Climate Change and its Effect on Engineering Practice.

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As stated recently by Al Gore during the launch of his documentary *An Inconvenient Truth* – "the climate change debate is over." As engineers we are faced with designing structures and facilities in the context of *a climate future which is not equal to the climate past*. The future climate is one of more variability and change – more and severe droughts and summer and winter storms, and different long-term averages. This will impact the effectiveness of engineering structures and facilities which are influenced, directly or indirectly, by weather. This includes water supply systems, wastewater treatment plants, hydropower, structures (via snow and wind loads), and many others. But perhaps most important for engineers, the precise future climate is inherently unknowable.

If we can't see the future, how as engineers are we supposed to design for it? Fortunately we are not without a clue. A host of *global climate models* have simulated possible future climates for locations around the world, and regional climate models are currently being developed for more detailed analysis. Additionally, we have *paleo-climatological data*, including tree rings, which provide glimpses into our recent climate history.

But even armed with such simulation and historical data, how can we design engineering structures given the inherent uncertainty in this information? Recent research and efforts toward *adaptive projects and policies* are helping engineers to design structures and facilities which are *robust* to a range of anticipated futures and have the *ability to adapt* to new unanticipated circumstances as they emerge over time.

The effect of climate change on engineering practice goes well beyond the notion of adaptation, and touches on the engineer's ethical responsibility for mitigation – for being part of the global effort to reduce greenhouse gas emissions. This manifests itself as more energy efficient engineering design and a de-carbonization of our economy via use of alternative low emission fuels and renewable forms of energy.

This presentation begins by providing a picture of global climate model simulations for Manitoba. Also described is the adaptation challenge facing engineering practice with innovative examples of adaptive project and policy design in North America and Europe. The mitigation challenge for engineering practice is articulated along with examples of innovative engineering.

While it is true that climate change poses many significant challenges for engineering practice, it is equally true that it presents a unique opportunity – to significantly increase the efficiency of numerous engineering products and to transform traditional engineering design so that it is better suited to a world of surprise, change and uncertainty – the reality of the world in which we live.

Climate Change and the Engineering Profession

The Mitigation and Adaptation Imperative for Professional Engineers

APEGM Professional Development Conference Oct. 6, 2006

Darren Swanson

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Vision:
Better living for all — *sustainably*
Mission:
To champion innovation, enabling societies to live sustainably

de•vel•op (di•vel′əp) *v.t.* 1. To expand or bring out the potentialities, capabilities, etc.

What is Sustainable Development?

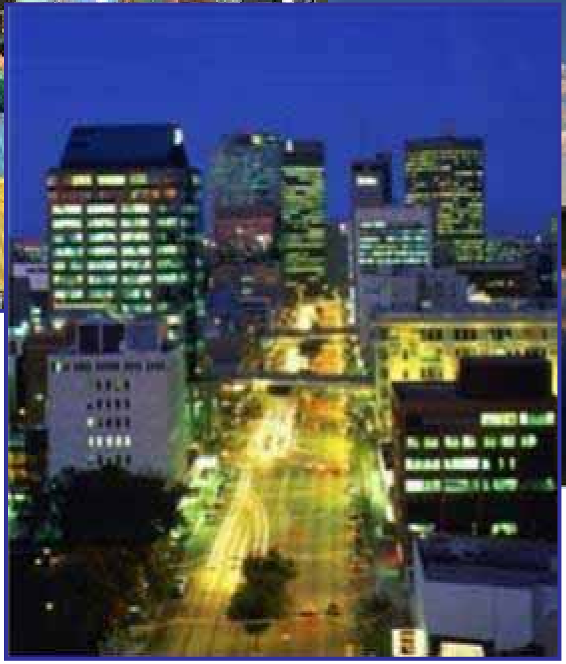
"development that meets the ***needs of the present*** without compromising the ability of ***future generations*** to meet their own needs"

http://www.unog.ch/unog01/Files/001_un_gva/f1_main.html

Brundtland Commission,
"Our Common Future"

"…take account of the interrelationships between people, resources, environment, and development."

