RENEWABLE RESOURCES JOURNAL

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About RNRF

Purposes

The Renewable Natural Resources Foundation (RNRF) is an I.R.C. §501(c)(3) nonprofit, public policy research organization, founded in 1972. It is a consortium of scientific, professional, educational, design and engineering organizations whose primary purpose is to advance science, the application of science, and public education in managing and conserving renewable natural resources. RNRF's member organizations recognize that sustaining the Earth's renewable resource base will require a collaborative approach to problem solving by their disciplines and other disciplines representing the biological, physical and social sciences. The foundation fosters interdisciplinary assessments of our renewable resources requirements and advances public policies informed by science.

Members

RNRF's members are membership-based nonprofit organizations with member-elected leaders. The foundation is governed by a board of directors comprised of a representative from each of its member organizations. Directors also may elect "public interest members" of the board. Individuals may become Associates.

MEMBER ORGANIZATIONS

American Geophysical Union

American Meteorological Society

American Society of Civil Engineers

American Society of Landscape Architects

American Water Resources Association

Geological Society of America

Society of Environmental Toxicology and Chemistry

Society of Wood Science and Technology

Programs

RNRF conducts national conferences, congressional forums, public-policy briefings and round tables, international outreach activities, and a national awards program.

Renewable Resources Journal

The quarterly journal, first published in 1982, features articles on public policy related to renewable natural resources. It also includes news from member organizations, general announcements, meeting notices, and international conservation news. The journal is provided as a program service to the governing bodies of RNRF member organizations, members of the U.S. Congress and staff of its natural resources- and science-oriented committees.

News and Announcements

Renewable Natural Resources Foundation

Now Accepting Nominations for RNRF's 2015 Awards Program

RNRF has three annual awards to recognize outstanding achievements in the renewable natural resources fields. Two of the awards, established in 1992, were the first to honor interdisciplinary achievements with an emphasis on the application of sound scientific practices in managing and conserving renewable natural resources.

The Sustained Achievement Award recognizes a long-term contribution and commitment to the protection and conservation of natural resources by an individual.

The Outstanding Achievement Award recognizes a project, publication, piece of legislation, or similar concrete accomplishment.

The Excellence in Journalism Award honors and encourages excellence in print journalism about natural resources. It recognizes work by an individual, group, or organization.

Nominations are due at close-of-business on **May 29, 2015.** For nomination guidelines and other information, visit our awards page at www.rnrf.org/awards.html.

"Mahogany's Last Stand" is Recipient of 2014 Excellence in Journalism Award

"Mahogany's Last Stand," written by Scott Wallace for National Geographic Magazine, is the recipient of RNRF's 2014 Excellence in Journalism Award. The award honors and encourages excellence in print journalism about natural resources, part of RNRF's goal to advance public education and understanding of important natural resources issues through dissemination of accurate and scientifically-based information about the environment.

"Mahogany's Last Stand" is an in-depth investigation into the illegal timber trade in Peru and its devastating impact on ecosystems and indigenous communities in the Amazon rainforest. To research his story, Wallace traveled to several remote watersheds to witness firsthand the social and environmental upheaval caused by illegal logging activities.

In 2001, Peru emerged as one of the world's largest suppliers of mahogany after Brazil declared a moratorium on logging big-leaf mahogany. The influx of logging activities has stripped many of Peru's watersheds of their most valuable trees. The last stands of mahogany are now nearly all restricted to indigenous lands, national parks, and territorial reserves set aside to protect isolated tribes. Now, illicit practices are believed to account for 75% of the annual Peruvian timber harvest, threatening both indigenous communities and critical habitats for forest species.

The article has had a significant impact in Peru and in global markets. It has led authorities to title indigenous lands in the Alto Tamaya River basin to combat illegal logging. It has also led authorities to implement a nationwide plan to bolster the protection of forest reserves set aside for highly vulnerable, isolated tribes. Internationally, importers of tropical hardwoods are implementing more stringent safeguards when sourcing timber from the Amazon and elsewhere.

The article can be read online at http://ngm.nationalgeographic.com/2013/04/mahogany/wallace-text.

Sustainability: Water is Recipient of 2014 Outstanding Achievement Award

Sustainability: Water is the recipient of RNRF's 2014 Outstanding Achievement Award. This award recognizes a project, publication, piece of legislation, or similar concrete accomplishment in the natural resources field.

NBC Learn produced this informative online video series in partnership with the National Science Foundation. *Sustainability: Water* is a seven-part collection of detailed stories explaining significant challenges to managing the water supply in selected regions and cities across the United States. The series advances public understanding of the effect of human activity and climate variability on water and its distribution system. Each video features an NSF-supported scientist from a variety of fields, geographic locations, and institutions explaining a scientific challenge and how these challenges are affecting the water supply.

Available cost-free to teachers, students, and the public, *Sustainability: Water* serves as a timely educational tool. Topics covered by the videos include: flow and storage processes in the water cycle; developing water management plans for the Ogallala Aquifer; measuring snow pack and snow melt for better water management; the impact of beetle-killed trees on water quantity and quality; efforts to reduce water imports with better plans to capture, store, and reuse water; better understanding of the urban water cycle; and the impact that agricultural runoff and changes in precipitation have on nutrient flow and algal blooms. The series is available online at http://nbclearn.com/Water.

Lynn Scarlett

Lynn Scarlett is Recipient of 2014 Sustained Achievement Award

Lynn Scarlett is the recipient of RNRF's 2014 Sustained Achievement Award. The Sustained Achievement Award recognizes a long-term contribution and commitment to the protection and conservation of natural resources by

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RENEWABLE RESOURCES JOURNAL

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Editorial Policy: The editors seek general interest articles concerning public policy issues related to natural resources management. Recommended maximum length of manuscripts is 4,000 words. All manuscripts will be reviewed by the editors and, where appropriate, by experts in the subject matter. (A "Guide for Contributors" is posted at RNRF's website.) ***Editorial Staff:*** Robert D. Day, editor; Melissa M. Goodwin, associate editor; Jennee Kuang, assistant editor.

Energy-Water Nexus: The Energy Sector's Water Use

Nicole T. Carter

Summary

Water and energy are critical resources that are reciprocally linked; this interdependence is often described as the water-energy nexus. Meeting energy-sector water needs, which are often large, depends upon the local availability of water for fuel production, hydropower generation, and thermoelectric power plant cooling. The U.S. energy sector's use of water is significant in terms of water withdrawals and water consumption. Thermoelectric cooling represented 38% of freshwater withdrawn nationally and 45% of all water (fresh and saline) withdrawn in 2010, and the broader energy sector's water use (including biofuels) represented around 14% of water consumed nationally. Energy-related water consumption is anticipated to continue to increase in coming decades as the result of more domestic biofuel and unconventional onshore oil and natural gas production. Policy makers at the federal, state, and local levels are faced with deciding whether to respond to the growing water needs of the energy sector, and if so, which policy levers to use (e.g., tax incentives, loan guarantees, permits, regulations, planning, or education). Many U.S. energy sector water decisions are made by private entities, and state entities have the majority of the authority over water use and allocation policies and decisions.

For fuel production, water is either an essential input or is difficult and costly to substitute, and degraded water is often a waste byproduct that creates management and disposal challenges. U.S. unconventional oil and natural gas production has expanded quickly since 2008, and U.S. natural gas and coal exports may rise. This has sparked interest in the quantities of water and other inputs "embedded" in these resources, as well as the wastes produced (e.g., wastewaters from oil and natural gas extraction) and how they are reused or disposed (e.g., concerns over induced seismicity from injection of oil and natural gas wastewaters). Much of the growth in water demand for unconventional fuel production is concentrated in regions with already intense competition over water (e.g., tight gas and other unconventional production in Colorado, Eagle Ford shale gas and oil in south Texas), preexisting water concerns (e.g., groundwater decline in North Dakota before Bakken oil development), or regions with abundant, but ecologically sensitive surface water resources (e.g., Marcellus shale region in Pennsylvania and New York).

Conventional hydropower accounts for approximately 8% of total U.S. net electricity generation, and more than 80% of U.S. electricity is generated at thermoelectric facilities that depend on cooling water. Water availability issues, such as regional drought, low flow, or intense competition for water, can curtail hydroelectric and thermoelectric generation. An assessment of the drought vulnerability of electricity in the western United States found broad resiliency, while also identifying the Pacific Northwest and the Texas grid at higher risk. Future withdrawals associated with electric generation may grow slightly, remain steady, or decline depending on a number of factors. These include reduced generation from facilities using once-through cooling because of compliance with proposed federal cooling water intake regulations or shifts in how electricity is generated (e.g., less from coal and more from certain natural gas technologies and wind).

Energy choices represent complex tradeoffs; water use and wastewater byproducts are two of many factors to consider when making energy choices. For many policy makers, concerns other than water—low-cost reliable energy, energy independence and security, climate change mitigation, public health, and job creation—are more significant drivers of their positions on energy policies.

