



Energy, Water and Land Use

UCC501 Sustainable Energy, Fall 2014

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Contents

- Energy, water, and land use
- Cycles
 - Water
 - Carbon
 - Nitrogen
 - Climate
- Land use
- Ocean use

Linking Energy, Water and Land Use

- Impacts on sustainability
 - Energy and its increasing consumption
 - Fresh water
 - Pollution
 - Depletion of important resources for future generations
 - Food supplies
 - Health
 - Biodiversity
 - Societal ability
 - Economics
- Interactions beyond energy: water, land, waste, etc.
- Cooperation across professional lines

Changing Energy Technologies and Usages

- How we live...
 - Finite planet and resources
 - Growth of human consumption
- Changes in global and regional systems
- Pollution
 - Agricultural and industrial activities
 - Water
 - GHGs
- Effect on Earth's ecosystems

Climate Models

- Major biophysical earth systems
 - Land
 - Fresh water
 - Oceans
 - Atmosphere
- Impacts by human activities
 - Agriculture
 - Energy production and distribution
 - Industry
 - Transportation
 - Residential and commercial buildings

Biogeochemical Cycles

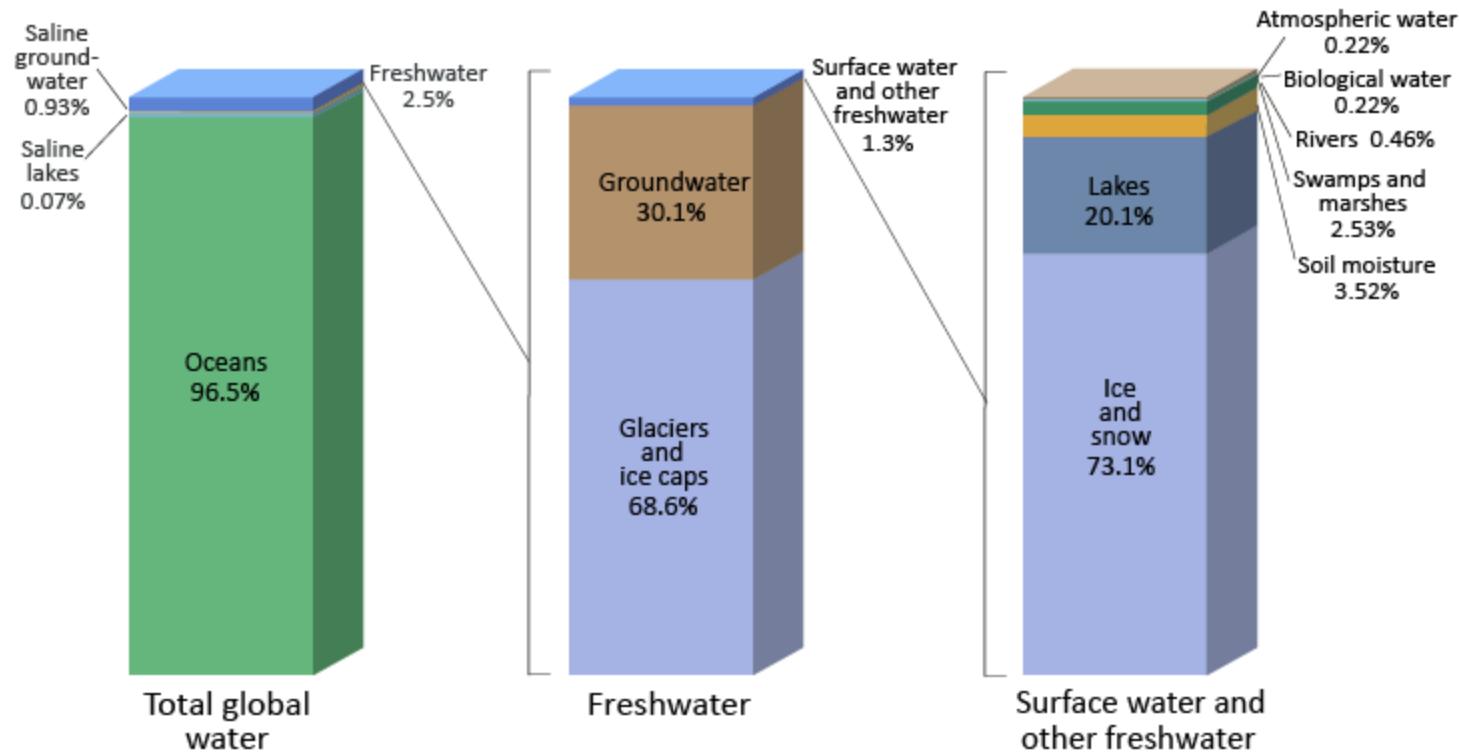
- Interchange of chemicals across physical systems
 - Oxygen
 - Hydrogen
 - Carbon
 - Nitrogen
- Cycles
 - Water
 - Carbon
 - Nitrogen
 - Climate

UN Millennium Summit 2000

- Program of action with specific targets by **2015**
 - Eradicate extreme poverty and hunger
 - Achieve universal primary education
 - Promote gender equality; empower women
 - Reduce child mortality
 - Improve maternal health
 - Combat HIV/AIDS, malaria, and other diseases
 - Ensure environmental sustainability
 - Develop a global partnership for development
- These goals depend on equitable access of people to:
 - Affordable clean water
 - Fertile land, and...
Energy!