Multi-dimensional



Multi-generational

Multi-scalar

Multi-stakeholder

This Session

I. Climate Change Context

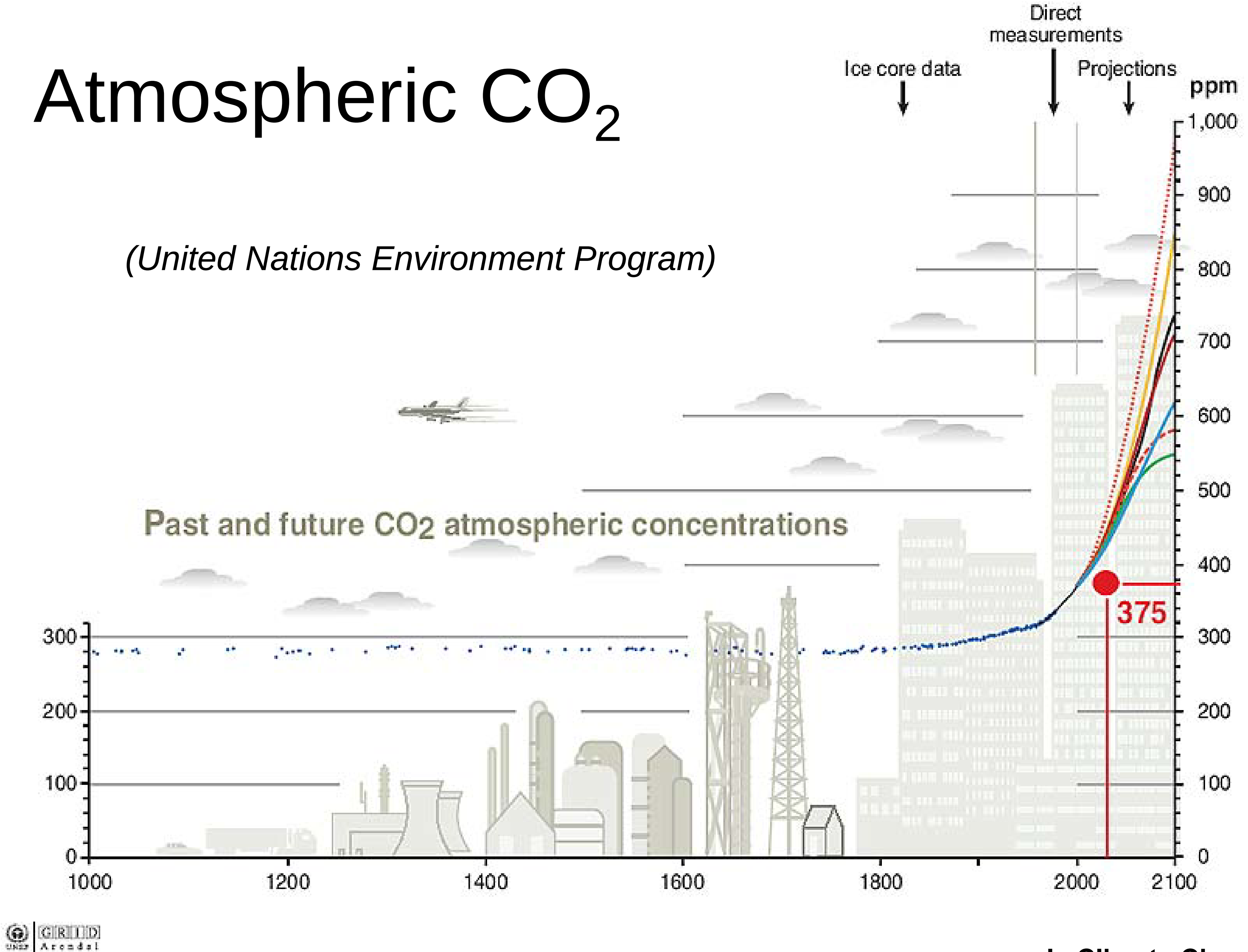
II. The Mitigation Imperative

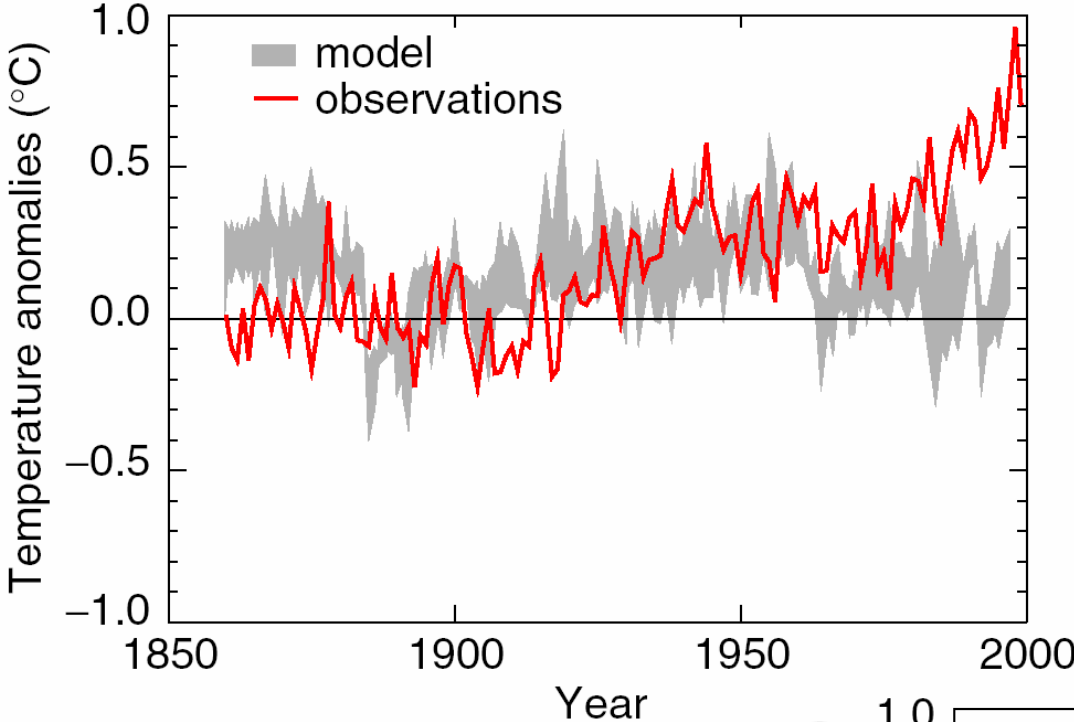
III. The Adaptation Imperative

IV. Tools
Adaptation

Atmospheric CO_2

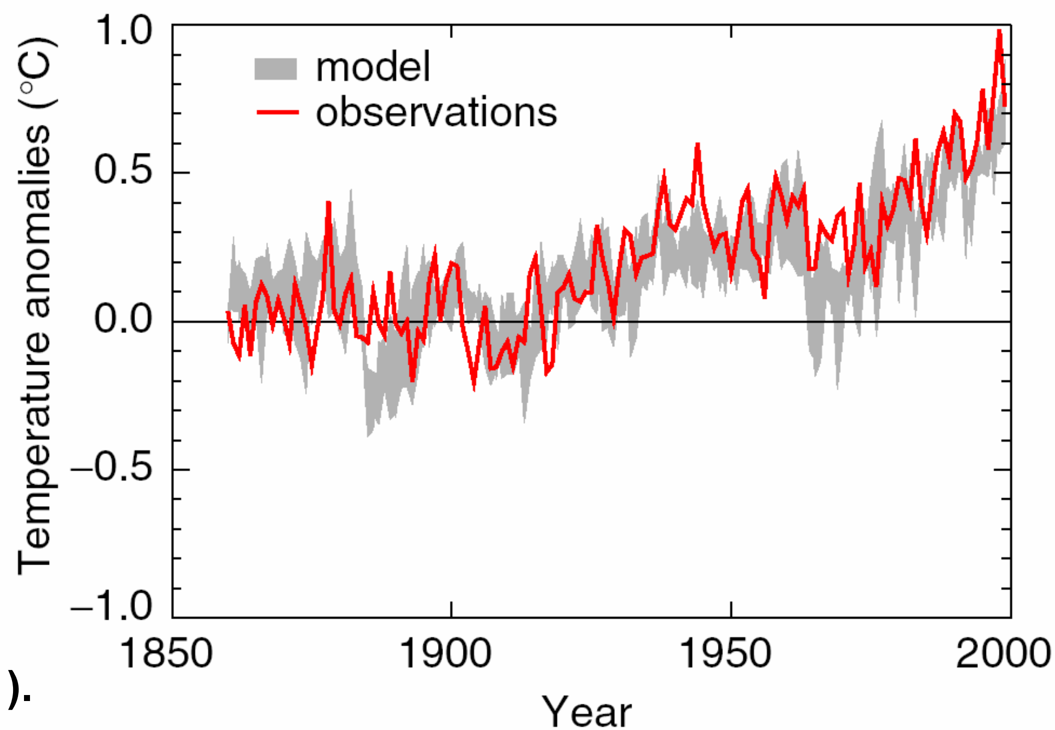
(United Nations Environment Program)



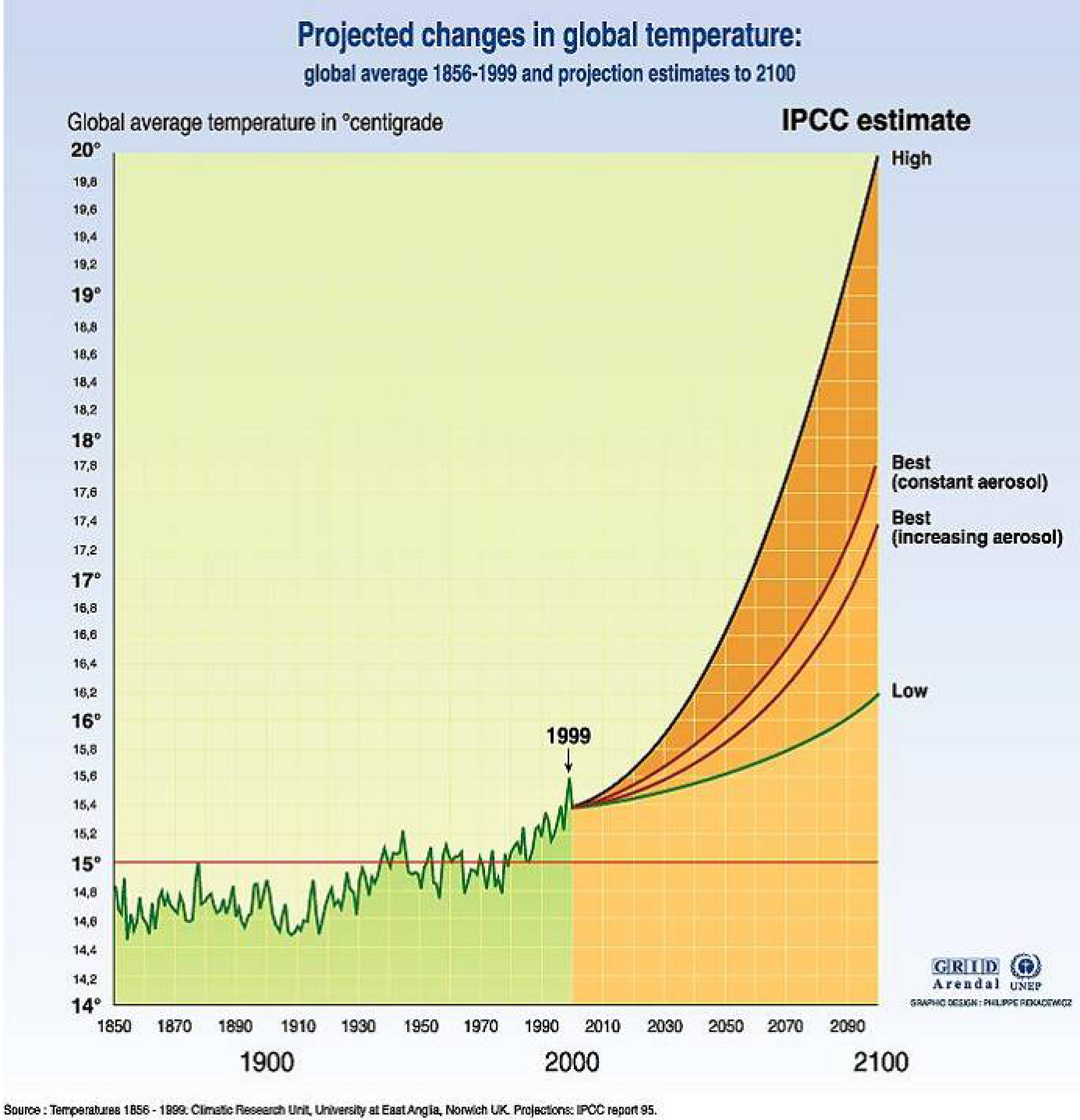


(a) Models using natural emissions only

(b) Models using natural and anthropogenic emissions

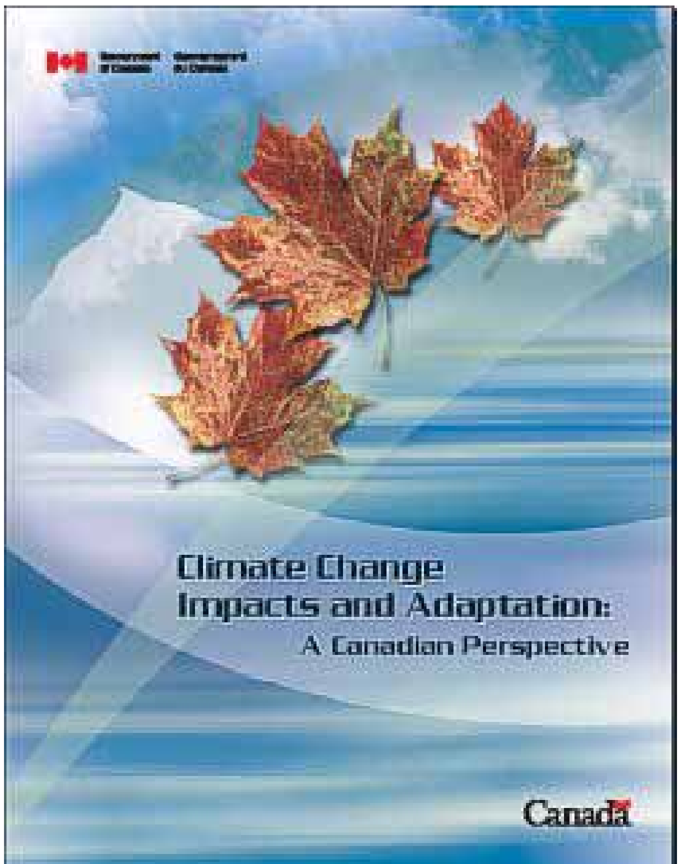


(from IPCC 2001 TAR, WG1 2001, p. 11).


Projected changes in global temperature:
global average 1856-1999 and projection estimates to 2100
Global average temperature in °centigrade
IPCC estimate
20°
19,8
19,6
19,4
19,2
19°
18,8
18,6
18,4
18,2
18°
17,8
17,6
17,4
17,2
17°
16,8
16,6
16,4
16,2
16°
15,8
15,6
15,4
15,2
15°
14,8
14,6
14,4
14,2
14°
High
Best (constant aerosol)
Best (increasing aerosol)
Low
1999
1850 1870 1890 1910 1930 1950 1970 1990 2010 2030 2050 2070 2090
1900
2000
2100
GRID Arendal
UNEP
Source : Temperatures 1856 - 1999: Climatic Research Unit, University at East Anglia, Norwich UK. Projections: IPCC report 95.