Introduction

Water and energy are critical resources that are reciprocally linked. Energy is required for the pumping, conveyance, treatment and conditioning, and distribution of water and for collection, treatment, and discharge of wastewater. Likewise, as described in this report, meeting energy sector needs depends upon the local availability

Carter is a Specialist in Natural Resources Policy with the Congressional Research Service. This article reflects updates made to the original report in November 2014.

of water, often in large quantities, for mineral fuel production,[1] hydropower, and thermoelectric power plant cooling. This interdependence is often described as the water-energy nexus. This report addresses how the U.S. energy sector uses and relies on water; it provides summary descriptions divided into four topics: (1) Water for Energy Primer, (2) Fuel Production, (3) Electric Grid and Generation, (4) Policy Response Options and Considerations. CRS Report R43200, *Energy-Water Nexus: The Water Sector's Energy Use,* addresses the related topic of energy needs of the water sector.

Water for Energy Primer

Energy-Sector Water Use and Vulnerability Is Receiving Increased Attention

Available projections estimate that, by 2030, U.S. water consumption will increase by 7% above the level consumed in 2005; 85% of this growth is attributed to the energy sector (including biofuels).[2] The U.S. energy sector's use of water is significant in terms of water withdrawals and water consumption.[3]

- **Energy Sector:** While agriculture dominates U.S. water consumption (71%), the energy sector (including biofuels, thermoelectric, and fuel production) is the second-largest consumer at 14%, and domestic and public uses are third at 7%.[i] Multiple factors contribute to the energy sector being the fastest-growing water consumer. Biofuels produced from irrigated feedstocks play a significant role, as well as expanding production of onshore unconventional oil and natural gas and hydro-stimulation of aging wells.
- **Electric Generation:** Water dependence is a risk for hydroelectric and thermoelectric generation. During low-flow or high-heat events, water intakes and high water temperatures may harm or limit thermoelectric cooling. Thermoelectric cooling water represented 38% of freshwater withdrawn nationally in 2010[4] and almost 6% of water consumed nationally.[5] Also, the withdrawal and discharge of cooling water can harm aquatic organisms.
- **Fuel Production:** Water is either an essential input or is difficult and costly to substitute; degraded water is often a waste byproduct. The potential for human-induced seismic events is receiving scientific and political attention because of concerns over the possible connection between oil and gas wastewater injection and the recent increasing frequency of earthquakes, particularly in the central and eastern United States.
- **Efficiency and Conservation:** Reducing energy demand through energy and water efficiency[ii] and more water-efficient generation (e.g., electricity from wind,[6] photovoltaics, or natural gas) can reduce water demand. Current water efficiency incentives in fuel production include minimizing water management costs and reducing operational disruptions.
- **Embedded Water:** U.S. unconventional oil and natural gas production has expanded quickly due to the combined use of hydraulic fracturing and horizontal drilling tech-

The U.S. energy sector's use of water is significant in terms of water withdrawals and water consumption.

1. In this report, production encompasses extraction and processing of fuels.
2. This report complements CRS Report R41507, *Energy's Water Demand: Trends, Vulnerabilities, and Management,* by Nicole T. Carter, which analyses how and where the energy sector uses water in the United States.
3. Consumption represents the water not available for immediate subsequent use. In the energy sector, water is consumed when it enters the atmosphere (e.g., power plant evaporative cooling towers), is lost to geologic formations, is sufficiently degraded to require permanent disposal, or needs treatment before use in freshwater applications or return to the environment.
4. U.S. Geological Survey, *Estimated Use of Water in the United States in 2010* (Circular 1405: 2014). Thermoelectric cooling represented 91% of the saline water withdrawn nationally.
5. D. Elcock, "Future U.S. Water Consumption: The Role of Energy Production," *Journal of the American Water Resources Association,* vol. 46, no. 3 (June 2010), pp. 447-480, hereinafter referred to as Elcock 2010. Some estimates put thermoelectric water consumption closer to 3%. Available data is anticipated to improve when the U.S. Geological Survey releases its five-year water use survey for 2010; the agency has stated that it is resuming its estimates (which had stopped with the 1995 data) of water consumption by thermoelectric power plants and released a report in November 2013 on the improved methods that it will be using for determining those estimates.
6. One study found that expanding the nation's electricity portfolio to 20% wind by 2030 would reduce water consumption by 1.2 billion gallons daily compared to expanding the current electricity mix. The water saved would be 41% in the Midwest/Great Plains, 29% in the West, 16% in the Southeast, and 14% in the Northeast (DOE, *20% Wind Energy by 2030: Increasing Wind Energy's Contribution to U.S. Electricity Supply,* July 2008, http://www1.eere.energy.gov/wind/pdfs/41869.pdf).

niques for well development.[7] This expansion has sparked interest in the quantities of water and other inputs "embedded" in energy resources.

Relevant Data and Research Are Improving; Significant Gaps Remain

In 2012, the Government Accountability Office, in *Energy-Water Nexus: Coordinated Federal Approach Needed to Better Manage Energy and Water Tradeoffs,* stated that "making effective policy choices will continue to be challenging without more comprehensive data and research."[iii] Improving data on water use by the energy sector is challenging for a number of reasons. For example, much of the U.S. energy sector is private; data consistency, accuracy, and currency are problematic; and it is costly to maintain high-quality data for an evolving and dispersed industry.

While data challenges exist, access to relevant research and data is improving. The Department of Energy (DOE) disseminates energy-water related studies on a public online platform.[8] DOE released a report in 2014, *The Water-Energy Nexus: Challenges and Opportunities,* which identified various data gaps and multiple technology research, development, and demonstration opportunities to increase the technological options available to reduce the water demands and impacts of the energy sector.[9] The reports mentioned in the box below provide additional information on the energy-water nexus while also identifying areas needing improved understanding. While these reports differ in their focus, they each mention the stresses that climate change places on the energy-water nexus.

Fuel Production

Unconventional Oil and Gas Production Often Concentrates Water Use Geographically and Temporally

Much of the growth in water demand for unconventional fuel production is concentrated in regions with already intense competition over water.

Regional water resource opportunities and challenges for fuel production vary based on several factors, including (1) which fuel is being produced in the region, (2) the local and regional significance of its water use, and (3) regional conditions for management of wastewaters.

- Much of the growth in water demand for unconventional fuel production is concentrated in regions with already intense competition over water (e.g., tight gas and other unconventional production in Colorado, Eagle Ford shale gas and oil in south Texas), preexisting water concerns (e.g., groundwater decline in North Dakota before Bakken oil development), or abundant but ecologically sensitive surface water resources (e.g., Marcellus shale region in Pennsylvania and New York).
- The cumulative water needs of multiple drilling and fracturing operations may be locally or temporally significant.[10] Often many shale gas, tight gas, and tight oil wells are located in close proximity to each other as a formation is developed, with many wells being drilled and fractured from the same location. Water use for these wells is concentrated in the early stages of well development, usually in the first few weeks. Once the well is producing, little or no water is required unless refracturing is performed. How much water is used for well development is highly variable both across and within formations.

7. Hydraulic fracturing is a technique developed initially to stimulate oil production from wells in declining oil reservoirs. The technique now is widely used to initiate oil and natural gas production in unconventional (low-permeability) formations that were previously inaccessible. Fracturing is currently used in more than 90% of new oil and natural gas wells. Hydraulic fracturing involves injecting large volumes of water, sand (or other propping agent), and specialized chemicals under pressure into a well to fracture the formations holding trapped oil or natural gas.

8. The site links to over 150 items related to energy-water issues: http://en.openei.org/wiki/Water_and_energy_studies. Also the Energy Information Agency in recent years has increased the type and frequency of data collection on power plant cooling systems. More state level data is being collected; for example, the Railroad Commission of Texas required oil and natural gas operators to disclose on FracFocus (http://fracfocus.org/) water volumes and chemicals used for hydraulic fracturing after February 2012.

9. U.S. Department of Energy, *The Water-Energy Nexus: Challenges and Opportunities,* June 2014, http://energy.gov/ downloads/water-energy-nexus-challenges-and-opportunities. The report identified the following water-for-energy technologies for more in-depth analysis: cooling, waste heat recovery, process water efficiency and quality, alternatives to freshwater in energy production, and hydropower.

10. For example, although hydraulic fracturing water use represented less than 1% of all water use in Texas, for some counties in the Barnett formation (north central Texas) it represented 10% to 30% of water use; in the Eagle Ford formation (south Texas), unconventional energy extraction was responsible for 38% of groundwater use. R. B. Jackson et al., "The Environmental Costs and Benefits of Fracking," *Annual Review of Environment and Resources,* vol. 39 (August 9, 2014), pp. 7.1-7.36.

Reports Linking Energy-Water Nexus to Climate Change

U.S. government reports and reports by stakeholders are increasingly addressing the links between energy, water, and climate change. Examples include the following reports:

- **May 2014, National Climate Assessment and Development Advisory Committee, *Third Climate Assessment Report*** (available at http://ncadac.globalchange.gov/). This report discussed how co-occurrence of heat waves and droughts can amplify impacts on water and electricity supply and demand, which can affect the energy sector in multiple and cascading ways. The report stated (p. 128 and p. 280, respectively) that "changes in water availability, both episodic and long-lasting, will constrain different forms of energy production," and "dependence of energy systems on land and water supplies will influence the development of these systems and options for reducing greenhouse gas emissions." It also noted (p. 280) that "jointly considering risks, vulnerabilities, and opportunities associated with energy, water and land use is challenging, but can improve the identification and evaluation of options for reducing climate change impacts." Recommendations for related research were included in a technical report developed to support the assessment effort (*Pacific Northwest National Laboratory, Climate and Energy-Water-Land System Interactions,* March 2012, http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-21185.pdf).

