosphere processes differently. These factors mean that one should use projections from multiple models and emissions scenarios to educate potential users about the range of changes their area might face. Displaying only a single projection, from a single model and emissions scenario, can mislead non-scientific users into thinking that the future climate in their area *will be* what the single projection shows.

Climate information sites such as Plan2Adapt therefore normally display multiple projections from multiple models in different formats – maps and plots – to try to educate users about future trends and ranges in variables like rainfall, temperature, or heating days. Examples are shown in Figures 7 and 8.

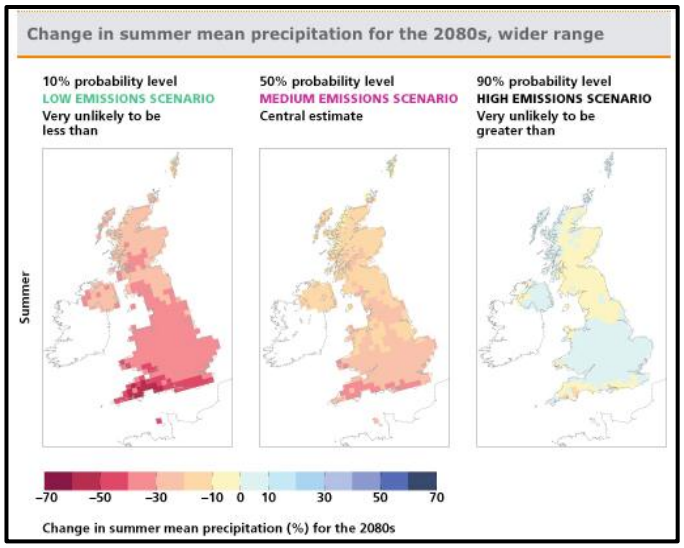

Figure 8: UKCIP maps showing the range of potential changes in mean summer precipitation for the UK in 2080's

Experience from Similar Initiatives

As awareness of climate change and its possible implications has increased, there is a growing demand for climate projection and impact information directed to audiences without scientific backgrounds. At the same time, however, many potential users do not know how to assess the burgeoning amount of "climate information" websites springing up – where to find credible and valid sources of information, and how to use it appropriately for a variety of contexts and needs. To meet the growing demand for credible climate and impact information, PCIC and other regional climate service providers have developed and are refining web-based tools for non-scientific users with a variety of needs and capacities. Climate information providers who wish to develop a similar broadly-targeted, web-based tool in their own region, may wish to also review these other English language sites with interactive mapping tools and treatment of uncertainty in representing future climate:

- UKCIP and UKCP09: http://www.ukcip.org.uk/ and http://ukclimateprojections.defra.gov.uk/content/view/12/689/
- Danish Information Centre for Climate Change Adaptation: http://klimatilpasning.dk/EN-US/Sider/ClimateChangeAdaptation.aspx
- Finnish Environment Institute's Finessi Tool: http://www.finessi.info/finessi/
- The Climate System Analysis Group at the University of Cape Town's Climate Information Portal: http://cip.csag.uct.ac.za/webclient/introduction

We discuss two of these websites – the Danish Information Centre for Climate Change Adaptation and UKCIP – in more detail, on the basis of site reviews and interviews with key informants. Both of these websites are very detailed, but their design and development suggests starting approaches for any information tool developer.

Danish Information Centre for Climate Change Adaptation
This website has versions in both Danish and in English, with a significant amount of content translated for English speaking audiences (see Figure 9). The website is geared for public consumption – with a focus on providing businesses, industry, local governments and politicians information that is easy to understand. The primary focus of the website is on communicating climate change *impacts* to a variety of users, rather than on conveying climate projections, which is a secondary focus.

Impacts are arranged according to various themes, ranging from health to building construction, which are displayed as toolbar tabs across the home page. Clicking on one of the theme tabs brings the user to a dedicated page describing how general trends in climate variables, such as increased precipitation during winter months, can affect that theme. Where possible, impacts to particular businesses or well-known entities such as Rail Net Denmark are mentioned. *The result is that impacts relate specifically to activities that are of direct relevance in users' daily lives.* No specific time periods are assigned to any of the impacts, which could be frustrating to users trying to

develop plans. However, some of the impacts tabs infer time periods by relating impacts to investment periods and development priorities under that specific theme.