Impacts (IPCC 2001)

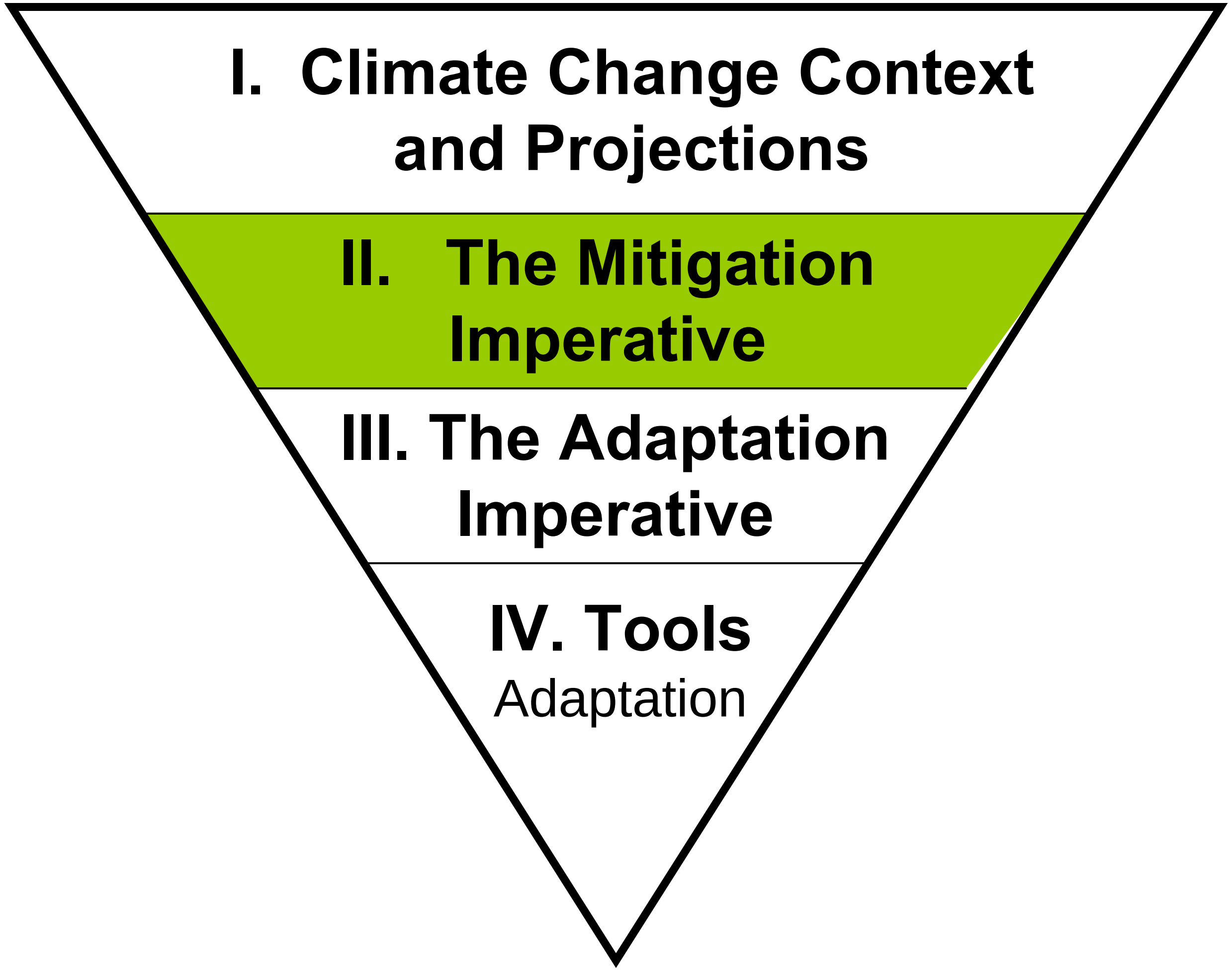
Climate Phenomena	*Climate Impact*
Higher Maximum Temperature (very likely)	• increased heat stress in livestock • increased risk of damage to a number of crops
Higher Minimum Temperatures (very likely)	• decreased risk of damage to a number of crops and increased risk to others • extended range of some pest and disease vectors
More Intense Precipitation Events (very likely)	• increased flood, landslide and mudslide damage • increased soil erosion
Increased Tropical Cyclone intensity (likely - over some areas)	• increased risks to human life, risk of infectious disease epidemics, many others • increase damage go coastal ecosystems such as coral reefs and mangroves
Increased Droughts and Floods associated with El Nino events (likely - over some areas)	• decreased agricultural and rangeland productivity in drought and flood-prone regions
Increased Asian Monsoon Variability (likely)	• increased flood and drought magnitude and damages



PARC
PRAIRIE ADAPTATION RESEARCH COLLABORATIVE

New national assessment is forthcoming

http://adaptation.nrcan.gc.ca/perspective_e.asp

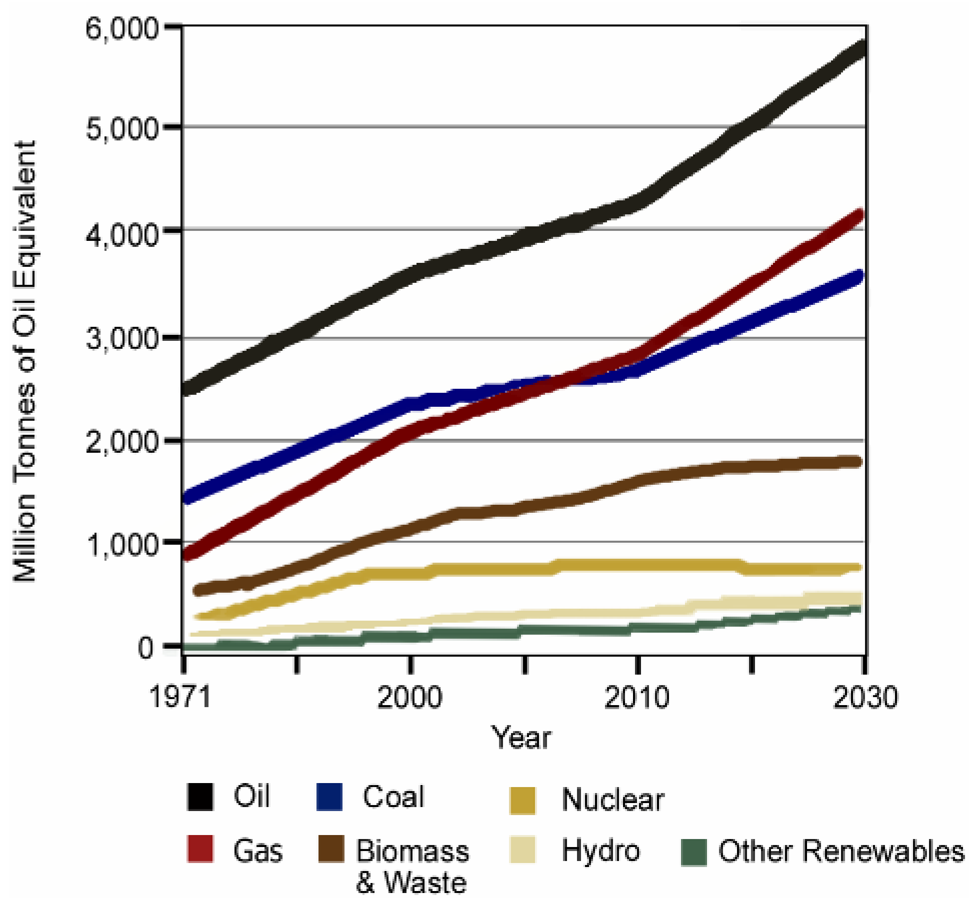

I. Climate Change Context and Projections
II. The Mitigation Imperative
III. The Adaptation Imperative
IV. Tools
Adaptation