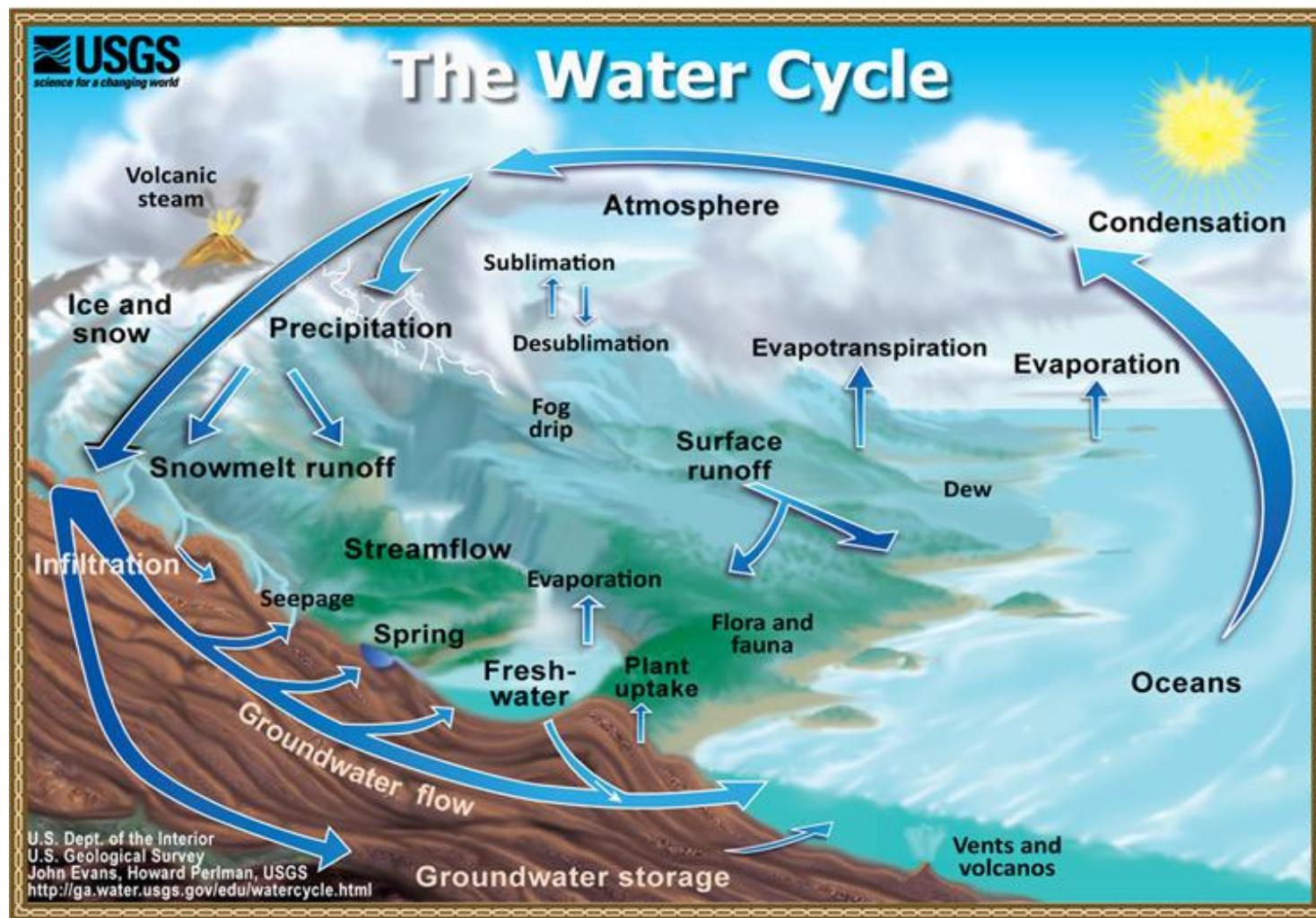
Water Cycle

Distribution of Earth's Water



Source: Igor Shiklomanov's chapter "World fresh water resources" in Peter H. Gleick (editor), 1993, Water in Crisis: A Guide to the World's Fresh Water Resources.

Water Cycle



Water Cycle

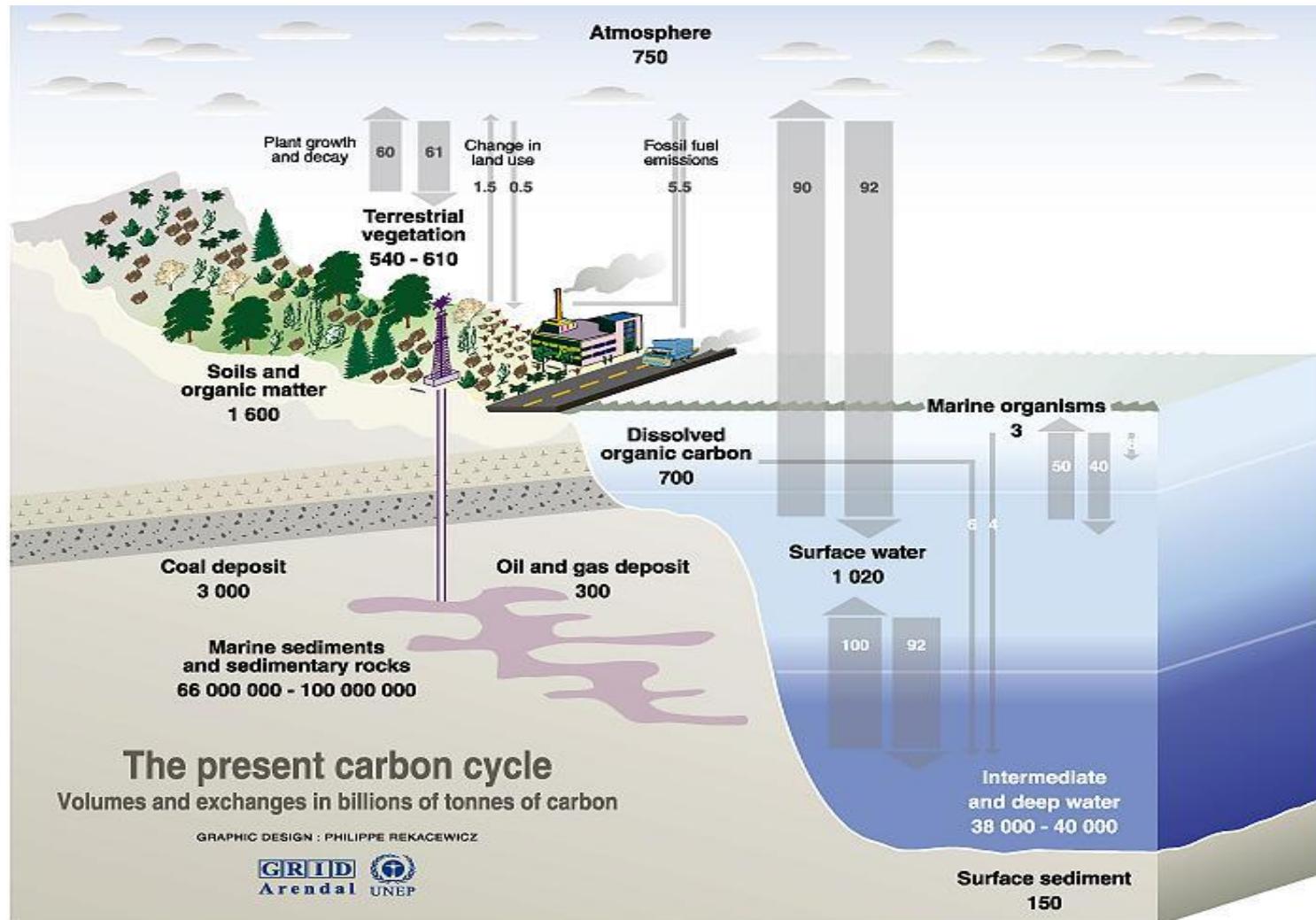
Use of water:

- Hydropower
- Heat sink for energy conversion
- Coal mining and hydrocarbon extraction
- Desalination
- Agriculture

Water issues

- Political instabilities
- Limiting factor for development
- Climate change

Carbon Cycle



Sources: Center for climatic research, Institute for environmental studies, university of Wisconsin at Madison; Okanagan university college in Canada, Department of geography; World Watch, November-December 1998; Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge press university, 1996.

Carbon Cycle

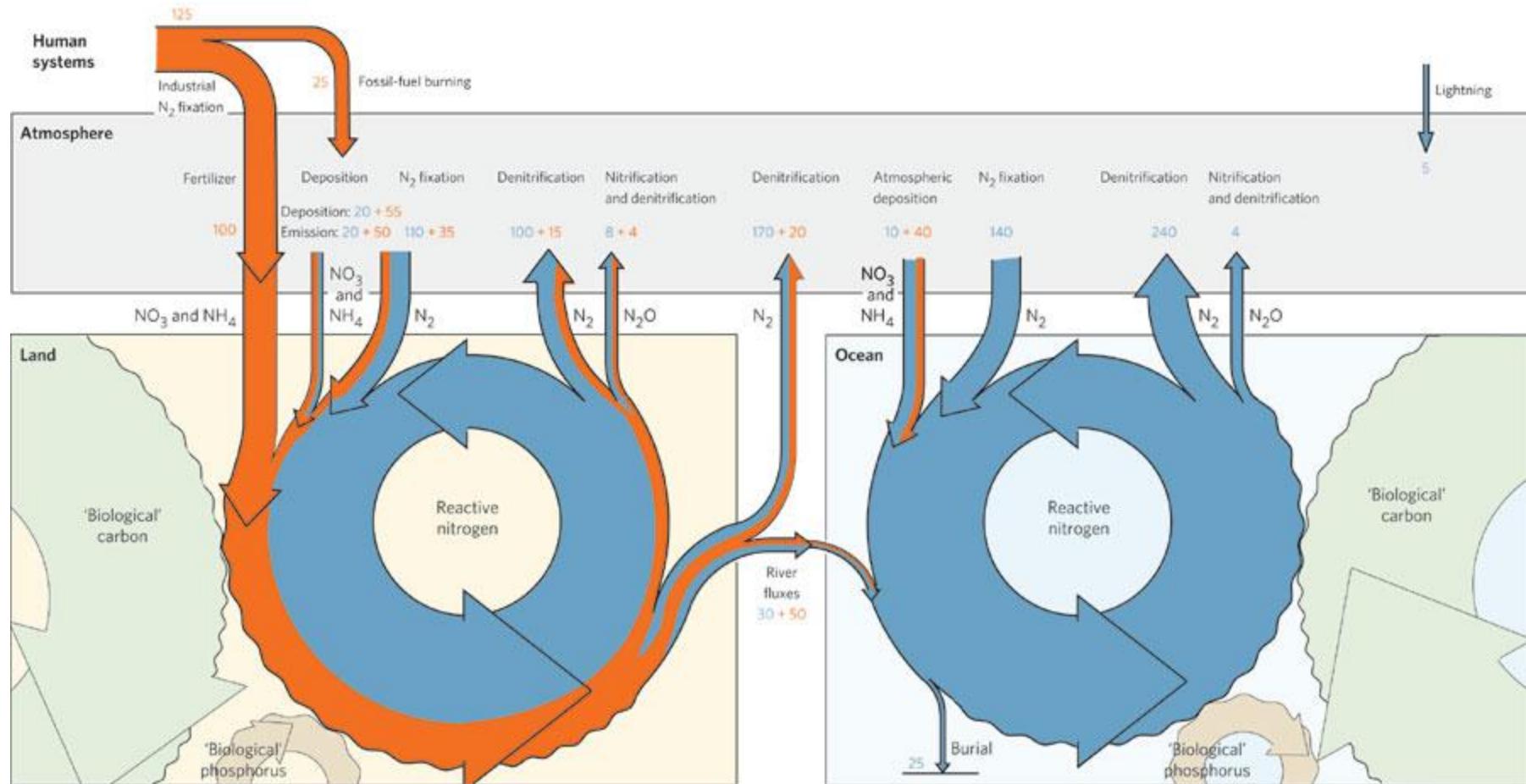
- Understanding the cycling of carbon
 - Life-cycle impacts of alternative energy
 - Interaction with the oceans
- Production of biomass
- Carbon capture and storage (CCS)
 - Public acceptance
 - Economic viability