This website is also arranged in a hierarchical manner – to accommodate more sophisticated users and to distinguish between types of users with different interests (municipalities, citizens and businesses). Short summary statements that are easy to digest, and repeat for news briefings or politicians, are the first types of information to be displayed. The language used in the first layer/view of the website is kept simple – "Wetter winters and sudden, heavy downpours make it even more important to direct rainwater and meltwater away from houses, paved areas, roads etc." Users who require more detailed information or wish to know more, are invited to click on case studies, FAQs, and the other links to expand upon the impacts related to the thematic area.

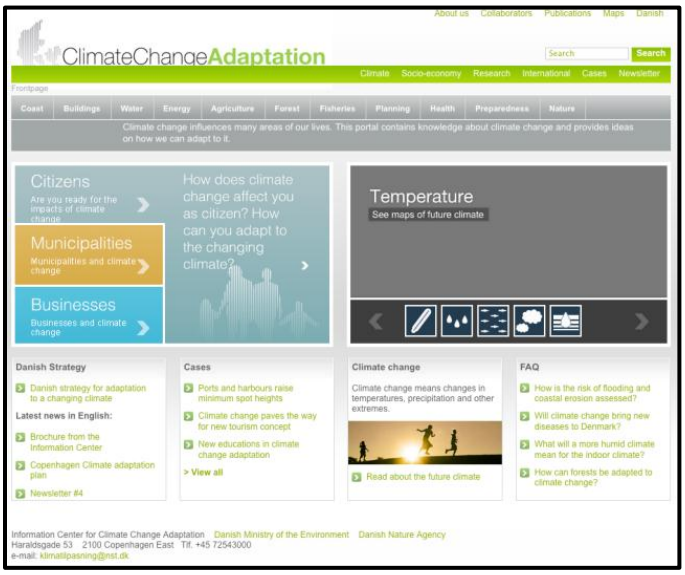

Figure 9: English Language home page of the Danish Climate Adaptation Tool

Users who would like to view climate change projection maps are able to do so through the map portal on the front page. The climate projection map tool is highly interactive, allowing the users to select a number of viewing options related to map scale, image layering and zooming. Users are also able to customize the climate information to be projected, select detailed case studies, and download data associated with particular scenarios for a location.

U.K. Climate Impacts Programme

The U.K. Climate Impacts Programme (UKCIP) represents a pioneering effort, established in 1997, to bridge the gap between climate scientists and those undertaking climate adaptation efforts in the United Kingdom. Impacts and projection information are bundled together under the "U.K. Impacts" tab. Once on the Impacts page, the user is able to examine projections and general impacts by region of the U.K. The U.K. Impacts tab links the user to basic, generalized impacts and projections from the UKCP09

initiative. The user is invited to explore more detailed information by clicking on the links to the UKCP09 website, which was also developed and is maintained by UKCIP.

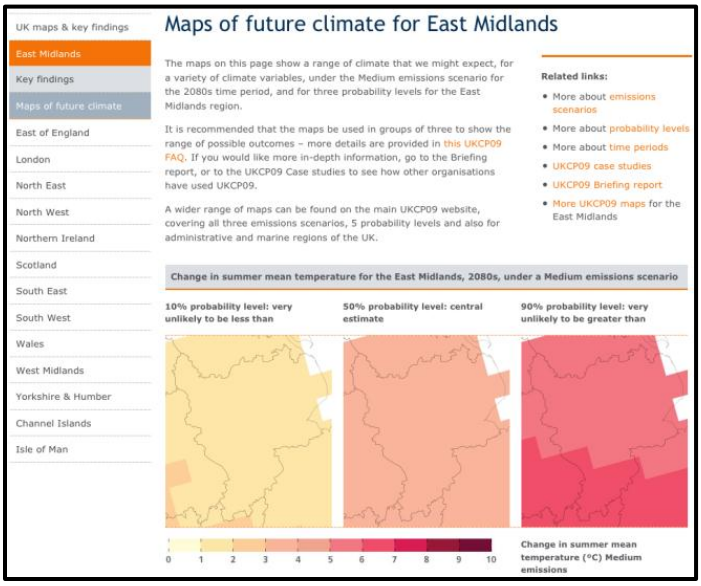

Figure 10: UKCIP display of range of projected temperature

UKCIP designed the website in a hierarchical manner, in order to engage more effectively with a variety of users with different comprehension levels and information needs:

- **Tier 1** – Basic climate projection and impacts information for unsophisticated users is provided via the UKCIP web interface. At this level, information is distilled to "sound bites" that politicians or press can use for briefings. Both projection and impacts information is displayed for the 2080s time period; if users require information covering other time periods they must proceed to Tier 2. Maps are kept simple and are always displayed in triplicate (low / median / high) to gradually introduce the user to the concept of climate uncertainty and the need to consider a range of projections, without explicitly discussing the underlying concepts (personal communication, R. Street and S. Ferguson, 2011). This is illustrated in Figure 10.