  ** Changes were made to the original report to reflect updates to the National Climate Assessment*

- **July 2013, Department of Energy (DOE), *U.S. Energy Sector Vulnerabilities to Climate Change and Extreme Weather*** (available at http://energy.gov/sites/prod/files/2013/07/f2/20130710-Energy-Sector-Vulnerabilities-Report.pdf). The report (p. i) stated the following when discussing the impacts of climate change on the energy sector and the potential for cascading and compounding impacts:

  > Some of these effects, such as higher temperatures of ambient water used for cooling, are projected to occur in all regions. Other effects may vary more by region, and the vulnerabilities faced by various stakeholders may differ significantly depending on their specific exposure to the condition or event. However, regional variation does not imply regional isolation as energy systems have become increasingly interconnected. Compounding factors may create additional challenges. For example, combinations of persistent drought, extreme heat events, and wildfire may create short-term peaks in demand and diminish system flexibility and supply, which could limit the ability to respond to that demand.

  The report identified a number of opportunities to enhance information, tools, and practices to reduce the energy sector's climate vulnerabilities. Some of the opportunities identified (p. 44) included better regional and local characterization of climate trends and extreme weather relevant to the energy sector (e.g., water availability, likelihood and magnitude of droughts); better characterization of the aggregate vulnerabilities of the energy sector to climate change and interdependencies with other sectors leading to cascading impacts; improved understanding of potential uses and challenges of advanced cooling technologies and alternative water sources; and additional assessments of impacts to hydropower.

- **July 2013, Alliance for Water Efficiency and the American Council for an Energy-Efficient Economy, *Water-Energy Nexus Research: Recommendations for Future Opportunities*** (available at http://www.allianceforwaterefficiency.org/WE-WhitePaper-PR.aspx). Its recommendations included continuing investigations into the water-energy tradeoffs of differing resource development and management choices; identifying regulatory barriers to co-implementation of energy and water efficiency programs; developing water and energy industry-accepted protocols for efficiency programs; and assessing potential impacts to water supplies and quality from energy resource development and identifying solutions to mitigate these impacts.

- Data on source water remain sparse. Groundwater often is used for shale operations when it is available and access is permitted. Surface waters also are used, but may require transport by truck. In cases of limited water access, well developers also have obtained water by purchasing it from municipalities or paying individual land owners for their supplies.

Available Data on Water Use Remain Problematic

As of mid-2013, gaps remained in the availability of authoritative and recent data on the amounts of freshwater consumed and wastewater produced in fuel production. Available data indicate the following:

- The amount of water needed per unit of fuel produced—referred to as the water intensity of a fuel—ranges from conventional natural gas at the lowest end (less than 1 gallons of water per MMBtu);[11] coal, unconventional gas, and uranium mining and enrichment next (roughly 1 to 10 gallons per MMBtu); oil next (10 to 100 gallons per MMBtu);[12] and irrigated biofuels at the upper end (100 to 1,000 gallons per MMBtu).[iv] The water intensity of conventional and unconventional oil produced using different techniques remains poorly documented. The water intensity for hydraulically fractured wells often is less notable than the concentrated, simultaneous demand for water for hydraulic fracturing in a region where many wells are being developed concurrently.
- Despite the recent increase in water demand for hydraulic fracturing, water use for stimulating oil production from conventional wells through water flooding and enhanced oil recovery have represented the largest water use by the oil and gas sector in the United States.[13] The use of these techniques is anticipated to increase; to what extent saline, wastewaters, or freshwater will be used is less clear. Limited data on production rates and quantities for many saline aquifers can be a disincentive to their use.
- Each fuel and production technique presents its own risks, potential water quality impacts,[14] and wastewater issues; also, some techniques may be more water-efficient but less efficient at recovering energy resources.[15] Data remain poor on the range of wastewater quantities and qualities derived from conventional and unconventional fuel production.

Each fuel and production technique presents its own risks, potential water quality impacts, and wastewater issues.

Fuel Production Remains Vulnerable to Water-Related Disruptions

The vulnerability of fuel production to freshwater availability is receiving attention in part because of increasing water demands (e.g., population growth) and concerns over changes to water supplies (e.g., drought and climate change).

- Instances of low flow and drought conditions have reduced the availability and increased the cost of water for operations in some locations (e.g., Susquehanna River basin in Virginia, West Virginia, and Pennsylvania, and Eagle Ford Shale region in Texas). No analysis is available of the risk posed by a multi-year drought in areas of intense water use for energy (e.g., North Dakota) and how to manage the risk.
- Fossil fuel transport also may be disrupted by water conditions, such as flood-induced pipeline breaks resulting from riverbed scouring, flood- or storm-related refinery or distribution system disruptions (e.g., Hurricane Sandy disruptions), and drought- or flood-impaired fuel transport. No analysis of energy sector transport risks is available.

11. MMBtu represent 1 million British thermal units which is a commonly used unit of energy.

12. Oil is produced by a variety of techniques, some of which can be particularly water-intensive (e.g., water flooding). Oil shale is largely not discussed herein. Oil shale is distinct from the tight oil produced from shale formations. Oil shale's near-term impacts on water resources are limited by the relatively small scope of anticipated near-term development (GAO, *Unconventional Oil and Gas Production: Opportunities and Challenges of Oil Shale Development,* Washington, D.C, 2012).

13. M. Matichich, *The Changing Value of Water to the US Economy: Implications from Five Industrial Sectors,* Boston: CH2M Hill, 2012. How much of the injected water is reused produced water from oil and gas operations is unknown.

14. A discussion of water quality impacts is beyond the scope of this report. For a regional discussion of water quality concerns associated with shale gas, see CRS Report R42333, *Marcellus Shale Gas: Development Potential and Water Management Issues and Laws,* by Mary Tiemann et al. For a general discussion, see L. Allen, et al., *Fossil Fuels and Water Quality,* in P. Gleick, *The World's Water.* Vol. 7, Washington, DC: Island Press, 2012, pp. 73-96.

15. Beyond water considerations, fuel production can have other development impacts (e.g., roads, housing). For example, see CRS Report R42611, *Oil Sands and the Keystone XL Pipeline: Background and Selected Environmental Issues,* coordinated by Jonathan L. Ramseur.

Wastewaters Represent Management Challenges and Some Opportunities

Produced water—wastewaters (often saline) brought to the surface by oil and gas wells—represents the largest byproduct of fuel production. Approximately 2.3 billion gallons are produced daily from onshore oil and gas wells in the United States.[16] For oil wells, this represents an average ratio of 7.6:1 of produced water to oil produced. By 2025, as a result of aging wells with decreasing oil production, the ratio is expected to average 12:1 for onshore crude oil.[v]

- U.S. energy-related wastewaters are primarily from conventional oil and natural gas and coal bed methane (CBM).[17] Research indicates that shale gas may produce less wastewater per unit of recovered gas than conventional natural gas (although water inputs during unconventional well development often exceed those for conventional natural gas, as described above).[vi] Disposal of shale wastewaters has received more attention recently than wastewaters from conventional production because of the rate of increase in shale development and its associated wastewaters in locations that are not accustomed to oil and natural gas development.
- Management of energy-related wastewaters is evolving rapidly, with different techniques dominating in different locations and raising concerns related to water quality and seismicity. Where deep wells for the permanent disposal of produced water are limited, producers increasingly are recycling and reusing produced water in fracturing operations. This reduces the amount of freshwater needed and relieves stress on disposal sites. At the same time, reuse of produced waters may increase the transport and handling of saline waters, potentially increasing a risk pathway for spills.
- The potential for human-induced seismic events associated with oil and gas wastewater injection is receiving scientific and political scrutiny in the context of the recent frequency of earthquakes, particularly in the central and eastern United States.[vii] Over 300 earthquakes of magnitude (M) 3 or greater occurred between 2010 and 2012 in the central and eastern United States, compared to an average of 21 earthquakes per year of M>3 between 1967 and 2000.[viii] The increase in seismicity seems to be correlated with the increase in the number of disposal wells, many of which are injecting wastewaters brought to the surface at shale oil and gas wells and in the use of hydraulic fracturing. Of the 30,000 injection wells in the United States used for wastewater disposal, however, only a few are correlated with seismicity of M >3.[ix] The largest seismic events associated with injection seem to involve faulting that is deeper than the wastewater injection, suggesting that transmission of pressure into the basement rocks elevates the potential for inducing earthquakes.[x]

The potential for human-induced seismic events associated with oil and gas wastewater injection is receiving scientific and political scrutiny.

Recent state actions and anticipated federal actions are affecting or are anticipated to affect the management of produced water.

- In Texas, produced water generally is disposed through deep-well injection (often on-site) or evaporation ponds; interest in reuse is increasing as the result of limited water availability in some regions (e.g., West Texas) and recent drought conditions. In May 2013, the Texas legislature clarified liability and ownership of produced waters transferred among oil and gas operators for purposes of recycling for a beneficial reuse.[18]
- Pennsylvania regulations constraining surface water disposal wastewaters from shale gas production and the limited in-state deep well-injection options have resulted in a rapid increase in the rate of produced water recycling for shale gas fracking.[xi] Operators in Pennsylvania are required to prepare a wastewater

16. This compares to an estimated 4.6 billion gallons per day of freshwater used for fuel production.

17. CBM production generally requires the dewatering of a coal formation for the natural gas to be released; the quantity and quality of CBM produced waters varies widely across formations (e.g., salinities ranging from freshwater or more saline than seawater). For more on CBM water issues, see National Research Council, *Management and Effects of Coalbed Methane Produced Water in the Western United States,* National Academies Press, August 2010.