Nitrogen Cycle

- Gaseous nitrogen (N_2) makes up about 78% of the atmosphere
 - “Fixation” to ammonium or nitrate ions makes nitrogen available for further biological processes
 - Natural processes for “nitrogen fixation” are:
 - › Lightning
 - › Nitrogen fixing bacteria

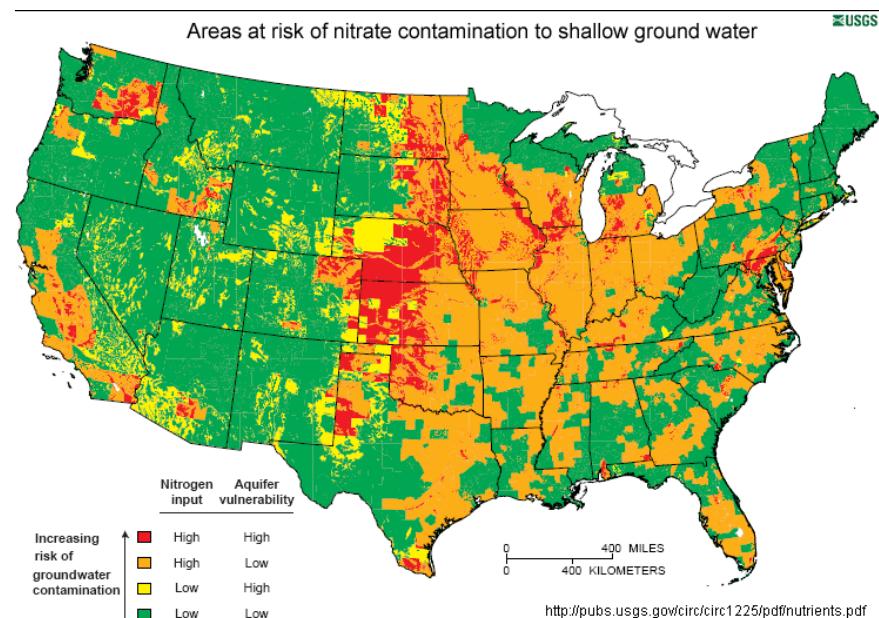
Nitrogen in	Giga-tons (GT)
Atmosphere	3.9 million
Oceans	23 thousand
Soils	460
Land plants	14
Land animals	0.2

Nitrogen Cycle

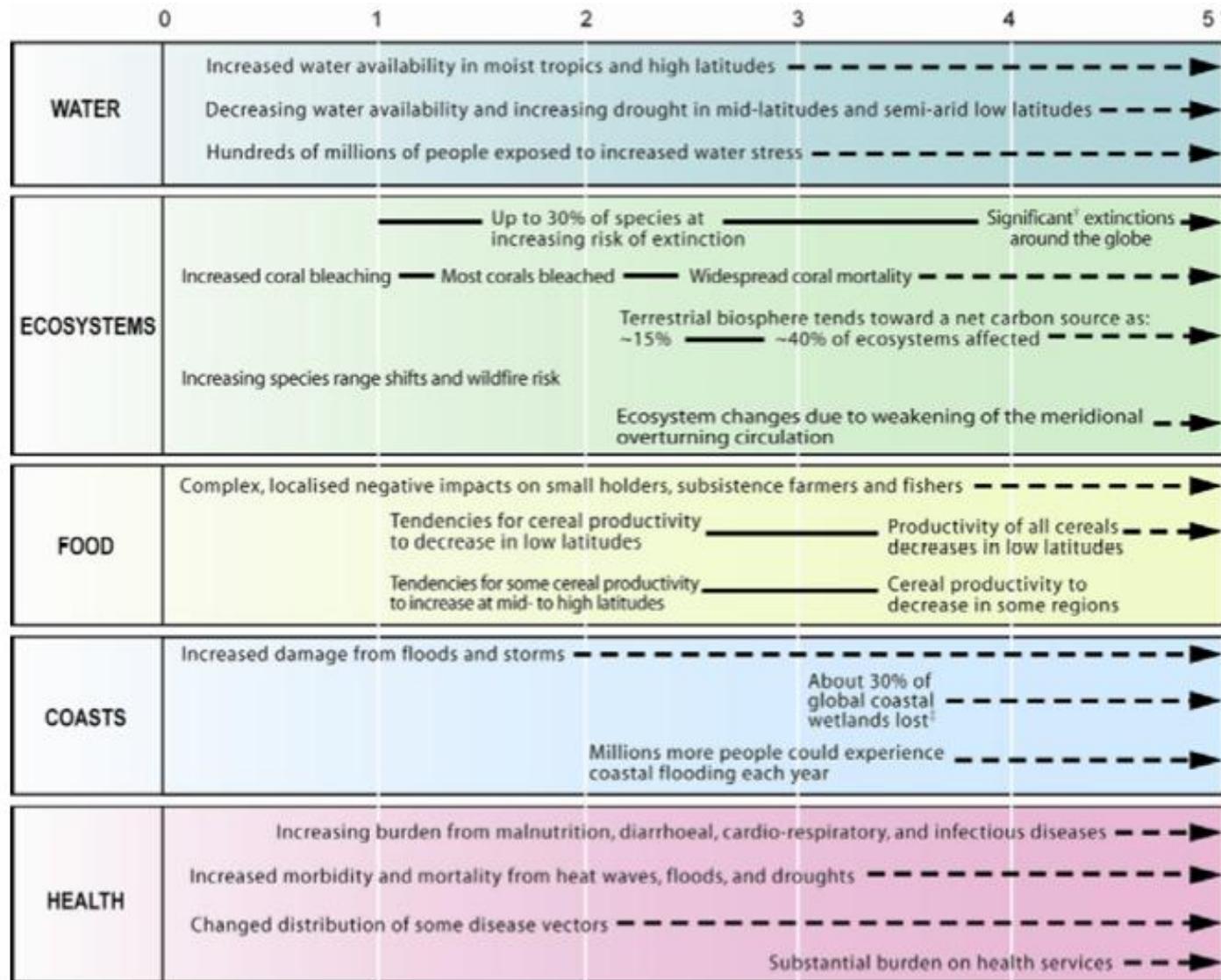


Nitrogen Cycle

- Use of fertilizers
- Excess nitrogen can cause overstimulation of growth of aquatic plants and algae
 - Use-up dissolved oxygen
 - Block light to deeper waters
 - Eutrophication