  Impacts are introduced as bullet points derived from UKCP09 research efforts and related to key sectors or areas of interest for broad categories of users. No time periods or specific numbers are mentioned in the simplified language on the UKCIP website, which instead uses phrases like "London's transport system and ancillary services are vulnerable to disruption from flooding and other extreme weather events that are expected to increase in frequency and intensity." If users require more detailed impacts information for their region, or wish to know more about impacts research or adaptation initiatives that might be relevant, they are directed to the ClimateUK website. From there, the user can select the regional initiative website that covers relevant impacts and adaptation initiatives for a particular geographic region. There are 12 regional initiatives (and websites), some of which are operated by regional governments and some of which are coalitions between

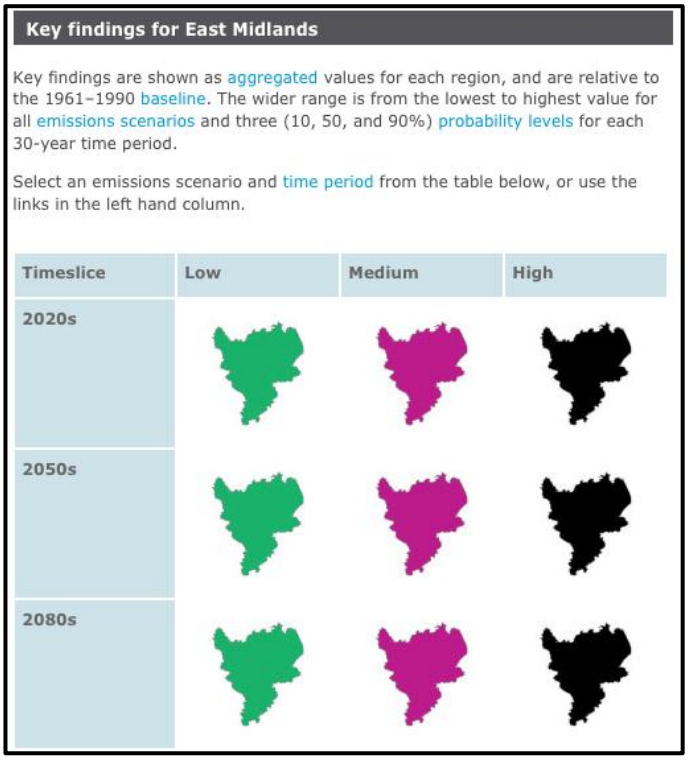

Figure 11: Second tier of information on UKCP09 website

local governments, businesses, non-governmental organizations, and research groups.

- **Tier 2** – The UKCP09 website is designed for more sophisticated users. Such users are directed to UKCP09 automatically whenever s/he clicks on any of the links under the "Related Links" section in the Impacts tab of the UKCIP website (see Figure 11). On this second tier, users are assumed to have more experience with understanding climate projections and impacts, including basic comprehension of probabilities, emissions scenarios, time periods and comparison with a baseline period, and uncertainty. If users are not that familiar with climate change or climate adaptation, they are asked to consider going back to the UKCIP website and/or encouraged to read an "essentials guide" before delving too deeply into UKCP09. UKCP09 does not provide detailed climate impacts information to users – that is provided via one of the regional partners to the ClimateUK website.

  The user is presented with two choices for accessing information – either a map matrix or the drop-down menu – both organized according to time period, emissions scenario and probability level. By clicking on one of the timeslices and emissions scenario combinations – such as "Low" and "2020s" in Figure 11 – the user will be directed to a text page describing possible changes in temperature and precipitation. To view projection maps, the user must click on "maps" from the drop-down menu link for the region of interest. The maps view provides a more complicated and detailed set of projections to the user, breaking the view down by variable (temperature and precipitation), season (annual, temperature and precipitation), and emissions scenario (low, medium and high). Each emissions scenario displays the 10th, 33rd, 50th, 67th and 90th percentile for three timeslices – 2020s, 2050s, and 2080s. This type of detailed projection display, including the ranges, was implemented after significant user feedback and requests at workshops.