18. H.B. 2767 (Texas). The Texas law would not affect potential liability under federal environmental law. Also in 2013, the Railroad Commission of Texas stopped requiring a recycling permit if operators are recycling on their own leases or transferring fluids to another operator's lease for recycling ("Railroad Commission Today Adopts New Recycling Rules to Help Enhance Water Conservation By Oil & Gas Operators," press release, March 26, 2013).

source reduction strategy to maximize recycling and reuse.
- In August 2013, EPA proposed to discontinue efforts to establish discharge standards for wastewaters from CBM under the agency's Effluent Guidelines Program. EPA has been unable to identify a wastewater treatment technology that would be economically achievable.[xii] The agency will continue with a rulemaking for wastewaters associated with shale gas extraction, which is expected to be proposed in 2015.

Electric Grid and Generation

Water availability issues, such as regional drought, low flow, or intense competition for water, can curtail hydroelectric and thermoelectric generation. Fuel and power plant choices and capital investments made in the near term are likely to establish the trajectories for electric generation's long-term water use and vulnerability.

Grid-Level Drought Vulnerability Exists in Select Basins

An assessment of the drought vulnerability of electricity in the western United States found the majority of basins showing limited disruption risk; also, most of this risk could be mitigated by known strategies, including maintaining excess generation and transmission capacity.[xiii] While identifying broad resiliency, the western U.S. assessment revealed two regions whose electric generation was at greater risk:

- The Pacific Northwest was shown to be vulnerable because of its heavy reliance on hydroelectric generation.
- The Texas grid was vulnerable because of heavy dependence on thermoelectric generation that relied on surface water for cooling, and because of the region's vulnerability to drought and poor connections to the other U.S. grids, which reduces the ability to purchase power to offset generation curtailment.

No similar assessment of grid drought vulnerability for the eastern United States has been performed. (See following section, "Thermoelectric Cooling Represents Difficult Tradeoffs," for a discussion of electric generation in the eastern United States.)

Recent drought experiences include the following:

- In the summer of 2011, high temperatures in Texas resulted in increased electricity demand. At the same time, the drought reduced the amount of water available for cooling electric generators. The grid operator put into effect its emergency action alert system, which at first recommended conservation by customers and later deemed customer conservation critical to avoid rotating outages. During a few days, the peak demand purchases in the real-time wholesale electricity market were at or near the market cap (i.e., $3,000 per megawatt-hour). In the end, only one Texas plant had water-curtailed generation; others were nearing curtailment when weather conditions improved.[19]
- During the drought of 2012, the mid-continent electric grid avoided major drought-related disruption. Some individual power plants curtailed operations due to water access problems or water temperature issues; others pursued regulatory waivers to continue operations at higher water temperatures or made cooling system investments. Lost generation at drought-impaired facilities was offset by other generation or purchasing power from other sources on the wholesale market.

Hydropower Vulnerability Has Been Initially Assessed

In Section 9505 of P.L. 111-11, Congress required the Secretary of Energy to assess the risks posed by climate change for water supply to federal hydroelectric power generators and to update the assessment every five years. The August 2013 report found:

Future changes to precipitation and runoff could potentially impact hydropower generation, water quality and supply, critical species habitat, and other important water uses that indirectly affect hydropower generation. At a national level, the median decrease in annual generation at federal projects is projected to be less than 2 billion kWh (2% of total), with a relatively high climate-model uncertainty. While these estimates are similar to the recently observed variability of generation from federal hydropower and may appear to be manageable, extreme water years (both wet and dry) will pose significantly greater challenges to water managers, especially in water systems that have more limited reservoir storage and operational flexibility.

For large reservoirs and reservoir systems, it is often the multi-year droughts that most harm generation,[20] as

19. During and after the summer of 2011, Texas power plant operators reduced their low water vulnerability by building pipelines to alternative and impaired water sources, acquiring additional water rights, lowering water intake structures, and installing additional groundwater pumping capacity. Also, the Texas grid operator instituted changes to reduce its water vulnerability. All new generation facilities as of 2013 must provide proof of water rights before being included in grid planning (which largely determines grid access). Few data are available on the extent to which low-water renewable technologies may be used to mitigate the Texas grid's drought risks.

20. For example, in 2012, hydropower production nationally was above average although drought conditions covered much of the continental United States. The Missouri River basin's strong hydropower generation in 2012 can be attributed to full reservoirs at the beginning of the year and the generation associated with releases of stored water to augment low river flows.

illustrated by summer 2013 conditions in the Colorado River Basin.

Thermoelectric Cooling Represents Difficult Tradeoffs

More than 80% of U.S. electricity is generated at thermoelectric facilities that depend on cooling water; these facilities withdrew 117 billion gallons of freshwater and 44 billion gallons of saline water daily in 2010, representing 45% of total water withdrawals.[xiv] The two common cooling methods for thermoelectric power plants are once-through cooling and evaporative cooling. Most once-through cooling is found at power plants located in the eastern United States and is associated with older facilities, or is at coastal facilities using saline waters. Newer facilities and those in more arid regions generally use evaporative cooling. DOE data indicate that 25% of proposed power plants are planning on using reclaimed wastewater for cooling, at least 22% are proposing fresh groundwater, and 17% are planning on dry cooling or generation technologies that do not require cooling.[xv]

- Once-through cooling, while largely non-consumptive, requires water to be continuously available for power plant operations.[21] This reduces the ability for this water to be put toward other water uses and can make cooling operations vulnerable to low flows.
- Evaporative cooling withdraws much smaller volumes of water for use in a cooling tower or reservoir, where waste heat is dissipated by evaporating the cooling water. Evaporative cooling consumes more water at the facility than does once-through cooling.
- Cooling technologies that consume less water and use degraded water supplies may reduce freshwater use. These options include dry cooling, hybrid dry-wet cooling, cooling with fluids other than freshwater (e.g., brackish groundwater, produced waters), and emerging technologies. While hybrid and dry cooling options may reduce water consumption, they can reduce operational efficiency (potentially increasing greenhouse gas emissions) and often are more costly.[22]
- Thermoelectric withdrawals were 20% less in 2010 than in 2005 for reasons including use of more water-efficient cooling technology by new power plants.[xvi] However, future withdrawals associated with electric generation may grow slightly, remain steady, or decline depending on a number of factors, including reduced generation from facilities using once-through cooling (industry actions resulting from proposed federal cooling water intake regulations)[23] or shifts in how electricity is generated (e.g., less from coal and more from certain natural gas technologies and wind).[24] In contrast, water consumption could increase, especially if more water-consumptive cooling is adopted (e.g., evaporative cooling) and if current carbon capture technologies are added to power plants.

Many Power Plants Produce Wastewaters

In addition to water for cooling purposes, many power plants also use water for handling solid waste, including ash, and for operating wet flue gas desulfurization scrubbers. According to the U.S. Environmental Protection Agency (EPA), in 2009, power plants discharged 0.7 billion gallons of wastewater daily. In 2013 EPA proposed revisions to Clean Water Act rules that govern wastewater discharges from such plants. The proposed rule would reduce the use of these process waters by 19%-58%, depending on the regulatory option selected when the rule is finalized.[xvii] A final rule is expected to be issued by September 2015.

Policy Response Options and Considerations

Policy makers at the federal, state, and local levels are deciding whether to respond to the growing water needs of the energy sector, and if so, which policy levers to use. In the United States, private entities make many of the energy sector's water decisions. Often federal entities lack authority over water use, and states have most of the water allocation authority. Instead of direct influence on water use, the public sector influences private water decisions through other routes (e.g., tax incentives, loan guarantees, permits, regulations, planning, and education). If action to manage energy-sector water issues is deemed appropriate, a range of options are available, as shown in

21. Once-through cooling pulls large quantities of water off a water body, discharges the power plant's waste heat into the water (which may raise the temperature of the withdrawn water by 10° to 20°F), and then returns the majority of the withdrawn water.

22. The National Science Foundation and the Electric Power Research Institute have an ongoing research collaboration on water for energy to further advanced dry cooling for power plants.

23. See CRS Report R41786, *Cooling Water Intake Structures: Summary of the EPA Rule,* by Claudia Copeland.

24. Natural gas-fueled generation is often less water-intense and less water-dependent than coal-powered electricity. This is because many natural gas-fueled electric facilities use engine-based technology (National Energy Technology Laboratory, *Estimating Freshwater Needs to Meet Future Thermoelectric Generation Requirements* (2009 Update), 2009).

Table 1. Policy Responses to Water Demands of Energy Sector

Water Demand Management Options	Water Supply Management Options	Options for Knowledge Development and Use
Minimize Energy Sector's Growth in Water Use	**Improve Energy Sector's Access to Water**	**Support Informed Decision-Making**
Promote water-efficient energy sources through standards, regulations, or incentives (e.g., rebates, water pricing)	Allocate sustainably available water, not otherwise allocated	Data and assessments; information sharing (e.g. data and research warehousing)
Promote water conservation and efficiency in the energy sector through standards, incentives, regulations, or pricing	Facilitate transfer of water from non-energy sectors (e.g., purchase of water from municipalities, or land owners; water markets)	Education, training, and dissemination of knowledge and information
Promote energy conservation and efficiency to reduce demand for energy and the embedded water		Integrated energy-water planning; coordination of research, decisions, and investments
Support research, development, scaling up, or adoption of technologies to reduce energy sector water use (e.g., public-private research collaborations)		Decision-support research and technical assistance; development of standard protocols and codes

Source: CRS

Table 1: minimize water use, facilitate access to water, or improve decisions and data. Energy choices represent complex tradeoffs; water use and wastewater byproducts are two of many factors to consider. For many policy makers, concerns other than water—low-cost reliable energy, energy independence and security, climate change mitigation, public health, and job creation—are more significant drivers of their positions on energy policies.