Climate Cycle

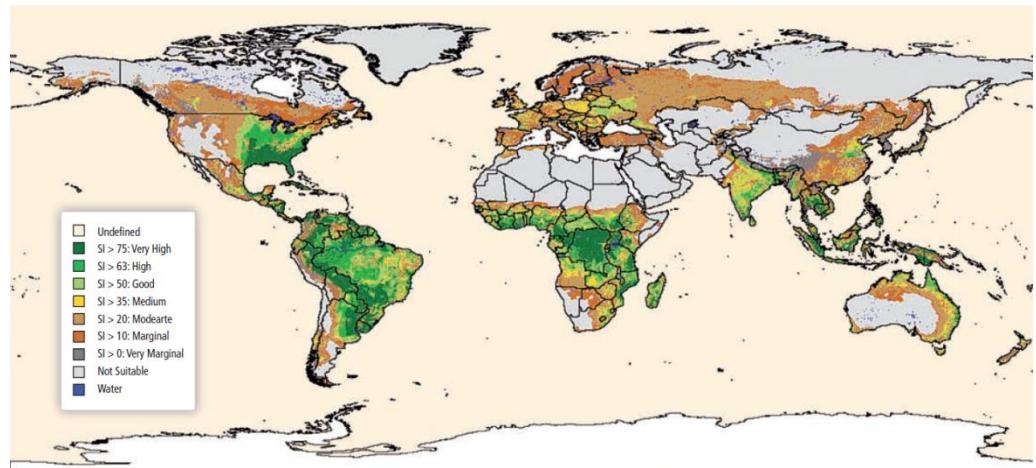


Climate Cycle

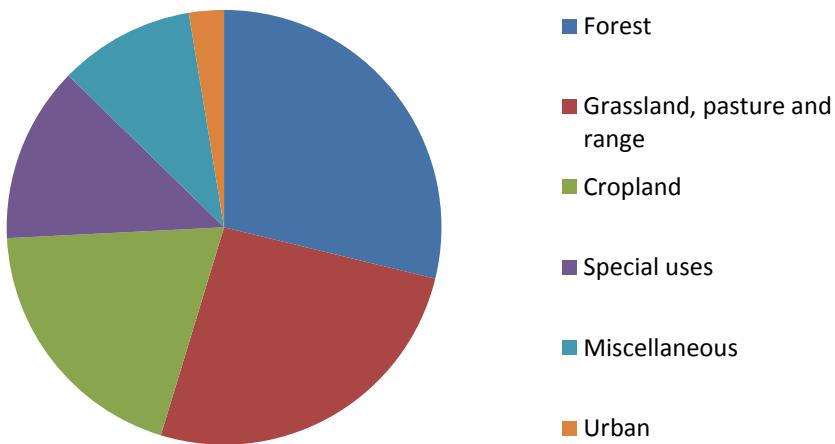
- A flexible, comprehensive, and integrative climate change science enterprise is needed
- Research (interagency program)
 - Improve understanding of human-environment systems
 - Effective responses to climate change
 - Tools and approaches to improve both understanding and responses
- Evolving policies should be treated as “best guesses”
 - More knowledge, data, mitigation initiatives → better guesses
- Diplomacy and cooperation

Land Use

- 30% of the earth's surface is land, 70% covered by water



Major Uses of Land US 2002



Land Use

- Energy impacts on land-use
 - Extraction
 - Large areas for transportation, transmission, and distribution system infrastructures
 - Emissions from energy conversion processes (e.g. acid rain)
 - Subsurface, water systems and habitats
- Use of land is governed by economics, policy and regulations
 - Do market forces influence the “best” choice of use for a particular land parcel?
Ideal markets rarely exist; special interests; value of externalities...

Land Use Issues

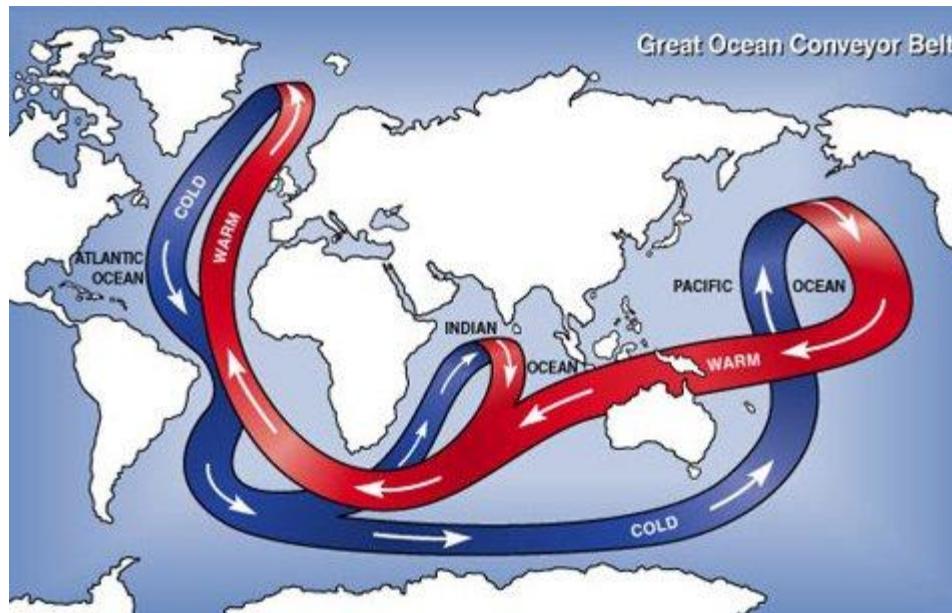
- Agriculture
 - Energy consumption in mechanization, economies of scale, irrigation, use of fertilizers and pesticides
- Forest management
 - Aging
 - Carbon storage
- Deforestation
- Erosion
- Bioenergy production

Monitoring Land Use Changes

- In 2002, the Group on Earth Observations (GEO) was created
 - Voluntary partnership of governments and organizations
- Global Earth Observing System of Systems (GEOSS)
 - 10-year implementation plan (2005 – 2015)
 - Societal benefit areas (Disasters, Health, Energy, Climate, Water, Weather, Ecosystems, Agriculture, and Biodiversity)
- NASA – Land Cover / Land-Use Change Program
 - GIS
- Surface Water Ocean Topography (US and France)

Ocean Use Issues

- Physical characteristics of oceans
 - Average salinity: 3.5% by weight
 - Reservoir of dissolved atmospheric gases
 - Ocean circulations: pathways for the transport of heat, fresh water, and dissolved gases; time scales



Ocean Use Issues

- Food chains
 - Phytoplankton, zooplankton
 - Ocean acidification
- Fisheries and aquaculture
 - Fish is the primary source of protein for nearly a billion people
 - Employment for 200 million
 - Overexploitation of stocks
- Monitoring ocean changes
 - Very poor understanding, much research needed