Issues

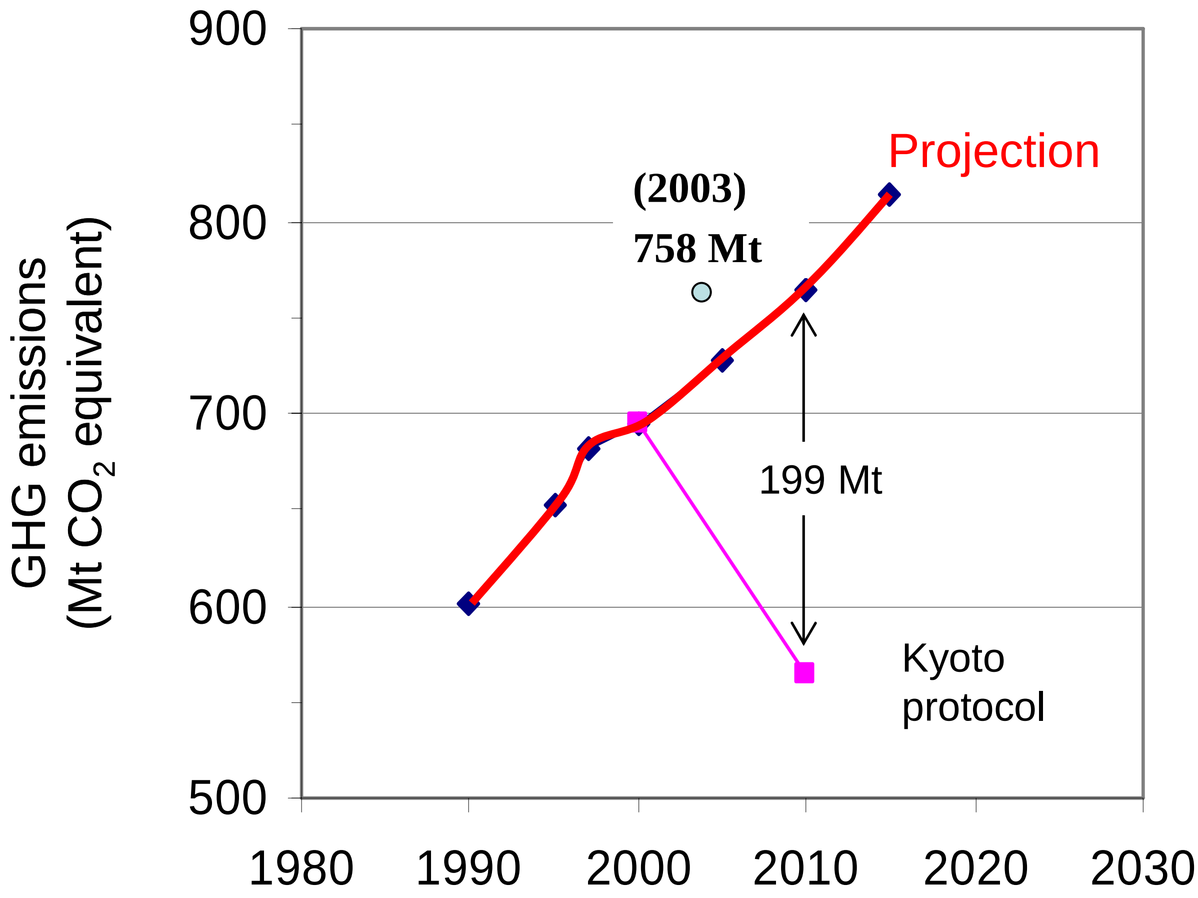
Developing world energy demand

- In 2030, total energy demand will be **66% greater** than today
- Fossil fuels accounted for 80% of world energy supply in 2002; they will account for 82% in 2030
- $16 trillion cumulative investment in infrastructure

World Primary Energy Demand
(International Energy Agency)



Canada's Mitigation Imperative



Source: Canada's Emissions Outlook: An Update. Analysis and Modelling Group, National Climate Change Process, Energy Policy Branch, Natural Resources Canada. December, 1999.

The Mitigation Imperative for Engineers

- **Energy Efficiency**
    - **Energy Efficiency**
        - **Energy Efficiency**

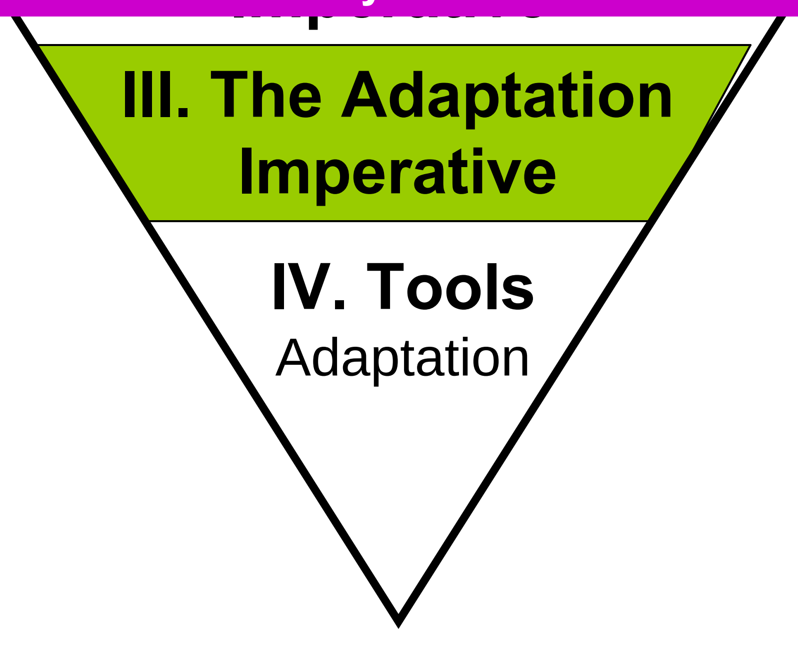
The Mitigation Imperative for Engineers

- **De-carbonize**
    - **De-carbonize**
        - **De-carbonize**


Gulf
Stream
Image © 2006 NASA
© 2006 Europa Technologies
©2005 Google

Experience has shown that a pathway to sustainable development cannot be charted in advance. Rather, the pathway must be navigated through processes of learning and adaptation.

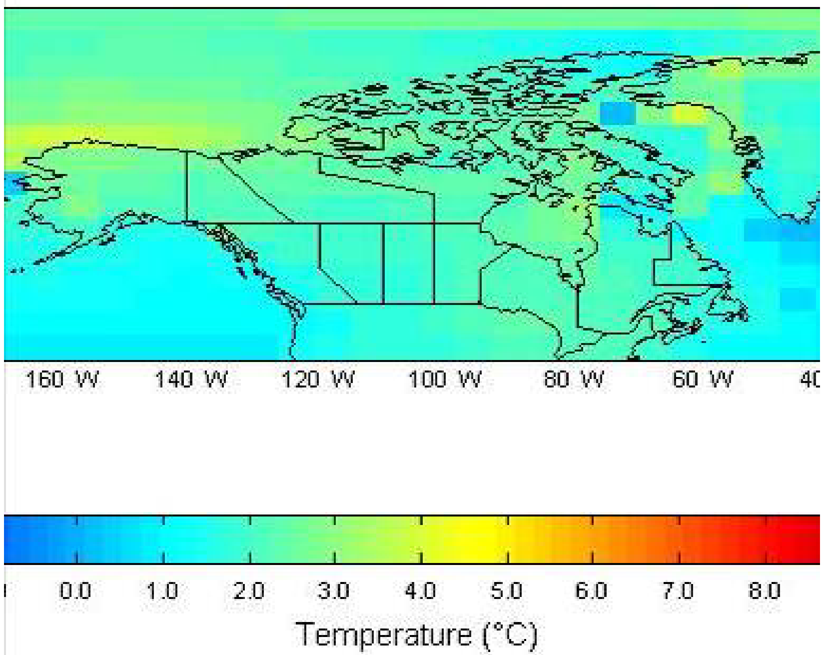
National Academy of Science 1999. Our Common Journey: A Transition Toward Sustainability.



Temperature Projections for Canada in the 2020s and 2080s.

2020s

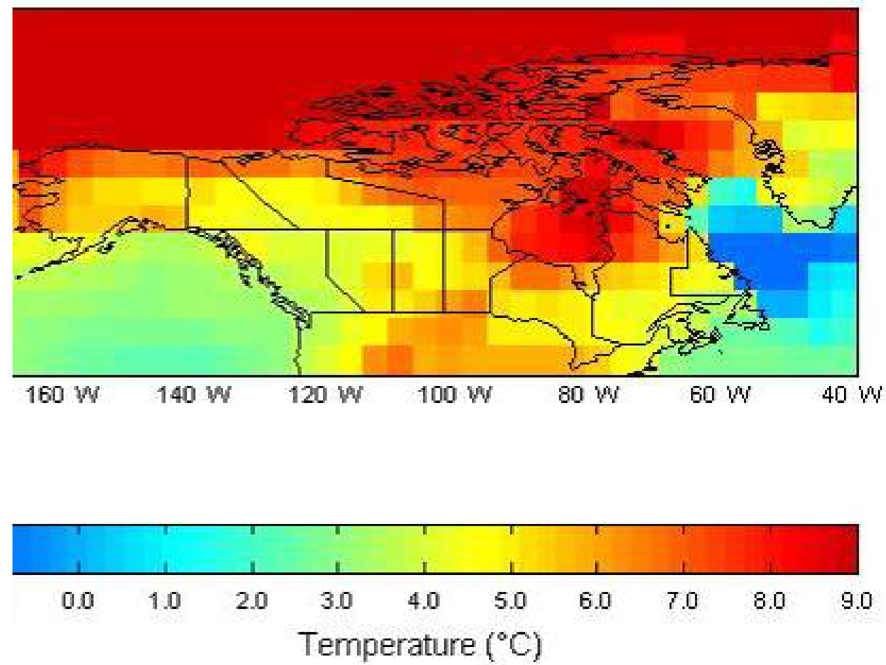
Average Projection: Model CSIROMK2b A1,
Emissions Scenario SRES A1



i) Temperature Change (degree C)