Analyses quickly get complex when attempting to comprehensively evaluate energy-water tradeoffs. Some energy alternatives, such as solar photovoltaics and wind turbines, do not pose significant energy-water tradeoffs, but may pose other challenges, such as intermittent production or reduced dispatchability, which is the ability and ease with which output from an electric generation facility can be altered. Other energy tradeoffs include transport and storage. Some fuels are easier to store and use existing transport networks and multiple transport modes, while others may require new or expanded infrastructure investments (e.g., pipelines). Significantly, low-carbon energy is not necessarily low in water or environmental impact (e.g., new hydropower reservoirs, freshwater-cooled utility-scale solar), and specific carbon mitigation policies and actions may increase or decrease water consumption. Because of these complexities and the difficulty in comparing different types of impacts, analyses supporting decision-making are often incomplete. It is within this complex and confusing context that policy decisions that influence future energy and related water policies are being made.

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Better Growth Better Climate: The New Climate Economy Report

The Global Commission on the Economy and Climate

The Global Commission on the Economy and Climate was set up to examine whether it is possible to achieve lasting economic growth while also tackling the risks of climate change. Its report seeks to inform economic decision-makers in both public and private sectors, many of whom recognise the serious risks cause by climate change, but also need to tackle more immediate concerns such as jobs, competitiveness, and poverty. The report brings together evidence and analysis, learning from the practical experiences of countries, cities, and business across the world.

This article is an excerpt from Part II of The Global Commission on the Economy and Climate's synthesis report, published in September 2014. The Commission is a major new international initiative to analyse and communicate the economic benefits and costs of acting on climate change. Commissioned by seven countries, it comprises former heads of government, finance ministers, and leaders in the fields of economics and business. The New Climate Economy is the Commission's flagship project, undertaken by a global partnership of research institutes and a core team. It provides independent evidence on the relationship between actions which can strengthen economic performance and those which reduce the risk of dangerous climate change. The report can be read in its entirety at http://newclimateeconomy.report/TheNewClimateEconomyReport.pdf.

The report's conclusion is that countries at all levels of income now have the opportunity to build lasting economic growth at the same time as reducing the immense risks of climate change. This is made possible by structural and technological changes unfolding in the global economy and opportunities for greater economic efficiency. The capital for the necessary investments is available, and the potential for innovation is vast. What is needed is strong political leadership and credible, consistent policies.

Future economic growth does not have to copy the high-carbon, unevenly distributed model of the past. There is now huge potential to invest in greater efficiency, structural transformation and technological change in three key systems of the economy—cities, land use, and energy.

1. Cities

Cities are crucial to both economic growth and climate action. Urban areas are home to half the world's population, but generate around 80% of global economic output,[1] and around 70% of global energy use and energy-related GHG emissions.[2] Over the next two decades, nearly all of the world's net population growth is expected to occur in urban areas, with about 1.4 million people—close to the population of Stockholm—added each week.[3] By 2050, the urban population will increase by at least 2.5 billion, reaching two-thirds of the global population.[4]

Given the long-lived nature of urban infrastructure, the way in which we build, rebuild, maintain and enhance the world's growing cities will not only determine their economic performance and their citizens' quality of life; it may also define the trajectory of global GHG emissions for much of the rest of the century. This chapter takes stock of cities' increasing contribution to both economic growth and climate change, examines the dominant patterns of development today, and presents an alternative pathway, as well as the policies needed to support and scale it up.

We focus in particular on three categories of cities:

- **Emerging Cities** are 291 rapidly expanding middle-income, mid-sized cities in China, India and other emerging economies, with populations of 1–10 million, and per capita incomes of US$2,000–20,000.
- **Global Megacities** are 33 major knowledge-, service- and trade-based urban hubs with populations above 10 million and per capita incomes over US$2,000, including capital cities such as London, Beijing and Tokyo.
- **Mature Cities** are 144 prosperous, established, mid-sized cities in developed countries, with per capita incomes above US$20,000, such as Stuttgart, Stockholm and Hiroshima.

Research carried out for the Commission shows that, on current trends, these cities combined will account for 60%

of global GDP growth between now and 2030. They will account for close to half of global energy-related GHG emissions. Some 300 emerging cities, with populations between 1 million and 10 million, will account for over half of this growth. The question for mayors, as well as for policy-makers in economics, finance, urban planning and environmental ministries, is how to plan urban development in a way that improves economic performance and quality of life while reducing GHG emissions.

A large share of urban growth around the world involves unplanned, unstructured urban expansion, with low densities and high rates of car use. If current development trends were to continue, the global area of urbanised land could triple from 2000 to 2030,[5] the equivalent to adding an area greater than the size of Manhattan every day. At the same time, the number of cars could double, from 1 billion today to 2 billion.[6]

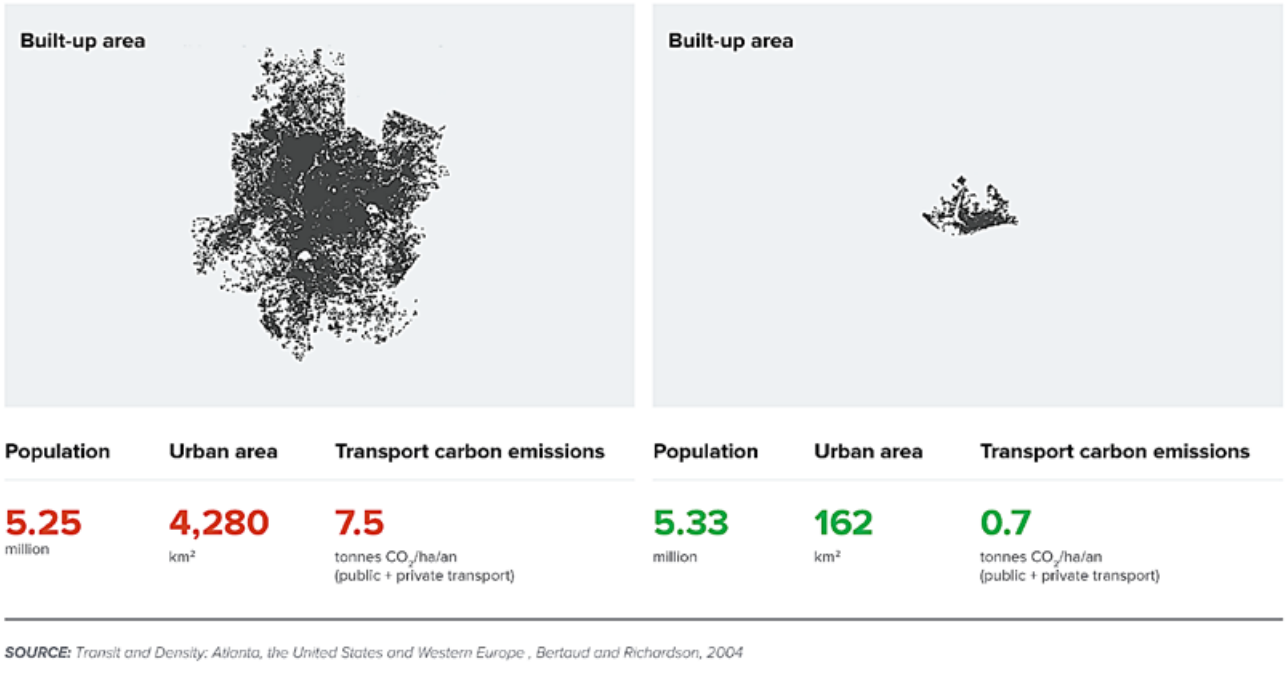
This sprawling pattern of expansion has major costs. It can double land used per housing unit, increase the costs of providing utilities and public services by 10–30% or more, and increase motor travel and associated costs by 20– 50%.[7] In fast-growing low- and middle-income countries, sprawled patterns can actually double or triple many costs, because they often have to import construction equipment. Sprawl also results in greater congestion, accident and air pollution costs; locks in inefficiently high levels of energy consumption; and makes it harder to implement more efficient models of waste management and district heating.

To unlock a new wave of sustained, long-term urban productivity improvements, we need a systemic shift to more compact, connected and coordinated development.