Implications for Sustainable Energy

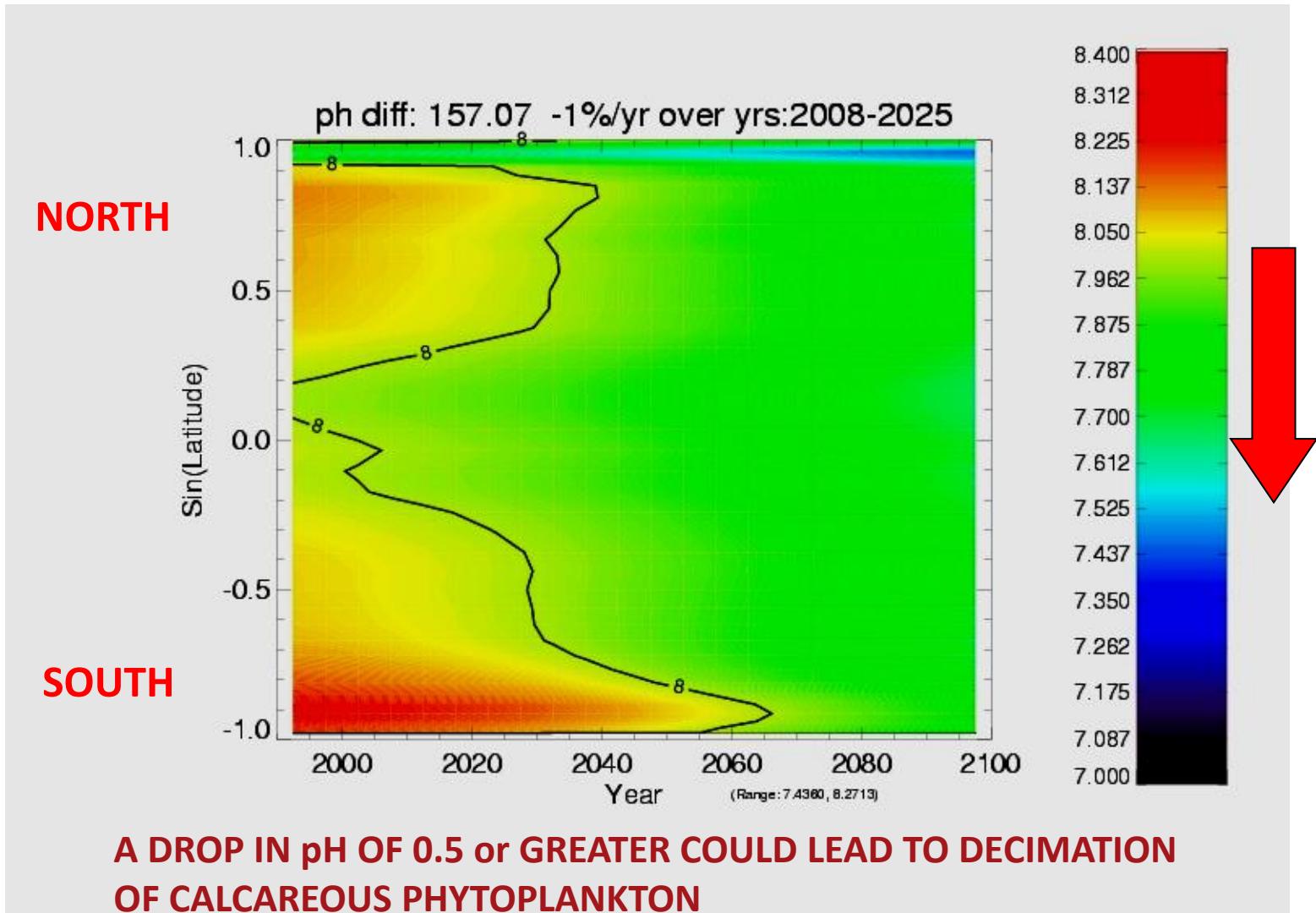
- Importance of a balanced portfolio of energy sources
- Use energy to protect the earth's environment
 - Precious resource
 - Energy-prosperity-environmental dilemma
 - Holistic systems approach to sustainability
- Land and water use issues are very complex
 - Interactions and feedbacks
 - Short-term vs. long term costs and benefits
 - Decision making in the face of uncertainty
 - Balancing competing interests at international, national, regional, and local scales
 - Societal behaviors; cooperation is key

Questions/Comments?

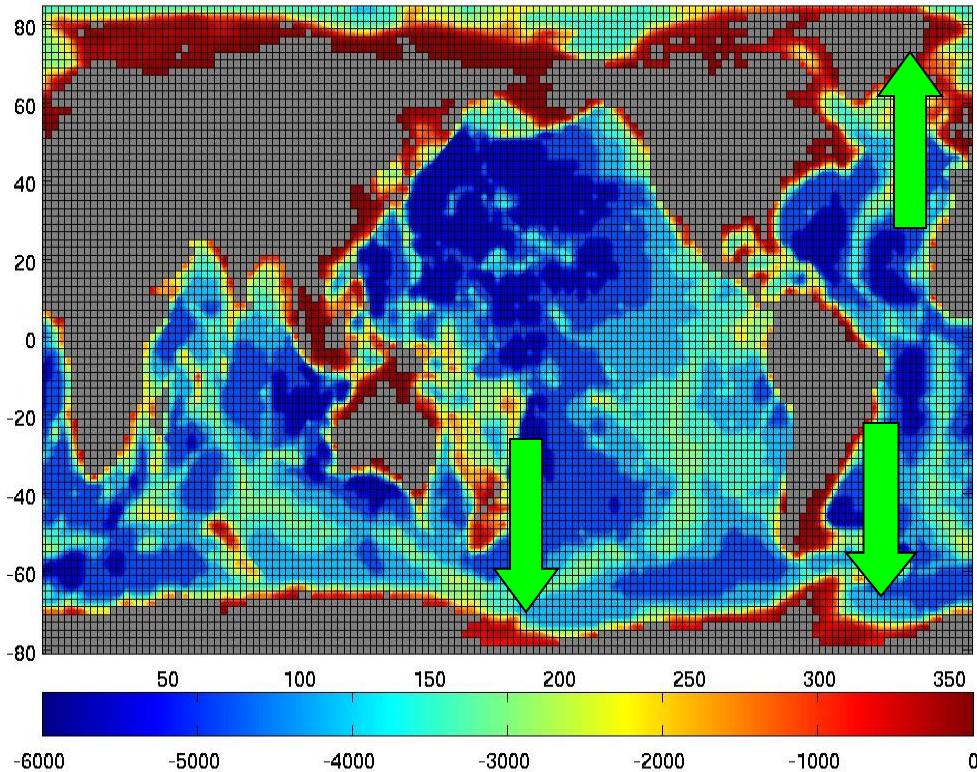
Nitrogen Cycle

- Biological transformation pathways:
 - N_2 to organic N; called *N fixation* (plants, protozoa)
 - Organic N to NH_4^+ ; called *mineralization* (by bacteria and fungi)
 - NH_4^+ to NO_3^- , producing NO and N_2O ; called *nitrification* (by bacteria)
 - NO_3^- to N_2 , producing N_2O ; called *denitrification* (by bacteria and fungi)
 - NO_3^- and NH_4^+ to organic N; called *photosynthesis* (uptake by plants)

Oceanic Acidity



Is the Deep Ocean Carbon & Heat Sink Stable?



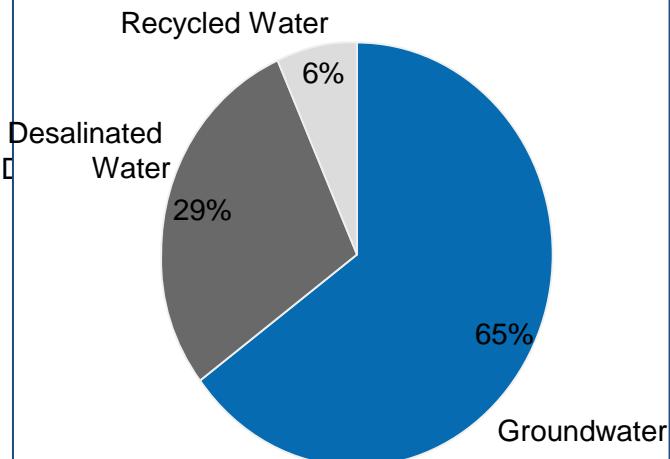
**OVERTURN DRIVEN
BY SINKING WATER
IN THE POLAR SEAS
(Norwegian, Greenland,
Labrador, Weddell, Ross)**