- **Tier 3 –** The Tier 3 information is accessed by clicking on any of the hot links to key terms and phrases scattered throughout the website or by accessing the UKCP09 User Interface. The interface requires separate registration, although it is free. Significant resources, including online training and workshops, are available to users once they register for the interface. Language and vocabulary associated with

tier 3 information is of a technical nature, and assumes a graduate level science background (personal communication, R. Street and S. Ferguson 2011). This level of the site includes a wealth of reference material including reports, explanations for derivation of climate projections at multiple scales over land and marine areas, and specialized tools such as the "Weather Generator" which produces simulated hourly or daily weather patterns for a user-specified location and timeslice. At this level, users can access a range of data directly and review the underlying assumptions of the modeling approach. Information is geared for sophisticated technical users such as graduate students, hydrologists, impact assessment and risk analysts who already have a fair amount of climate knowledge.

8. Lessons for Climate Information Websites

Lessons from Plan2Adapt and from other sites

The experience of developing and supporting Plan2Adapt in B.C. has led PCIC to a number of lessons, which will be relevant to other organizations interested in developing climate information tools. Additional lessons can be gathered from a review of the experience from other similar sites. These are collected and summarized below.

- Users want concise, accessible information that is easy to reproduce and share.
- Climate information user groups are diverse, in terms of demands and needs for information, and in capacity to understand and distill information.
- Users want a clear narrative of change, and why climate change matters in their context, without being didactic. Having access to baseline data, and graphics that help visualize change are both important for users. The information about impacts clearly communicates that climate change matters by bringing up practical considerations from familiar sectors for further local investigation.
- Information providers should consult (frequently) with potential sets of users that have been identified as a target audience. Content should be developed around their understanding of climate change, potential impacts, and what these might mean for their contexts, as well as desired information formats and website layout.
- The communication of uncertainty requires attention. If only one projection is represented (in charts, maps or tables) users who are new to climate change concepts are likely to take this at face value as the "best" estimate of future climate change. But in many planning applications, it can be more important to consider the range or extreme values.
- Uncertainty can be effectively communicated without getting in the way of the basic message, e.g. by showing ranges of results or multiple alternative outcomes. To the

extent that Plan2Adapt informs decision-making processes, the major uncertainties of concern to users are generally linked to other factors besides climate science.

- It is helpful to provide multiple visual representations of the same data sets. Users want both maps and charts to represent future climate. The different representations highlight different aspects of the information. Together the summary table, plot graph and maps provide core information in a way that is accessible to a range of learning styles and audiences.

- Well-designed graphics will be reproduced and shared. It is therefore important to have well designed graphics that convey a clear narrative of change and to make it easy for users to reproduce these in their own processes and as communication points in the local context.

- Websites providing information should have an intuitive interface. The target audience for general climate information includes people who are new to the subject matter, so they are simultaneously learning how to navigate the web site *and* the content that it presents. To be appealing and useful, the layout should be clear and easy to navigate.

- An effective approach is to layer information to provide greater detail to those who are willing to look for it. General information should be easily accessible with the tool. Plan2Adapt, for example, opens to the summary table of climate data. More information that relates the climate data to other sectors or data sets, in the impacts tab or in map overlays, is accessible to users who take a few moments to look for it. This presentation of information is hierarchical: general information is available first, with more refined information available as users interact with the surface layer.

- A web tool supports conversation and learning with climate and impacts scientists, but it *does not replace live interactions*. The design of the Plan2Adapt site and the way that the impacts material is framed are intended to lead users into a process of deepening their engagement with climate science as well as with community expertise. The tool is a way to establish a baseline of climate science knowledge, but the integration of climate science with decision making still requires further engagement and learning.

- Climate scientists and impacts scientists are not necessarily in the best position to determine web portal design - scientists typically have a poor understanding of decision-making processes, user needs, and how users interpret information. Collaboration between users, scientists, web page designers and online tool developers is essential.

- A site will need regular refinement. Updating the site to include links to other complementary tools and completed assessment reports as they are developed helps to support the ongoing learning and broader dialogue in which the tool is situated. Technical upgrades based on improved modeling results and presentation upgrades based on user feedback are also important.

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10. Appendix 1: Key Contributors to Plan2Adapt

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11. Appendix 2: Participants at Climate Impacts Description Workshop, January 2012

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