2080s

Average Projection: Model CGCM1 ga2,
Emissions Scenario IS92a



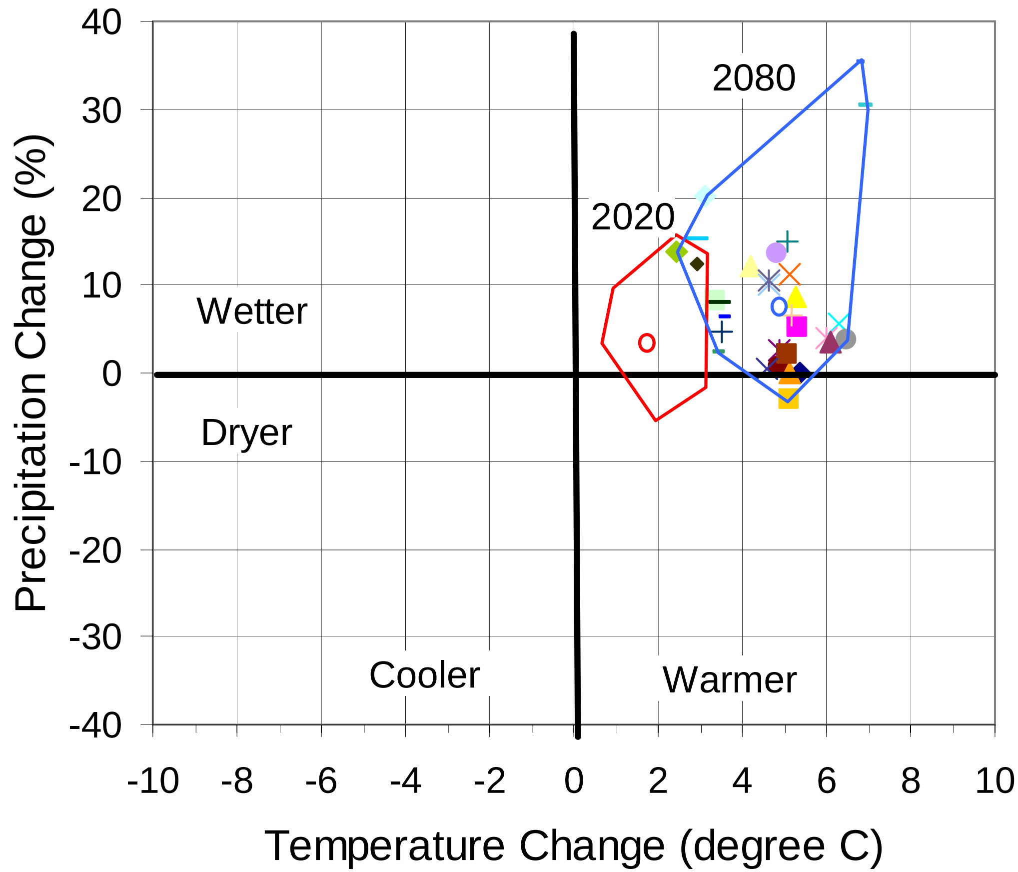
i) Temperature Change (degree C)

Color Grid Maps from The Canadian Climate Impacts Scenario (CCIS) website - University of Victoria, Victoria, B.C., Canada < http://www.cics.uvic.ca/scenarios/> (accessed 2003)

Global Climate Model Projections for Central Manitoba

Precipitation & Temperature

Multiple emissions scenarios, multiple models

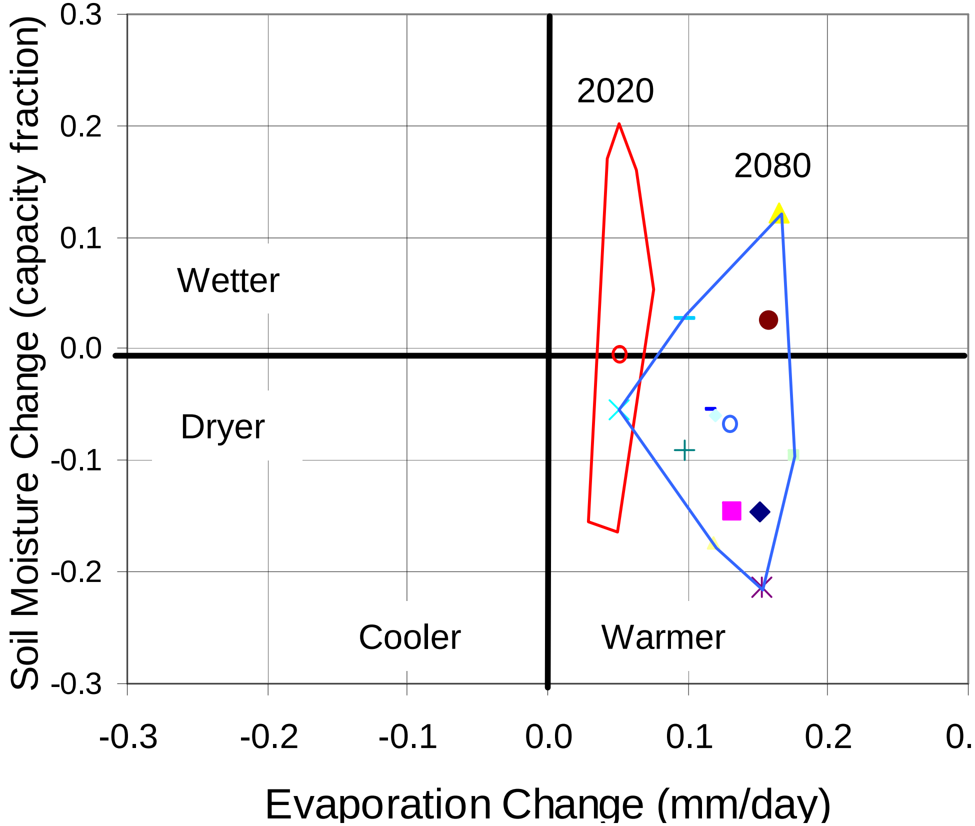


Data compiled from The Canadian Climate Impacts Scenario (CCIS) website - University of Victoria, Victoria, B.C., Canada < http://www.cics.uvic.ca/scenarios/ > (accessed 2003)

Global Climate Model Projections for Central Manitoba

Soil moisture & evaporation

Multiple emissions scenarios, multiple models



Data compiled from The Canadian Climate Impacts Scenario (CCIS) website - University of Victoria, Victoria, B.C., Canada < http://www.cics.uvic.ca/scenarios/> (accessed 2003)

Projected Climate Variability

- Experts in Canada note that:
  - 1-in-40 year precipitation event could be decadal experience by 2090s
  - dry spell with 50-year return could have a 20-year return
  - 1-in-10 cold extreme may occur 1-in-80 years by 2090s
  - 1-in-80 year hot temperature event may occur 1-in-10 years by 2050s

Hengeveld, H.G. 2000. Projections of Canada's Climate Future: A Discussion of Recent Simulations with the Canadian Global Climate Model. Meteorological Service of Canada, Environment Canada. CCD 00-01. pp. 19.

Thames Water Company - UK

- Thames Water ***required to take a view on the likely impacts of climate change in deriving the Water Resources Plan*** submitted to the Environment Agency in April 2004.

- This looks at water resources strategy to 2030 and as such, is an ***input to the Strategic Business Plan***

- On the supply side, GCMs ***used to re-evaluate Deployable Output for the 2020s***
  - hydromeoterological time series have been perturbed to account for climate change to 2030

Northwest Power Planning Council - US

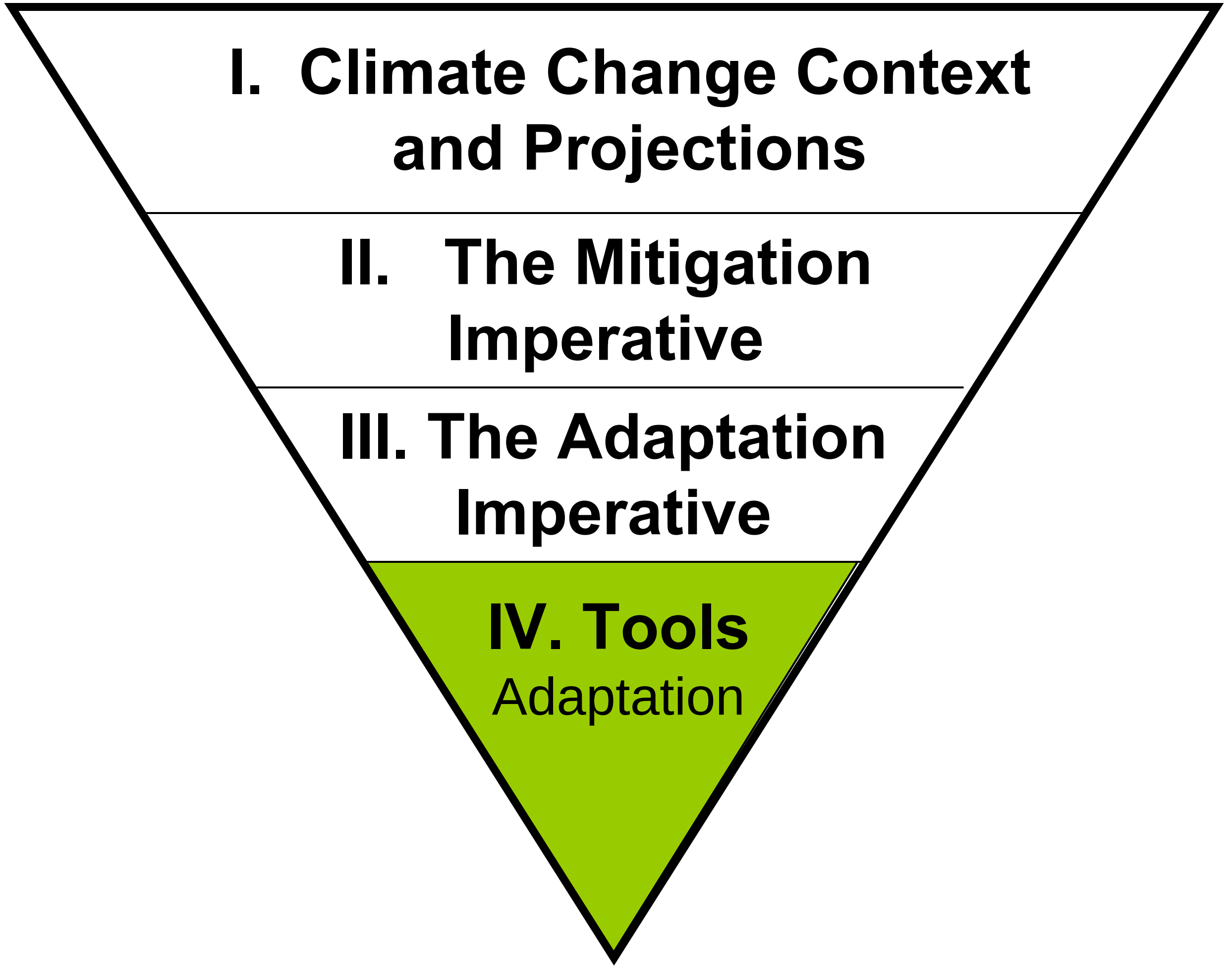
- Draft 5th Power Plan (2004) included an assessment of the effects of climate change on its hydroelectric system
- Comprehensive assessment of the effects on:
  - River flows
  - Electricity demand
  - Changes to generation

Table N-2: Summary of Energy and Cost Impacts

	Change in Annual Energy (average megawatts)		Annual Benefits (Millions)	
	2020	2040	2020	2040
HC (wet)	1982	333	777	169
COMP	164	-477	74	-155
MPI (dry)	-664	-2033	-231	-730

Where is the Adaptation Imperative for Engineers?