**SLOWED BY DECREASED
SEA ICE & INCREASED
FRESH WATER INPUTS
INTO THESE SEAS**

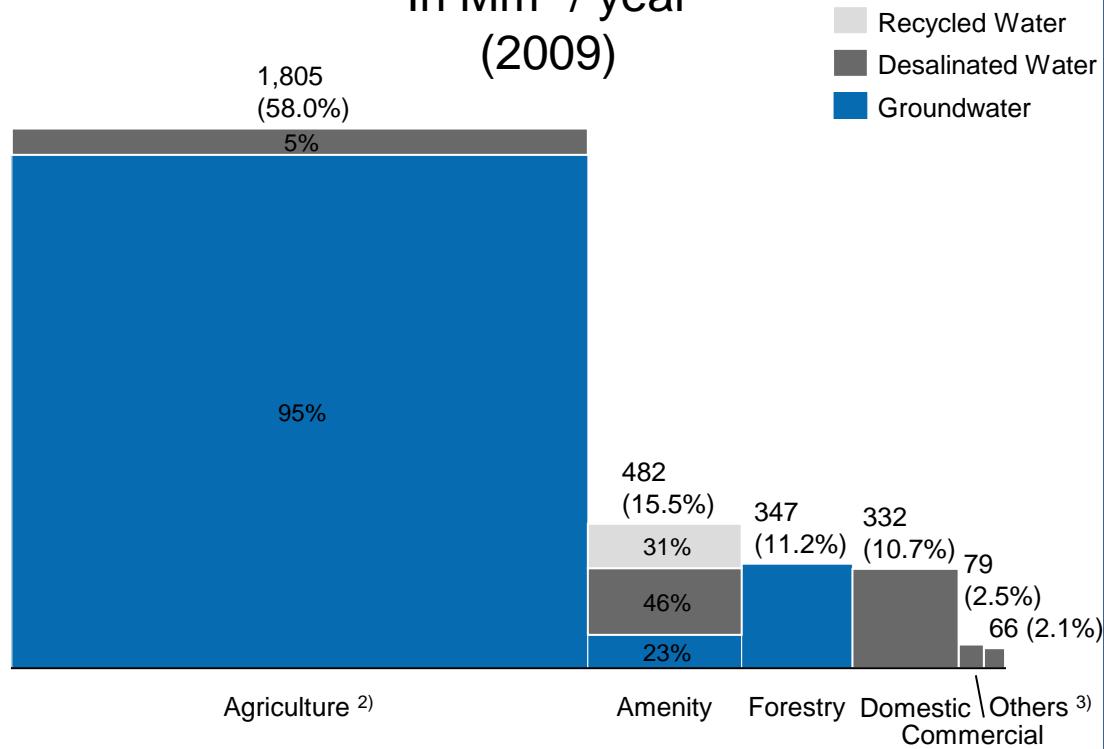
**INCREASED RAINFALL,
SNOWFALL & RIVER
FLOWS, & DECREASED
SEA ICE, EXPECTED WITH
GLOBAL WARMING**

Abu Dhabi has 3 key sources of water which are mostly consumed in agriculture, domestic, amenity and forestry sectors

Total Water Supply in Abu Dhabi By Source
- In % -
(2009)



Total Water Consumption in Abu Dhabi By Sector¹⁾
- In Mm³ / year -
(2009)



Total Water Supply = 3,355 Mm³

Total Water Consumption = 3,112 Mm³/year

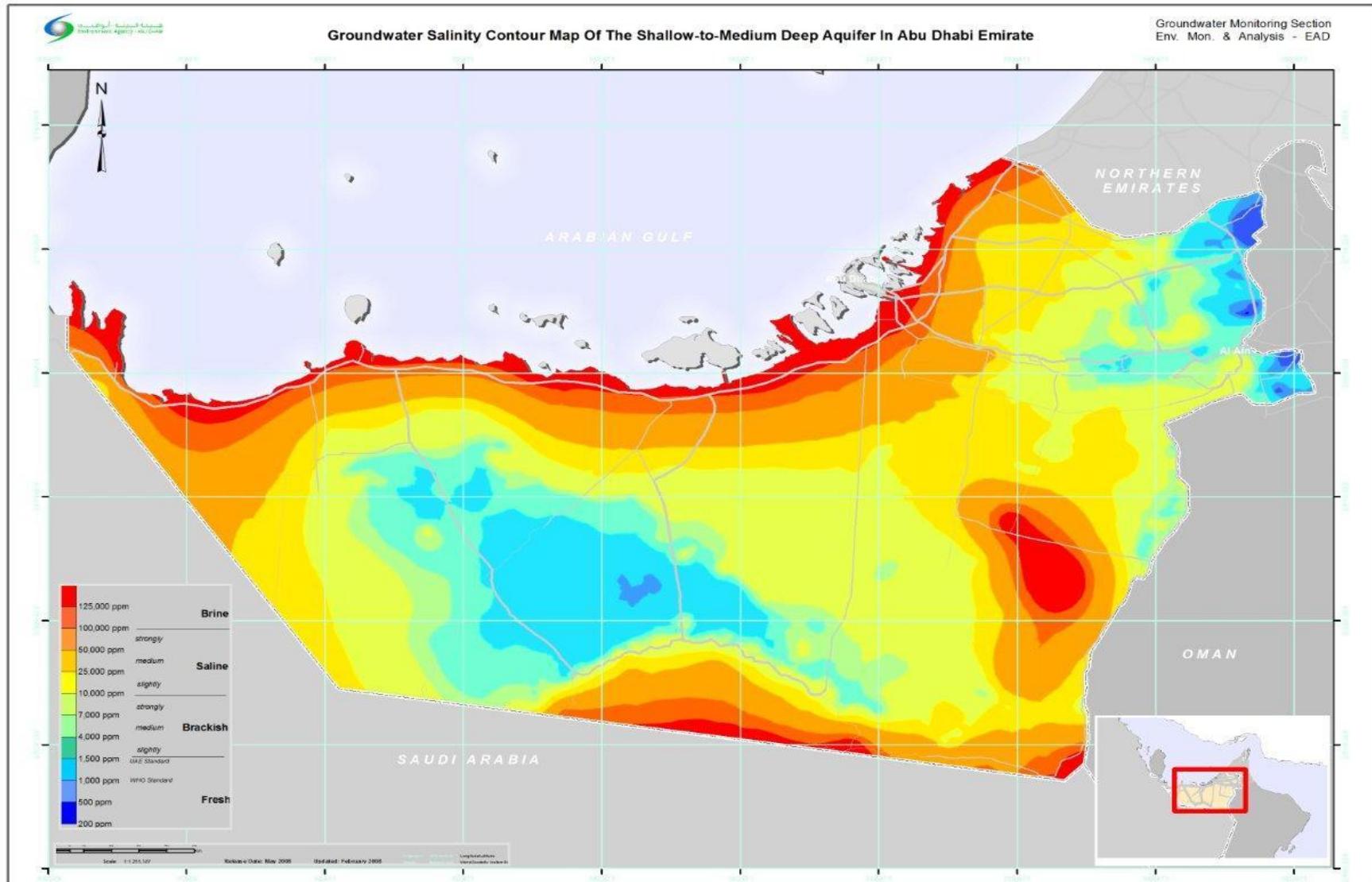
1) 2009 breakdown of desalinated water is assumed to be the same as the breakdown in 2008