New modelling for this report shows that the incremental external costs of sprawl in the United States are about $400 billion per year, due to increased costs of providing public services, higher capital requirements for infrastructure, lower overall resource productivity, and accident and pollution damages.[8] Costs can be even more acute in rapidly urbanising countries where resources are more limited. In China, urban sprawl has reduced productivity gains from agglomeration and specialisation, and led to much higher levels of capital spending than necessary to sustain growth.[9] Research from 261 Chinese cities in 2004, for example, suggested that labour productivity would rise by 8.8% if employment density doubled.[10]

New analysis reviewed by the Commission shows that even in this context,

Atlanta and Barcelona have similar populations but very different carbon productivity



cities around the world have significant opportunities in the next 5–10 years to boost resource productivity and reduce GHG emissions through economically attractive investments in the buildings, transport and waste sectors. However, without broader structural shifts in urban design and transport systems, the benefits of those measures would quickly be overwhelmed by the impacts of sustained economic and population expansion under business-as-usual patterns. In fast-growing Emerging Cities in particular, the evidence suggests energy savings and emission reductions could be erased within seven years or less.[11]

Thus, to unlock a new wave of sustained, long-term urban productivity improvements, we need a systemic shift to more compact, connected and coordinated development. Cities that meet these criteria are more productive, socially inclusive, resilient, cleaner, quieter and safer. They also have lower GHG emissions—a good example of the benefits of pursuing economic growth and climate change mitigation together. The figure on the previous page, for example, contrasts the land use and GHG implications of urban development patterns followed in the US city of Atlanta and in Barcelona, Spain.

1.1 A better model for urban development

The alternative to unplanned, unstructured urban expansion is a more efficient urban development model, based on managed growth which encourages higher densities, mixed-use neighbourhoods, walkable local environments, and—in Global Megacities and Mature Cities—the revitalisation and redevelopment of urban centres and brownfield sites, complemented by green spaces. This model prioritises high-quality public transport systems to make the most of compact urban forms and to reduce car dependence and congestion. It also boosts resource efficiency through "smarter" utilities and buildings. It has the potential to reduce urban infrastructure capital requirements by more than US$3 trillion over the next 15 years.[13] Fast-growing Emerging Cities and small urban areas have a particularly important opportunity to adopt this model from the outset, learning from others' experience.

Shifting towards this alternative model would unlock significant medium- to long-term economic and social benefits. It would boost infrastructure productivity through the agglomeration effects of greater density, improve air quality, and deliver substantial cost savings in the transport sector. Estimates for the United States suggest that transit-oriented urban development could reduce per capita car use by 50%, reducing household expenditures by 20%.[14] At significantly lower fuel prices, sprawling Houston spends about 14% of its GDP on transport compared with 4% in Copenhagen and about 7% in many Western European cities. (Notably, Houston is now making ambitious efforts to overcome the legacy of sprawl through urban renewal and sustained investment in public transport systems.)[15]

Stockholm reduced emissions by 35% from 1993 to 2010 while growing its economy by 41%, one of the highest growth rates in Europe.

Adopting a compact, transit-oriented model in the world's largest 724 cities, new analysis for the Commission shows, could reduce GHG emissions by up to 1.5 billion tonnes CO_2e per year by 2030, mostly by reducing personal vehicle use in favour of more efficient transport modes. While achieving such savings would require transformative change, it would lay the foundation for even greater, sustained resource savings and emission reductions over the following decades.

In fact, such a shift is already happening. Re-densification is taking place in cities as diverse as London, Brussels, Tokyo, Hamburg, Nagoya and Beijing. More than 160 cities have implemented bus rapid transit (BRT) systems, which can carry large numbers of passengers per day at less than 15% of the cost of a metro.[16] The BRT in Bogotá, Colombia, for example, carries up to 2.1 million passengers per day, complemented by a citywide network of bicycle paths that connect residents to public transport, community spaces and parks.[17] China will have 3,000km of urban rail networks by 2015.[18] Nearly 700 cities had bike-sharing schemes at the end of 2013, up from five in 2000.[19]

From Copenhagen, to Hong Kong, to Portland, Oregon, in the U.S., cities are also showing how they can build prosperity, improve air quality, reduce GHG emissions all at once through more compact, connected and coordinated urban growth models. Stockholm reduced emissions by 35% from 1993 to 2010 while growing its economy by 41%, one of the highest growth rates in Europe.[20] Curitiba is one of the most affluent cities in Brazil, but has 25% lower per capita GHG emissions and 30% lower fuel consumption than the national average due to its groundbreaking approach to integrated land use and transport planning.[21]

1.2 A strategic approach to managing urban growth at national level

Countries need to prioritise better-managed urban development and increased urban productivity as key drivers of growth and climate goals. This is especially the case for countries with rapidly urbanising populations, as current institutional arrangements often result in urban development being driven by other national priorities. Here, coordination and cooperation between

national and regional governments and city leaders is essential.

Several countries are already making major policy changes to promote more compact, mixed-use land development, contain urban sprawl, maximise resource efficiency, and curtail the negative externalities of pollution, congestion and CO_2 emissions. A high-profile example is China's New National Urbanisation Plan, which places urban policy at the heart of Chinese decision-making.[22]

The Commission urges all countries to develop national urbanisation strategies in conjunction with city governments, with cross-departmental representation and assigned budgets, overseen by the centre of government and/or Ministry of Finance. They should also provide greater fiscal autonomy for cities, potentially linked to economic, social and environmental performance benchmarks, and consider setting up a special-purpose financing vehicle at the national level to support cities' efforts to become more compact, connected and coordinated, with appropriate private-sector participation. Existing infrastructure funding should be redirected to support this transition.

1.3 Stronger policies and institutions to drive compact, connected and coordinated urban development

Building better, more productive cities is a long-term journey. It requires persistence in several key areas to shift away from business-as-usual urban expansion, with countries, regions and cities working together. As a first step, cities should seize some of the numerous opportunities available to boost resource productivity in the short- to medium term, in sectors as diverse as buildings, transport and waste management. The evidence suggests that these smaller steps could build momentum for broader, longer-term reform, especially in capacity-constrained cities.

To drive the broader structural transformation of cities, governments should prioritise strengthening strategic planning at the city, regional and national levels, with a focus on improved land use and integrated multi-modal transport infrastructure. Only about 20% of the world's 150 largest cities have even the basic analytics needed for low-carbon planning.[23] These efforts should be supported by regulatory reform to promote higher-density, mixed-use, infill development, and new measures such as efficient parking practices.

It is also crucial to change transport incentives. **The Commission recommends that governments reform fuel subsidies and introduce new pricing mechanisms such as road user charges to reduce and eventually eliminate incentives to fossil-fuelled vehicle use.** They should also consider charges on land conversion and dispersed development, and measures that place a higher price on land than on buildings such as land taxes and development taxes. These reforms can raise revenue to invest in public transport and transit-oriented development.

Key ecosystem services are being compromised, and the natural resource base is becoming less productive.

In addition, there is a need for new mechanisms to finance upfront investments in smarter urban infrastructure and technology, such as greater use of land value capture, municipal bond financing, and investment platforms to prepare and package investments to attract private-sector capital. This should be complemented by more effective and accountable city-level institutions.

1.4 The role of the international community

The international community also has a key role to play in fostering better-managed urban growth, both by building and sharing knowledge about best practices, and by steering finance towards compact, connected and coordinated urbanisation, and away from sprawl.

The Commission recommends developing a Global Urban Productivity Initiative to promote and assist in the development of best practices in boosting urban productivity and support countries' and cities' own efforts. The initiative should: build on the existing work of key international organisations already working in this field, including city networks such as C40 and ICLEI—Local Governments for Sustainability,[24] and involve rapidly urbanising countries, mayors and business leaders. Key activities could include reviewing institutional options for systematic collection of city-level data, developing urbanisation scenarios and best practice guidance, creating an international standard for integrated municipal accounting, and targeted capacity-building.

In addition, a global city creditworthiness facility should be set up to help cities develop strategies to improve their "own source" revenues and, where sovereign governments allow it, increase their access to private capital markets. Only 4% of the 500 largest cities in developing countries are now deemed creditworthy in international financial markets; every US$1 spent to correct this can leverage more than US$100 in private-sector finance.[25] The new facility should build on and scale-up the existing programme of the World Bank, and assist cities in both developing and developed countries.

Finally, it is crucial that multilateral development banks (MDBs) rapidly phase out the financing of investments that lock in unstructured, unconnected urban expansion. The banks should work with client and

donor countries to redirect overseas development assistance and concessional finance towards supporting integrated citywide urban strategies and investment in smarter infrastructure and new technology. Greater consideration should also be given to redirecting overall MDB funding to account for the growing importance of cities in economic development in rapidly urbanising countries, as well as the scaling-up of support to help cities prepare and package urban infrastructure investments.

2. Land use

Rapid global population growth, urbanisation, rising incomes and resource constraints are putting enormous pressure on land and water resources used by agriculture and forests, which are crucial to food security and livelihoods. Roughly a quarter of the world's agricultural land is severely degraded,[26] and forests continue to be cleared for timber and charcoal, and to use the land for crops and pasture.[27] Key ecosystem services are being compromised, and the natural resource base is becoming less productive. At the same time, climate change is posing enormous challenges, increasing both flood and drought risk in many places, and altering hydrological systems and seasonal weather patterns.