- Any engineering project influenced by climate conditions:
  - structures (via snow and wind loads)
  - drainage and flood protection systems
  - water supply systems,
  - wastewater treatment plants,
  - hydropower,
  - Others…..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Determinants of adaptive capacity

(modified from Smit et al., 2001).

Determinant	Explanation
Economic resources	Greater economic resources increase adaptive capacity
Technology	Lack of technology limits range of potential adaptation options
Information and skills	Greater access to information increases likelihood of timely and appropriate adaptation
Infrastructure	Greater variety of infrastructure can enhance adaptive capacity, since it provides more options
Institutions and networks	Well-developed social institutions help increase adaptive capacity
Equity	Equitable distribution of resources increases adaptive capacity Both availability of, and entitlement to, resources is important

Smit, B., Pilifosova, O., Burton I., Challenger B., Huq S., Klein R.J.T. and Yohe, G. (2001): Adaptation to climate change in the context of sustainable development and equity; in Climate Change 2001: Impacts, Adaptation and Vulnerability, (ed.) J.J. McCarthy, O.F. Canziani, N.A.

Climate Projections

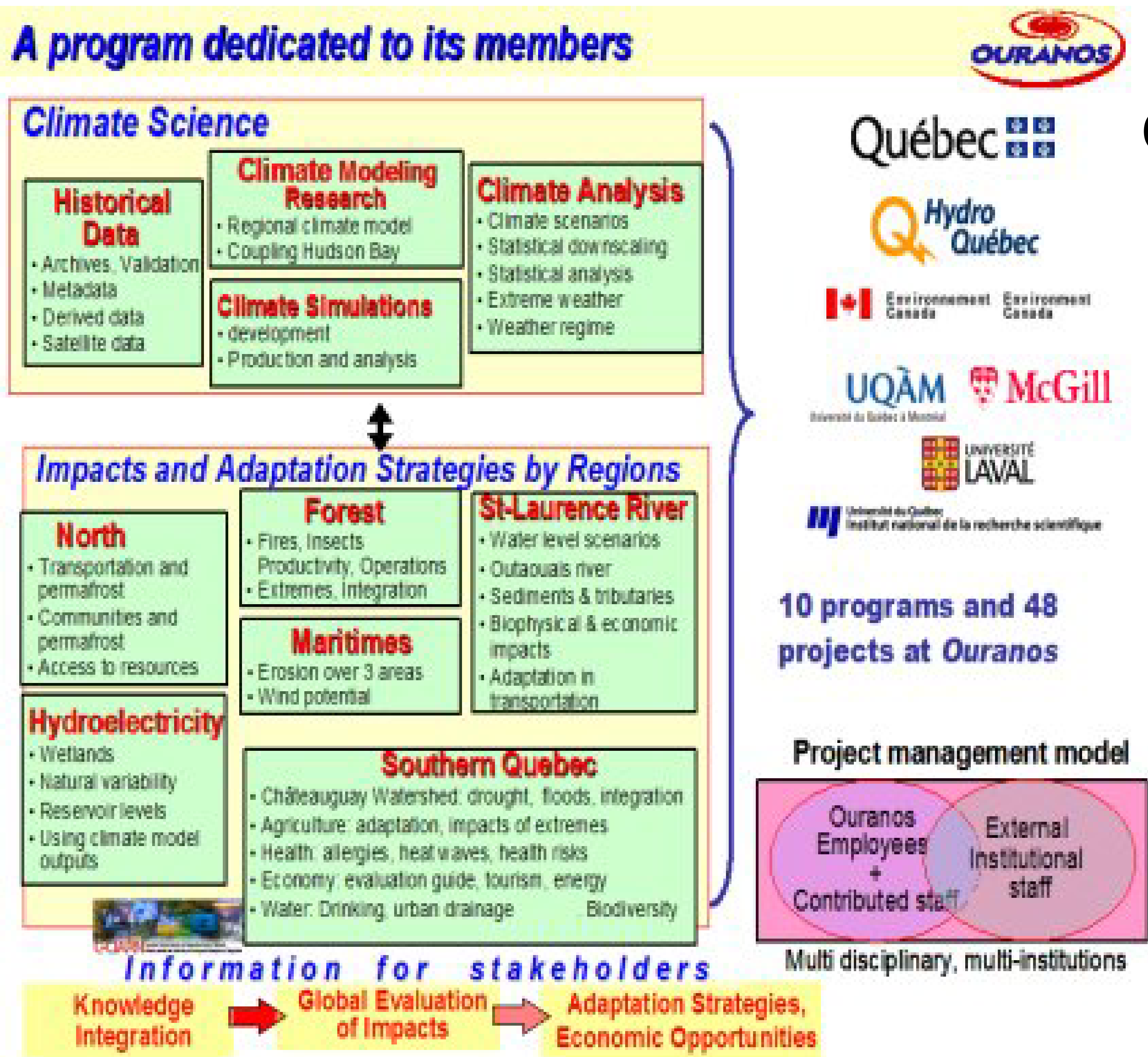
- Ouranos Consortium
  - **http://www.ouranos.ca/**
- Canadian Climate Impacts Scenarios Project
  - **http://www.cics.uvic.ca/scenarios/index.cgi**
- Prairie Adaptation Research Collaborative (PARC)
  - **http://www.parc.ca/datasets.htm**

Partnering to Understand Hydrologic Impacts of Climate Change

- Common approach observed…..Interaction or affiliation with a scientific research organization with capacity for climate model and/or hydrologic projections

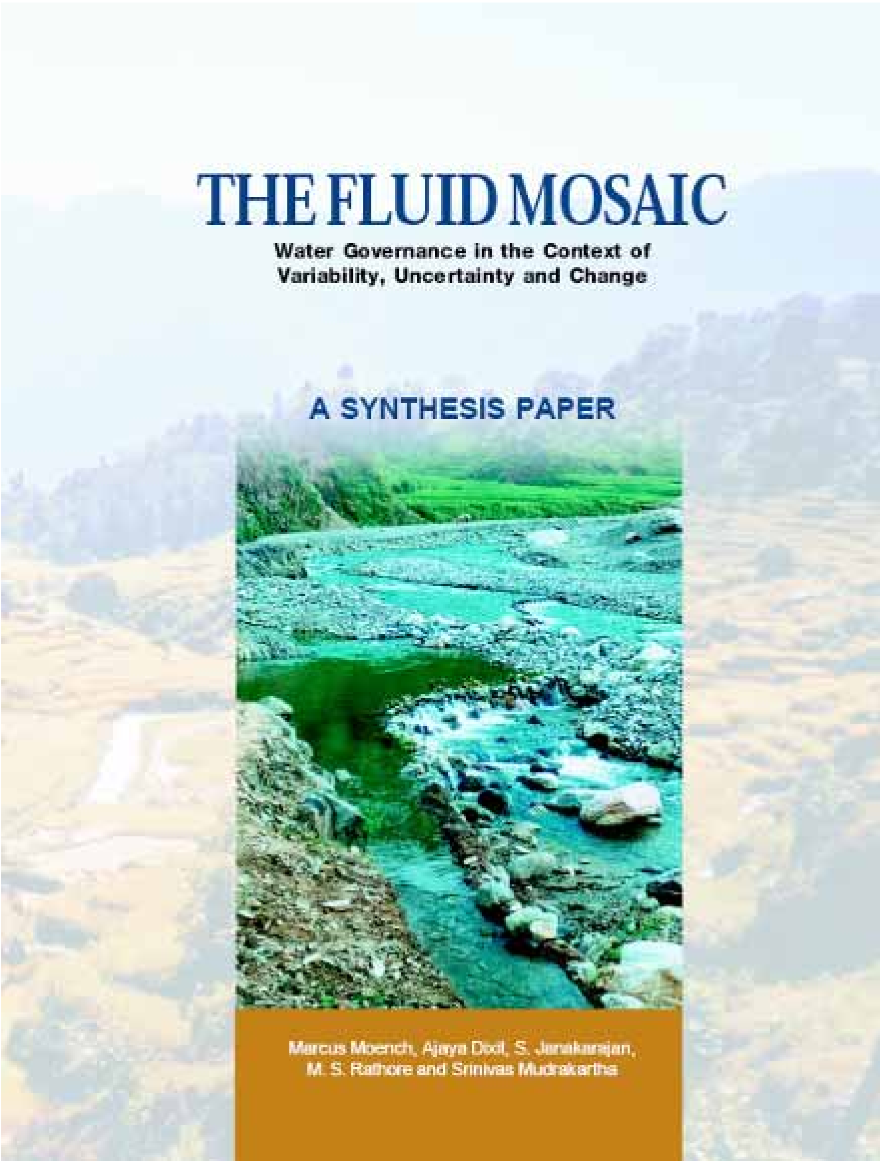
Region	**Affiliated Research Organization**
United Kingdom	UK Water Industry Research Ltd.
U.S. Pacific Northwest	University of Washington, Department of Civil Engineering's Climate Impacts Group
Quebec	Ouranos Consortium
Sweden	Swedish Regional Climate Modelling Programme
Nordic Counties	Climate, Water and Energy Research Project

Ouranos Consortium



http://www.ouranos.ca/

The International Development Research Centre - Canada



"When situations are characterized by variability, uncertainty and change, conventional planning scenarios provide little guidance regarding future needs and conditions."