2) Agriculture includes fruit and vegetable farms as well as field crops

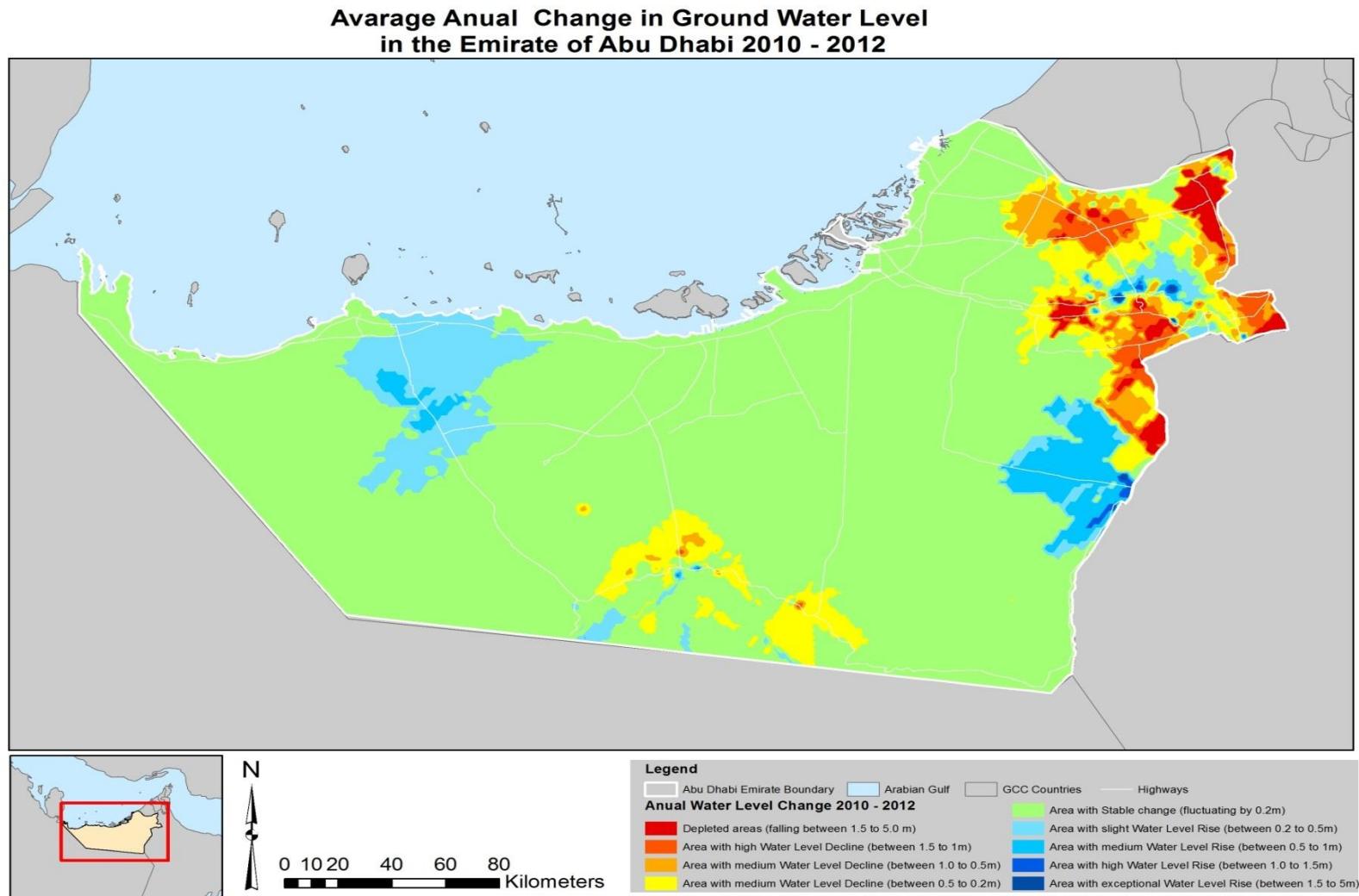
3) Includes government buildings (equivalent to 10% of total government consumption; this is the portion assumed to be used indoor while the rest is accounted for in amenity), industry & other sectors

Source: Abu Dhabi Water Statistics 2006, 2009; Abu Dhabi Statistical Yearbooks 2009 and 2010; Env2030 Team analysis

There are two areas with fresh groundwater in Abu Dhabi



We are seeing significant depletion of groundwater aquifers



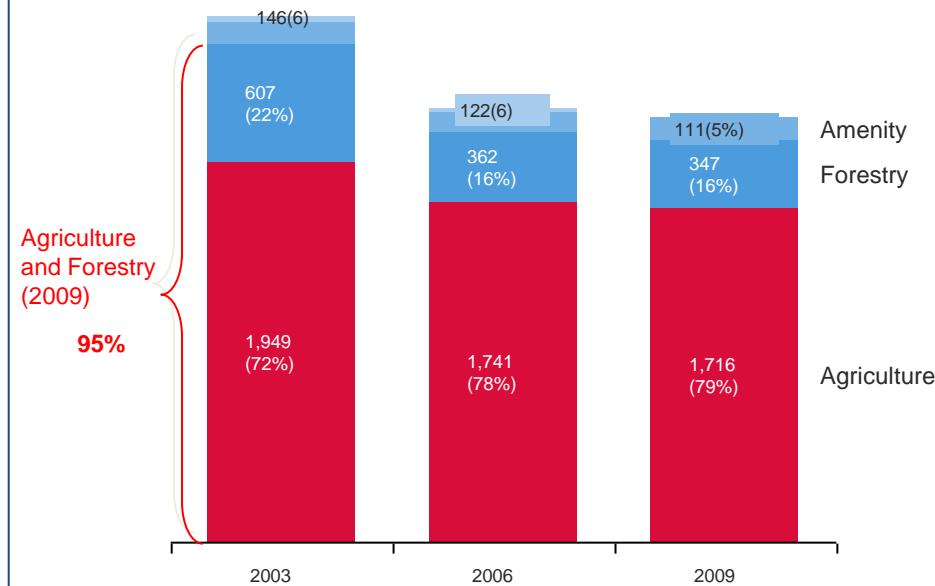
Agriculture is the largest user of groundwater in Abu Dhabi

Although decreasing, significant amounts of water are consumed by the agriculture and forestry sectors in Abu Dhabi, accounting for 95% of total groundwater consumption in 2009

Groundwater Consumption in Abu Dhabi by Use

- In Mm³ -
(2003-2009)

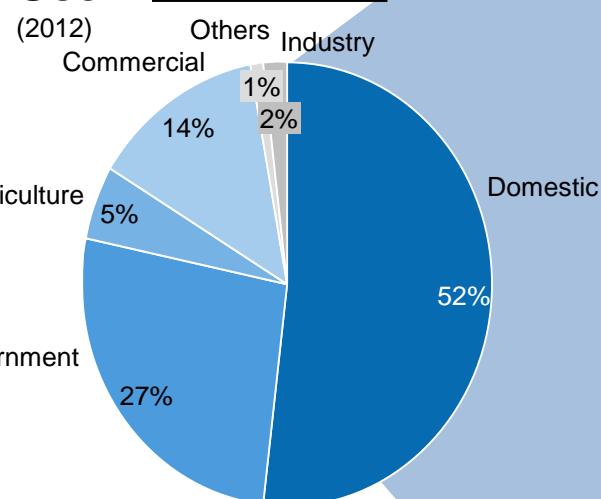
2,702 2,226 2,174 _{Total}



Abu Dhabi uses a large volume of desalinated water for domestic activities, resulting in our per capita water consumption being one of the highest in the world

Breakdown of Desalinated Water Consumption in Abu Dhabi

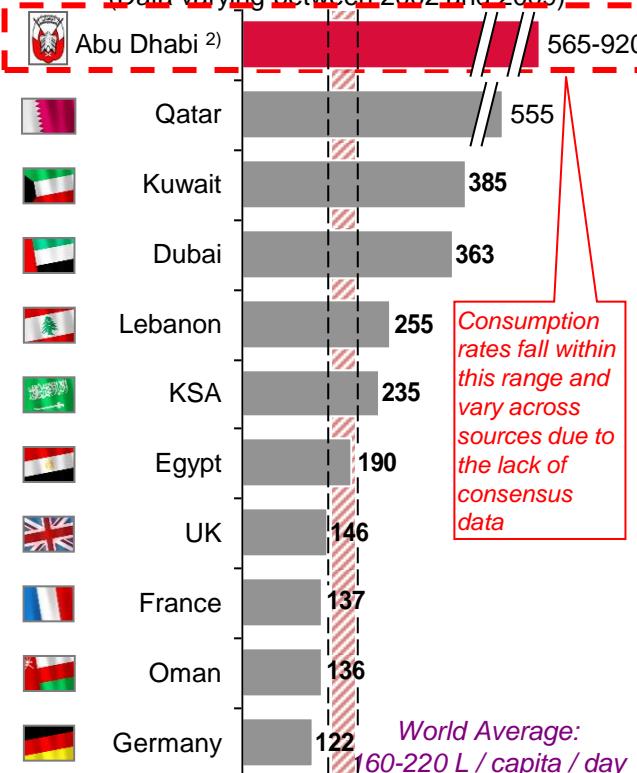
Annual Desalinated Water Consumption by Use¹⁾ PRELIMINARY



Total Desalinated Water Consumption
1059 Mm³

Domestic Water Consumption

- In L / capita / day -
(Data varying between 2002 and 2009)



Comments

- Domestic activities account for 52% of desalinated water consumption
- In fact, Abu Dhabi exhibits one of the highest per capita domestic consumption rates in the world varying between 565 and 920 L / capita / day
- Abu Dhabi's high consumption per capita is driven by high indoor water consumption and further exacerbated by outdoor consumption (i.e., car washing, gardening, swimming pools, etc.)