Agriculture, forestry and other land use (AFOLU) also account for a quarter of global GHG emissions.[28] Deforestation and forest degradation are responsible for about 11% of global GHGs, net of reforestation;[29] the world's total forest land decreased by an average of 5.2 million ha per year over 2000-2010.[30] Emissions from agriculture include methane from livestock, nitrous oxide from fertiliser use, and carbon dioxide (CO_2) from tractors and fertiliser production

Those factors combined make agriculture and forests top-priority sectors for climate policy, particularly in tropical countries, which often include substantial areas of carbon-rich forest. They are also crucial to many developing economies: in countries in the US$400–1,800 per capita GDP range (2005$), many of them in Asia, the World Bank found agriculture was 20% of GDP on average; in sub-Saharan Africa, it was 34%, and accounted for almost two-thirds of employment and a third of GDP growth in 1993–2005.[32] Globally, 70% of the poorest people live in rural areas and depend on agriculture for their livelihoods, mostly in the tropics.[33]

Developing countries are also where more than 80% of the global demand growth for agricultural and forest products will occur over the next 15 years.[34] By 2050, the world's farms will need to produce 70% more calories than in 2006, mainly due to population growth, rising incomes and changing diets in developing countries.[35] Meeting this new demand will be critical to growth, food security and poverty alleviation; it will also create huge opportunities for businesses—from small farms and local businesses, to multinationals. How this demand is met will be critical to climate outcomes.

Many countries subsidise inputs to try to boost productivity, but they can also lead to waste and environmental damage.

2.1 Supply-side measures in agriculture

The "Green Revolution"—a multi-decade effort to modernise farming in the developing world—boosted crop yields by developing high-yield grain varieties and sharply increasing the use of agricultural inputs (irrigation water, fertilisers). Many of the measures needed today are more location-specific, addressing issues such as drought, floods, pests and saltwater intrusions. There are already promising innovations, such as "Scuba rice," which can withstand submersion in water, a common situation as floods increase in South and Southeast Asia. The variety was introduced in India in 2008 and has since been adopted by 5 million farmers in the region.[36]

For major cereal crops, the research supported by the Consultative Group on International Agricultural Research (CGIAR), a US$1 billion-a-year global partnership, will be invaluable. Public-sector support in individual countries is also crucial, particularly for rice and "orphan crops"—some starchy root crops, vegetables, legumes, etc.—that have little global market value but are local dietary staples. Yet in 2008, governments only spent US$32 billion on agricultural R&D—including US$15.6 billion (2005 PPP) in developing and emerging economies. Private-sector funding added another US$18 billion (2005 PPP), primarily in developed countries.[37]

There is considerable scope to increase funding for agricultural R&D to increase productivity and resilience, whether through multilateral, regional or national institutions. **The Commission recommends that bilateral donors, foundations and national governments in developing countries collectively double the financing of crop, livestock and agroforestry R&D in developing countries, from US$15 billion in 2008 to US$30 billion in 2030.**

One way to free up funds for R&D is to reduce input subsidies (mainly for fertiliser and water). Agricultural subsidies in China rose to US$73 billion in 2012, or 9% of agricultural output;[38] India provided roughly US$28 billion in input subsidies to nitrogenous fertilisers and electricity for pumping agricultural water in 2010.[39] OECD country governments paid farmers US$32 billion based on input use in 2012.[40] Many countries subsidise inputs to try to boost produc-

tivity, but they can also lead to waste and environmental damage.

Governments should phase out direct agricultural input subsidies, and redirect the savings to pay for the provision of social goods and provide more direct support to low-income farmers. This would incentivise better, more targeted input use, reduce associated pollution and GHG emissions, and save farmers money, since they pay for inputs even if they are subsidised. Potential GHG emission reductions of 200 million tonnes of CO_2e per year have been estimated from more efficient use of fertilisers in China alone,[41] and close to 100 million tonnes of CO_2e per year from more efficient use of water in India.[42]

Halting and reversing land degradation should also be a priority. About one-quarter of agricultural land globally is now severely degraded.[43] Case studies in China, Ethiopia, Mexico, Uganda, Rwanda, Chile and Indonesia found land degradation decreased productivity by 3–7% per year.[44] Well-tested practices can add organic matter to the soil and control water runoff, jointly improving water retention and soil fertility, and increasing carbon storage in soils, plants and trees.

The Commission recommends that government and their development partners commit to restoring 150 million ha of degraded agricultural land through scaled-up investment and adoption of landscape-level approaches.

Such approaches consider ecosystems, resource use and human activities across the broader landscape, not just farm-by-farm. They also typically involve planting trees on farms and/or restoring and protecting forested areas around farms. They can be large-scale and capital-intensive, or more narrowly targeted, introducing a handful of proven techniques.

The 1994-2005 Loess Plateau projects in China, which mobilised US$491 million in funding and curbed soil erosion on nearly 1 million ha, are a shining example of large-scale efforts. The projects focused on halting the activities that led to degradation—in particular planting on steep slopes, tree-cutting, and free-range grazing of goats; introduced heavy equipment to build wider and sturdier terraces for grain cultivation, and encouraged farmers to plant trees and to allow marginal land to grow wild again. The projects sharply increased grain yields and lifted more than 2.5 million people out of poverty. Soil carbon storage also increased, mostly due to the restoration of forests and grassland.[45] The project model has since been scaled up to cover large areas of the country, through China's US$40 billion "Grain for Green" programme.[46]

Demand for timber, pulp and bioenergy is projected to grow over the next 15 years, putting even more pressure on lands currently supporting natural forests.

The Maradi and Zinder regions of Niger, meanwhile, show what can be achieved even at a low cost. Farmers interplanted nitrogen-fixing trees on cropland, or allowed roots and stumps to regenerate, increasing tree and shrub cover 10- to 20-fold. Agricultural productivity was significantly increased on 5 million ha of severely degraded farmland,[48] and biodiversity and soil fertility improved across the entire area. Real farm incomes more than doubled, stimulating local non-farm services as well.[49] Similar conditions exist on another 300 million ha of drylands in Africa alone, suggesting considerable potential for scaling.[50]

Perceptions of increasing climate and market risk following the food price spikes of 2008 have made both governments and smallholder farmers overly risk-averse in the poorer countries. This has hindered adoption of market-oriented policies, investments and technologies that may be essential for sustained increases in farm income. However, failure to pay attention to increased uncertainty can also be catastrophic for the poor. Solid institutions and leadership are needed to encourage collective action; appropriate incentives and more secure property rights are also crucial. **Multilateral and bilateral funders, as well as foundations, should sharply increase finance for climate change adaptation, prioritising the poorest farmers in countries that are exposed to significant climate hazards and lack credible access to infrastructure, alternative employment, and risk insurance mechanisms.**

2.2 Forests as natural capital

Forests also need much better protection. Demand for timber, pulp and bioenergy is projected to grow over the next 15 years, putting even more pressure on lands currently supporting natural forests.[51] Projections to 2050 indicate a threefold increase in wood removals by volume compared with 2010.[52] Increasing the profitability of alternative land uses, such as through agricultural intensification, also increases pressures to clear land. Yet the value generated by agriculture in former forestlands and by the extraction of forest products also brings costs. Forests are an important form of natural capital, generating economic returns (and climate benefits) for countries, companies and citizens. The ecosystem services that forests provide are especially important to the resilience of agricultural landscapes. Thus, protecting remaining natural forests and restoring forest cover—globally and in individual regions—is a key part of feed-

ing the world and building a resilient economy.

Millions of hectares of forest are being lost or degraded each year, due to agricultural expansion, timber harvesting, extraction for fuelwood or charcoal, mining and road- building.[53] Once trees have been removed, leading to forest degradation, the land is often converted to other uses, such as agriculture—which is what is technically known as deforestation. While forest degradation and deforestation in the forests often go together, the drivers are different and may require differing approaches.[54] The increasing demand for forest products from growth in emerging economies is central to forest degradation, while the decision on whether to allow degraded forest land to regenerate into forest or to convert it to other uses is driven by the financial viability of alternative uses, property rights, and governance of markets and resources.

Problems arise because market prices, tax policies, lending conditions, and commodity procurement practices often do not reflect (or "internalise") the wider economic value of a forest. These shortcomings are compounded by lack of information, lack of accountability, and in some places, corruption and powerful vested interests. Any form of capital needed to underpin strong economic growth—whether natural, financial or human—cannot be enhanced and used effectively under such market and governance failures.

Policy interventions are needed to address these problems, and there are many successful examples, from Brazil, to Costa Rica, to Korea. Payments for ecosystem services, such as under REDD+, can also play a key role in helping countries preserve their natural capital. **The Commission recommends that developed countries aim to provide at least US$5 billion per year in REDD+ financing (focussed increasingly on payments for verified emission reductions).**

Options for the latter include a results-based REDD+ window (subfund) in the Green Climate Fund,[55] or countries counting emission reductions from REDD+ as part of their "nationally determined contributions" under the 2015 climate agreement. Over time, carbon markets are expected to play an increasing role. Law enforcement and the verification necessary for results-based finance are greatly facilitated by the convergence of low-cost satellite imagery, cloud computing, high-speed internet connectivity, smartphones and social media. These are ushering in a new world of "radical transparency," where what is happening in a far-away forest can now be known close to home.

On a caloric basis, a quarter of world's food is now wasted between farm and fork.

Ambitious forest restoration targets are needed as well. **The Commission recommends that countries commit to restoring 350 million ha by 2030, and promptly begin to do so.** This is consistent with Aichi Target 15, which calls for restoring 15% of degraded ecosystems,[56] and could generate net benefits on the general order of US$170 billion per year from watershed protection, improved crop yields, and forest products.[57] Pathways for restoration at this high level would need to include agroforestry and mosaic restoration in agricultural areas (perhaps on degraded steep slopes of limited commercial value), in addition to assisted or natural regeneration of forests. This would sequester about 1–3 Gt CO_2e per year, depending on the pathways used and biomes prevalent in the areas restored.[58]

2.3 Demand-side measures

To ease pressure on the land, demand-side measures are also important. On a caloric basis, a quarter of world's food is now wasted between farm and fork. For example, food waste reduction measures in developed countries could save US$200 billion per year by 2030, and reduce emissions by at least 0.3 Gt of CO_2e.[59] Policy-makers should also work to reduce demand for food crops for biofuels and promote a shift in diets, away from red meat especially.