"…clear need for frameworks that are "adaptive" - that reflect uncertainties and can respond and adapt as contexts change or unforeseen problems emerge."

"Specific solutions are less important than the existence of processes and frameworks that enable solutions to be identified and implemented as specific constraints and contexts change."

[Moench et al, 2003]

Scenario Planning

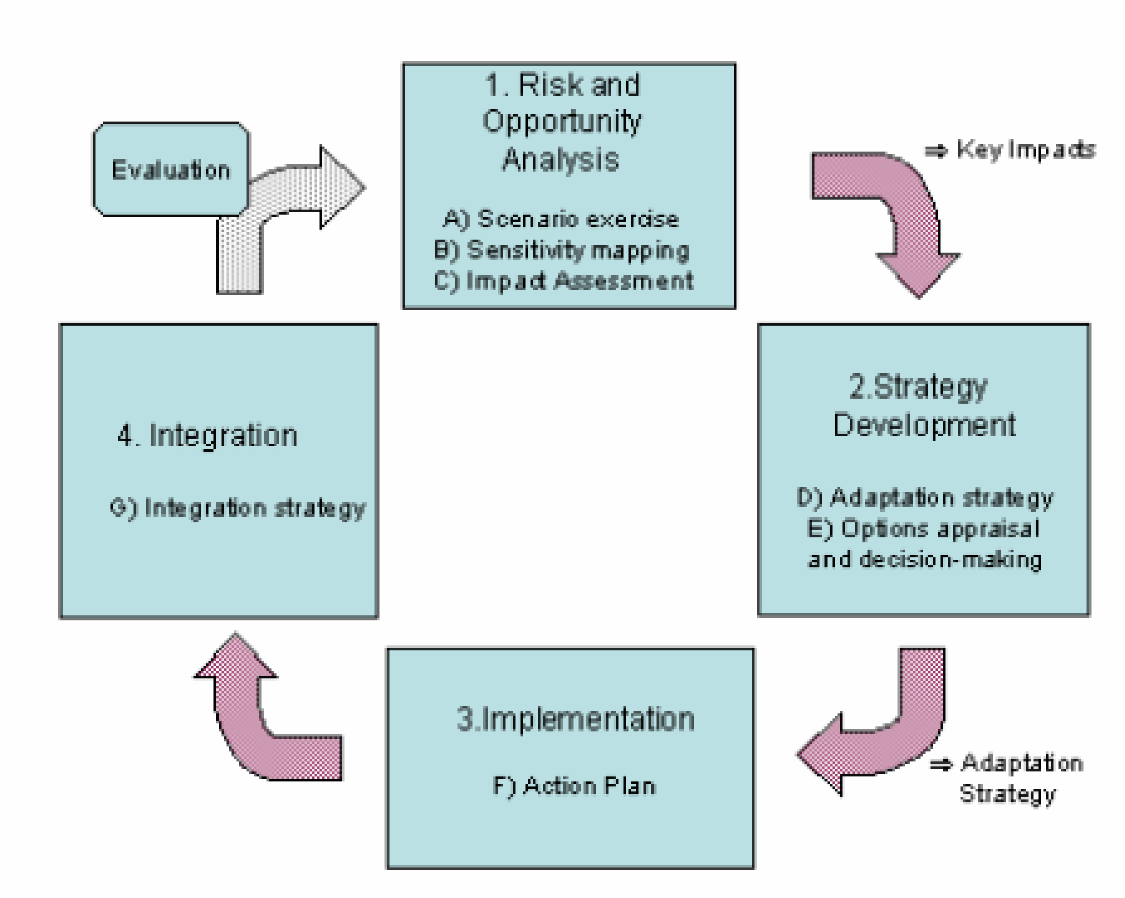
don't need to wait for perfect information

- organizational learning and adaptive management mechanism
- Pioneered by Royal/Dutch Shell in the 1970s in response to anticipated future fluctuations in oil prices
  - to "encourage people to look outward, using stories of the future to surface assumptions about business and political forces of the present"
- Shell learned that
  - "by helping managers clarify their assumptions, discover internal contradictions in those assumptions, and think through new strategies based on new assumptions, they ***gained a unique source of competitive advantage*** (Senge 1990)"

Senge, P.M., Kleiner, A., Roberts, C., Ross, R.B. and Smith, B.J. 1994. The Fifth Discipline Fieldbook: Strategies and Tools for Building a Learning Organization. New York: Doubleday.

Adaptation Framework for Businesses

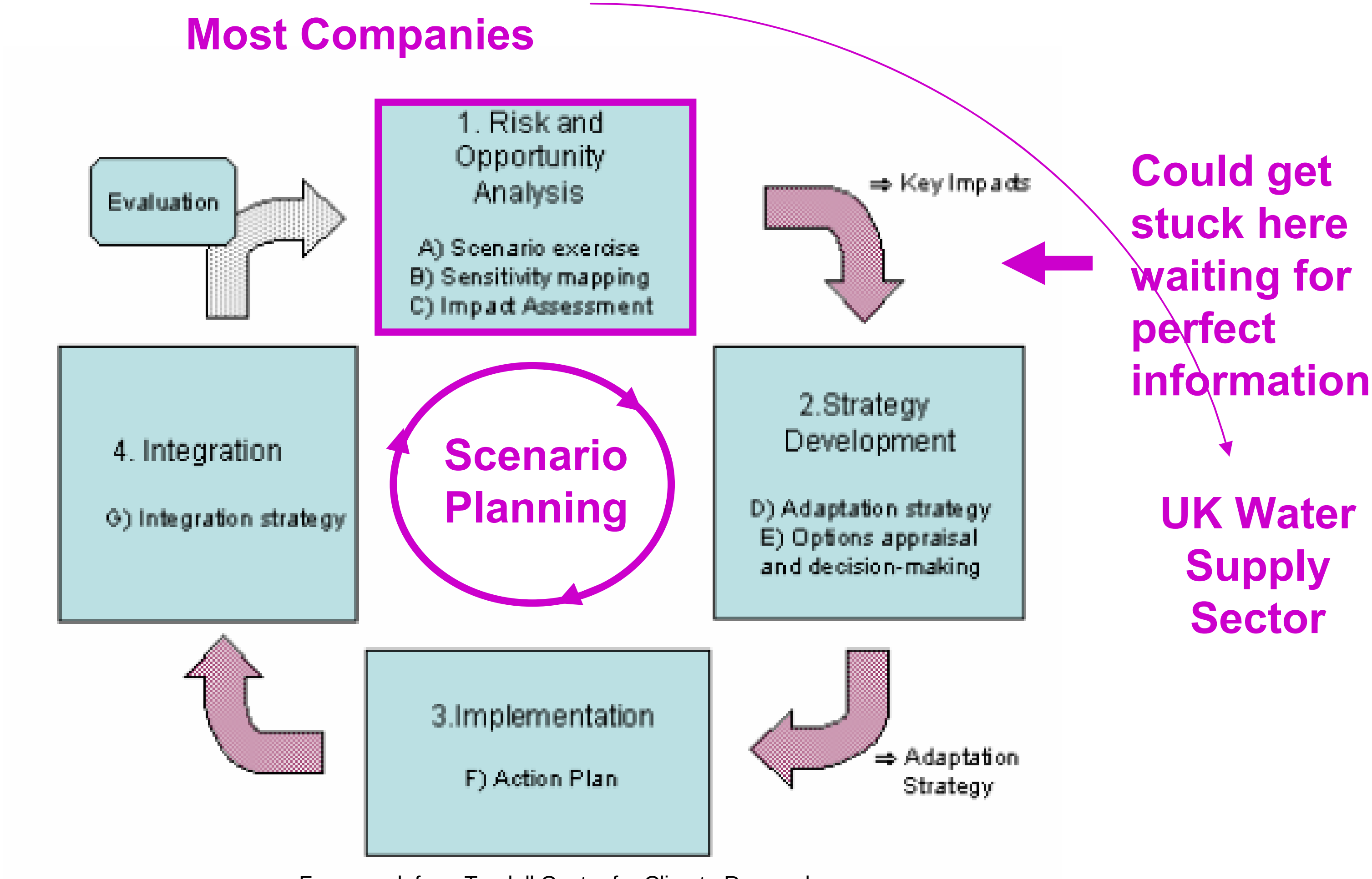
Tyndall Centre for Climate Research



- To help businesses organize efforts toward adaptation
- Intuitive steps
- Towards specific adaptation strategies for key vulnerabilities