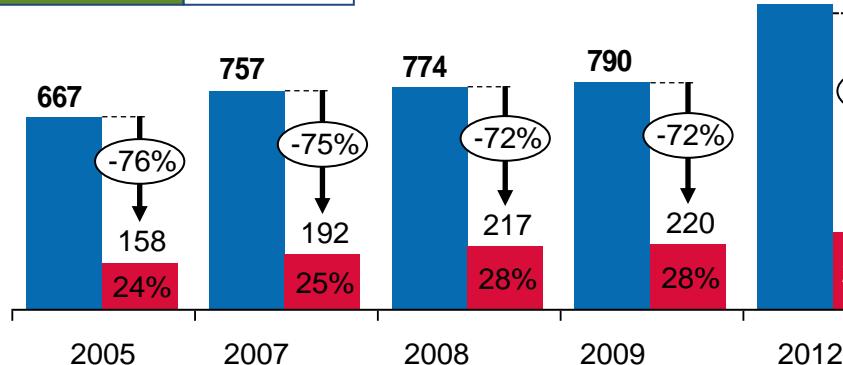
1) Desalinated water consumption breakdown is preliminary and varies across sources due to the absence of consensus breakdown data. 2) Water for domestic use is fully supplied by desalinated water. Domestic consumption per capita based on 2008 consumption and population figures. Source: Abu Dhabi Statistical Yearbook 2010; ADWEC Statistical Report 1998-2009; RTI International - Demand-Side Management for Electricity and Water Use in Abu Dhabi (EAA - May 2009); Report Consumption - Water and Electricity (RSB); GWI - Water Markets Middle East 2010; Federal Statistical Office of Germany; UK Defra; Eaufrance; Env2030 Team analysis

In terms of recycled water, around 25% of the consumed water is recycled, of which 45 - 50% is used for amenity irrigation

Recycled Water Snapshot

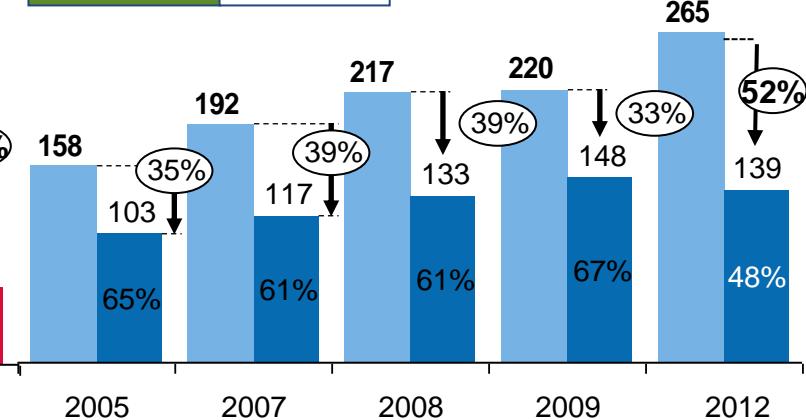
Desalinated Water Consumption and Recycled Water Production

- In Mm³/ year
(2005-2012)



Recycled Water Production and Reuse

- In Mm³ / year -
(2005-2012)



 Desalinated Water Consumption
 Recycled Water Production

 Recycled Water Production
 Reused Recycled Water

% of water that does not return to sewer
 X% of water that does not return to sewer

Quality Issues

Quality issues (such as high salinity due to groundwater infiltration) are currently being addressed by on going infrastructure projects (e.g. STEP Tunnel)

Discharge Issues

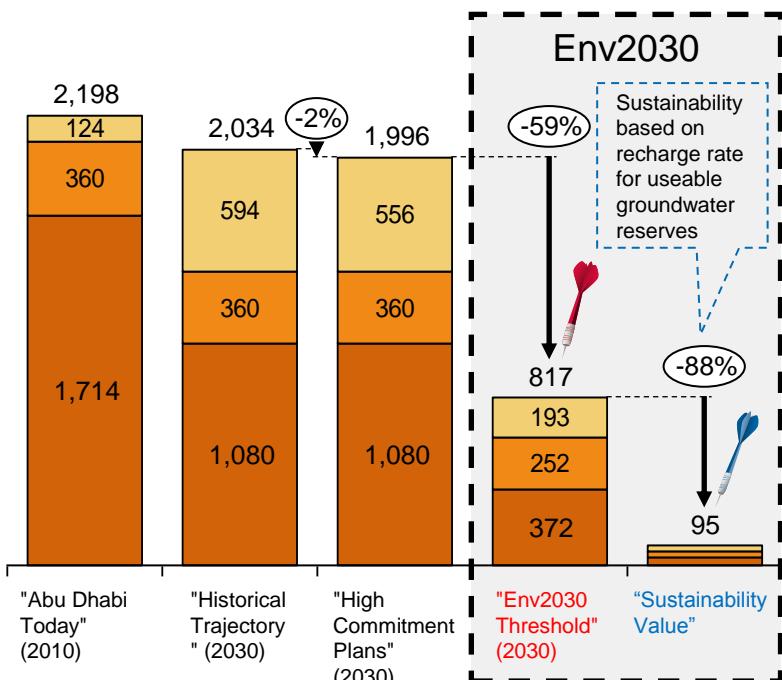
~30-40% of recycled water is discharged into the Desert or into the Gulf; however, these issues are being addressed through pipeline projects

The Environment Vision 2030 aspires to a more sustainable patterns water use relative to current and historical growth trajectories

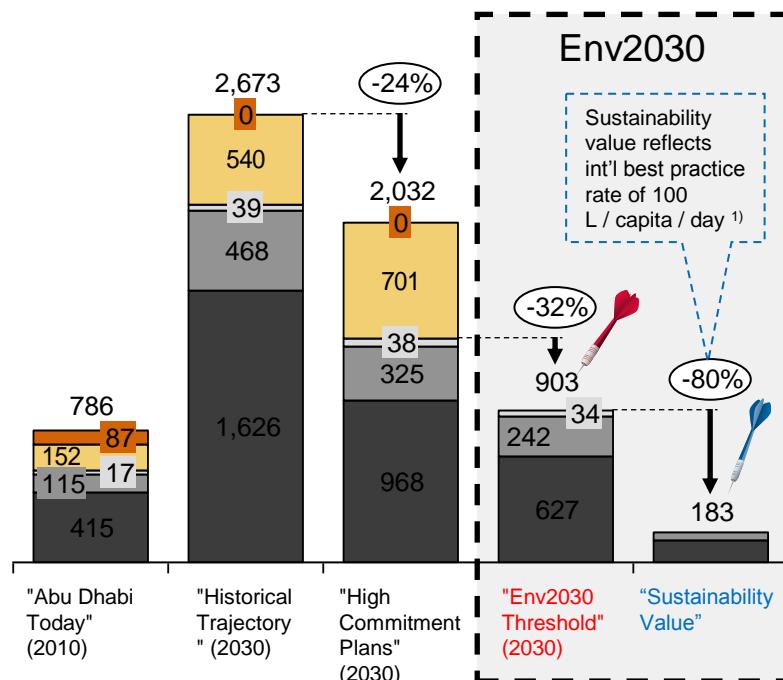
Groundwater and Desalinated Water Consumption in Abu Dhabi (2010-2030)

PRELIMINARY

Total Consumption of Groundwater by Sector
– In Million m³ per Year –



Total Consumption of Desalinated Water by Sector
– In Million m³ per Year –



Legend  Amenities  Forestry  Agriculture  Industry and Others ²⁾  Commercial  Domestic

1) 100 L / capita / day reflects achievement of UK building standards for water efficiency; 2) Others mainly includes water desalination for strategic reserves Note "Historical Trajectory" assumes continuation of current activity at historical growth rates, not accounting for changes in strategies and plans; "High Commitment Plans" are plans that Abu Dhabi has already committed to implementing, notably the Economic Vision 2030, Surface Transport Master Plan, Estidama, Livestock Vision 2030; "Env2030 Threshold" reflects the desired state of the environment for Abu Dhabi in 2030, and which is underpinned by a set of specific sector and cross-sector policy imperatives detailed in later sections; "Sustainability Value" reflects the ultimate state of sustainability that any nation should seek to achieve in the long-term Source: UK Code for Sustainable Homes; Env2030 Team analysis