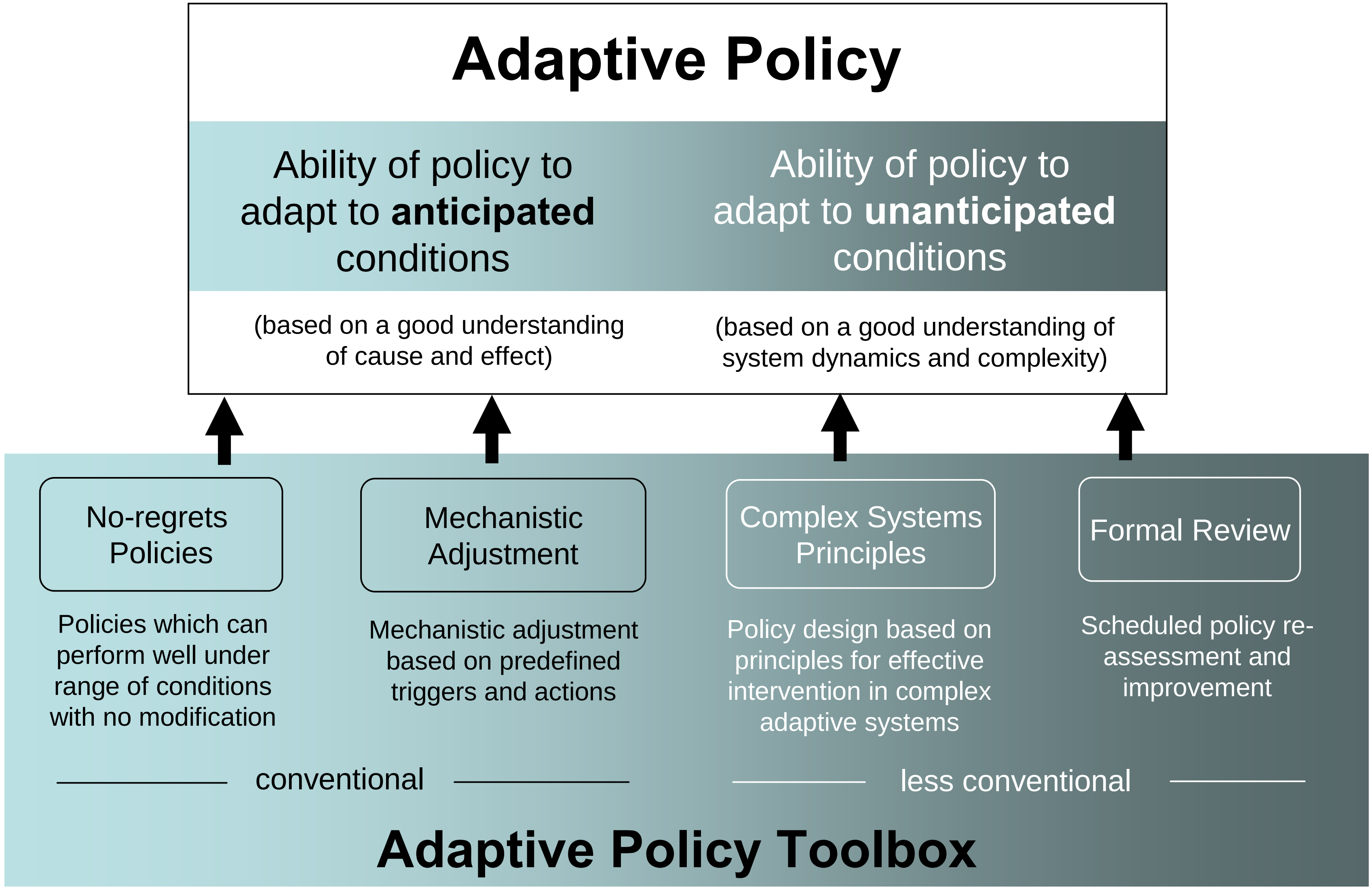
Available at http://www.tyndall.ac.uk/research/theme3/final_reports/it1_23.pdf.

State of Adaptation in the Sector



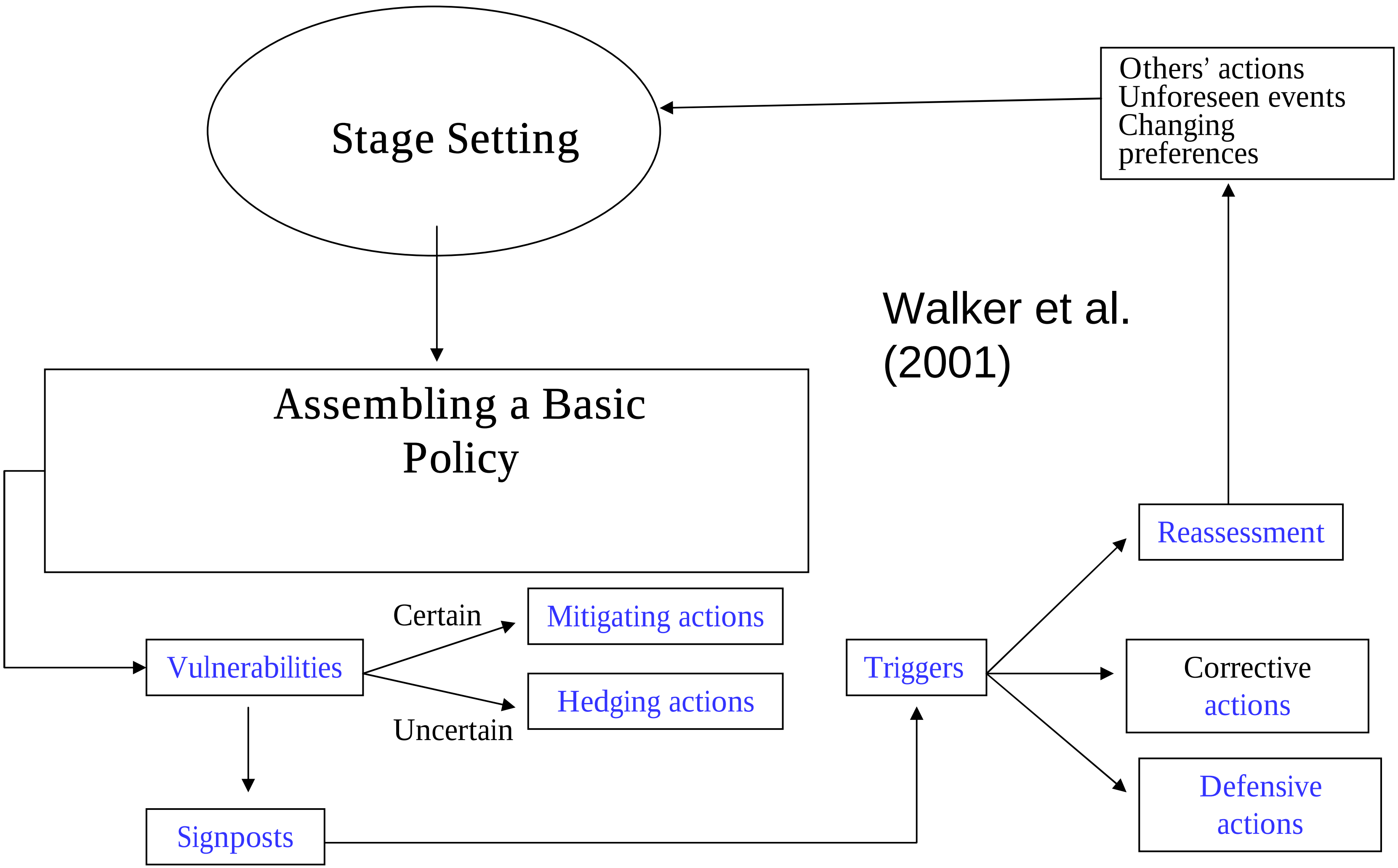
Framework from Tyndall Centre for Climate Research

Adaptive Policymaking



http://www.iisd.org/climate/canada/adaptive_policy.asp

Civil Aviation Adaptive Policy and Management in the Netherlands



Walker et al. (2001)

from Walker, W.E., S.A. Rahman, and J. Cave 2001. Adaptive policies, policy analysis, and policy-making. European Journal of Operational Research 128: 282-289.

Complex Adaptive Systems

The reality of human interactions with economy and the environment

- ***many individual, self-organizing elements*** capable of responding to others and to their environment.
- ***network of relationships*** and interactions, in which the whole is very much more that the sum of the parts.
- A ***change in any part*** of the system, even in a single element, produces reactions and ***changes in associated elements*** and the environment
- system ***cannot be predicted with complete*** *accuracy*
- system is ***always responding and adapting to changes and the actions of individuals***.
- At the same time, the ***tendency of elements within the system to organize themselves offers opportunities*** to bring out changes that benefit the system."

(Glouberman et al. 2003)

Principles for Effective Policy and Management in integrated socio-economic and ecologic systems

- ***Gather Information*** – Understand local conditions, strengths and assets
- ***Respect History*** – "Adaptive systems are shaped by their past and a knowledge of this history may suggest constraints on and opportunities on what can be done in the future."
- ***Consider Interaction*** – Understand interactions with the natural, built and social environment.
- ***Promote Variation*** – "Introducing small-scale interventions for the same problem offers greater hope of finding effective solutions." "It is critical to understand and accept that many interventions will fail. Such failures should not be viewed as failures of the overall way of understanding the system – this is simply a feature of how one develops successful interventions in complex adaptive systems."
- ***Conduct Selection*** – In complex adaptive systems possible solutions undergo selection by the system. It is therefore important to include "evaluating performance of potential solutions, and selecting the best candidates for further support and development."
- ***Fine-tune Process*** – "In complex systems, which change over time and respond dynamically to outside forces, it is necessary to constantly refine interventions through a continual process of variation and selection."
- ***Encourage self-organization*** – "Complex adaptive systems often spontaneously generate solutions to problems without external input or formally organized interventions." "This self-organizing capacity is a free good that can be valuable in producing innovative and novel approaches to problems."

(from Glouberman *et al*. 2003)

In Conclusion

I. Climate Change Context

the debate is over

II. The Mitigation Imperative

energy efficiency, de-carbonization

III. The Adaptation *Imperative*

climate past ≠ climate future

IV. Tools for Adaptation

Do exist

Thank You!

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www.iisd.org

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Vision:
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Mission:
To champion innovation, enabling societies to live sustainably