The Commission recommends that nations and companies commit to reducing the rate of post-harvest food loss and waste by 50% by 2030 relative to present levels. In addition, governments that subsidise or mandate the use of biofuels should phase out these interventions to the extent that they involve food crops.

Our report estimates that following the above recommendations in agriculture, forests and land use change would very conservatively yield an abatement range of between 4.2 to 10.4 Gt CO_2e per year in 2030, with an expectation of 7.3 Gt CO_2e. The main sub-components of this estimate are: boosting agricultural productivity through a focus on "climate-smart agriculture" innovation (0.6–1.1 Gt); improved forest governance and conservation measures to achieve zero net deforestation, supported by REDD+ (1.6–4.4 Gt); restoring 150 million ha of degraded agricultural land and 350 million ha of degraded forest landscapes, for a total of 500 million ha (1.8–4.5 Gt); and reduced food waste (0.2– 0.4 Gt).

3. Energy

We are in a period of unprecedented expansion of energy demand. Global energy use has grown by more than 50% since 1990,[60] and must keep growing to support continued development. As much as a quarter of today's energy demand was created in just the last decade, and since 2000, all the net growth has

occurred in non-OECD countries, more than half of it in China alone.[61] Past projections often failed to anticipate these dramatic shifts, which nonetheless have affected the energy prospects of nearly all countries. The future is now even more uncertain, as projections show anything from a 20% to 35% expansion of global energy demand over the next 15 years.[62]

A major wave of investment will be required to meet this demand: around $45 trillion will be required in 2015–2030 for key categories of energy infrastructure.[63] How that money is spent is critically important: it can help build robust, flexible energy systems that will serve countries well for decades to come, or it can lock in an energy infrastructure that exposes countries to future market volatility, air pollution, and other environmental and social stresses. Given that energy production and use already accounts for two-thirds of global GHG emissions,[64] and those emissions continue to rise, a great deal is at stake for the climate as well.

The next 15 years offer an opportunity to create better energy systems that also reduce future climate risk. Achieving this will require a multi-faceted approach. The starting point must be to get **energy pricing right, implementing energy prices that enable cost recovery for investment and less wasteful use of energy, and removing subsidies for fossil fuel consumption, production and investment.** Other, complementary initiatives also will be required. One key task is to increase resource efficiency and productivity—to make the most of our energy supplies. Some countries have already made significant gains in this regard, but there is much untapped potential. It also will be necessary to expand our energy supply options. Innovation in technology, as well as business models, financing systems, and regulatory frameworks, is already doing this, from unconventional gas and oil, to the rapid growth of renewable energy technologies.

3.1 A changing outlook for coal

Coal has been abundant and affordable for many generations, and in several fast-growing economies, it remains the default option for rapid expansion of the power supply and for heavy industry. But conditions are changing, driven by fast-rising demand and a sharp increase in coal trade. Prices are twice the levels that prevailed historically,[65] with projections for continued high levels in the range of US$85-140 per tonne, even as other options, notably shale gas in the U.S. and renewable energy sources globally, have fallen in cost. The future security advantage of coal is also less clear than before. India has imported more than 50% of new coal requirements in recent years, and may face still higher import dependence without a change of course.[66]

Renewable energy can compete only where institutions and markets are set up to accommodate it.

The damage from air pollution has proven substantial and hard to address once coal-based infrastructure is built out; in China, mortality from air pollution is now valued at 10% of GDP.[68] In many countries, properly accounting for the cost of pollution erodes the cost advantage of coal. For example, coal-fired power has a financial advantage in much of Southeast Asia, at costs of US$60–70 per MWh. But properly accounting for air pollution can add a cost of US$40/MWh or more, enough to bridge or exceed the cost gap to alternatives.[69]

Coal is also the most carbon-intensive of fossil fuels, accounting for 73% of power sector emissions but only 41% of generated electricity.[70] Reducing coal use is an essential feature of pathways to reduce CO_2. For example, the IEA 450 scenario sees coal-fired power generation falling to 60% of 2011 levels by 2030, and total reductions in coal emissions of 11 Gt CO.[71] Analysis carried out for the Commission suggests that as much as half of this reduction could be achieved at zero or very low net cost, once the changing cost of alternatives, and reduced health damages and other co-benefits are taken into account.[72]

Given the known risks associated with coal, it is time to reverse the "burden of proof," so coal is no longer assumed to be an economically sound choice by default. Instead, governments should require that new coal construction be preceded by a full assessment showing that other options are infeasible, and the benefits of coal outweigh the full costs.

3.2 A new era for renewable energy sources

Renewable energy sources have emerged with stunning and unexpected speed as large-scale, and increasingly economically viable, alternatives to fossil fuels, particularly in the power sector.[73] Over a quarter of the growth in electricity generation in 2006–2011 came from renewables.[74] Hydropower has long been a major energy source, but rapidly falling prices are also making wind and solar power increasingly cost-competitive with coal and gas in many markets.[75] In Brazil, for example, wind power was the cheapest source of new power at recent auctions, and South Africa has procured wind power at costs up to 30% below those of new coal-fired power.[76]

Solar photovoltaic (PV) power remains costlier than wind, but now costs half as much as in 2010,[77] as module prices have fallen 80% since 2008.[78] The world's largest, unsubsidised solar PV plant, 70 MW in Chile's Atacama Desert, was contracted in 2013.[79] At least 53 solar PV plants over 50 MW were operating by early 2014, in at least 13 countries, and several planned

projects are now considered competitive without subsidies.[80] Small-scale solar is also already competitive with retail electricity in many countries, and is rapidly becoming cheaper than other off-grid options such as diesel generators.[81] Biomass, geothermal and nuclear power are also proven technologies. Overall, a sea change in expectations has taken place. Even baseline scenarios now foresee wind and solar power contributing large shares of new power in the next two decades,[82] and zero-carbon sources overall can be a mainstay of meeting future energy needs.

There is significant potential to go further. Costs are still falling, and virtually all countries have resources that they can exploit. But there also is strong inertia and specific challenges. Harnessing this potential will require active effort and support for these new ways of supplying power. Renewable energy can compete only where institutions and markets are set up to accommodate it. The benefits of energy security and lower pollution need to be accounted for. Markets and financing arrangements now set up for fossil fuels will need to be adapted. In addition, the variability of solar and wind power output leads to some additional costs of grid integration and the need to adjust electricity system planning as the share increases. Pioneer countries that are now increasing their share of variable renewables to high levels have a key role to play in developing the solutions that will enable others to reach high shares in decades to come.

Nonetheless, with the right mechanisms in place most countries can give renewables a central role in new supply for the next 15 years. Yet on current course there is a risk that the potential is not realised. **The Commission recommends that countries raise the ambition for renewable and other zero-carbon energy.** All should articulate and evaluate an energy strategy with significant contributions from renewable and other zero-carbon energy, and adapt electricity system planning, market and financing arrangements, and support systems to enable these options to fulfil their potential in meeting future power needs.

3.3 Natural gas as a 'bridge' to low-carbon energy and the role of CCS

Natural gas also is changing its role. Outside a few countries dependent on coal, it already is a dominant source of new energy.[84] In the United States, cheap shale gas has swung the pendulum strongly away from coal, and there are potential reserves in many other countries. Gas has also been discussed as a potential "bridge" to lower-carbon energy systems, because it can quickly displace coal, reducing both CO_2 and local air pollution.[85] In addition, gas can support power systems with higher shares of variable renewable energy.

In developed countries, energy efficiency improvements have cut the effective demand for energy by 40% in the last four decades.

However, the potential for gas as "bridge" fuel is not guaranteed.[86] Strong accompanying policies will be needed, such as attributing to coal its full social cost, regulating production to limit fugitive methane emissions, putting a price on carbon emissions, and supporting low-carbon technologies so their development and deployment are not slowed down. **The Commission also urges prompt action to address non-CO_2 GHG emissions from energy, starting by accelerating efforts to identify and curtail fugitive methane emissions from oil and gas production.**

Carbon capture and storage (CCS), meanwhile, offers the potential to reduce CO_2 emissions while continuing to use some fossil fuels. Many scenarios to limit global warming to 2°C rely on some level of CCS deployment, and estimate that costs would be higher if this option were not available.[87]

Yet although CCS is a proven technology in the upstream petroleum sector, in the power sector, it is still in the early stages, and investment is a fraction of what the IEA estimates is needed.[88] Scaling up CCS so it becomes a realistic option will require both a social license to operate and long-term, stable climate policy: support for demonstration projects, as well as mechanisms to create demand, underpin investment in infrastructure, and enable the development of new business models.

3.4 Making the most of our energy supply

The greatest opportunity to benefit from modern energy is for the 1.3 billion people who have no access to electricity, most of them in Africa and Asia, and the 2.6 billion who lack modern cooking facilities.[89] Furthermore, in many urban and peri-urban areas in the developing world, large numbers of people have only partial or unreliable access to electricity.

Proven routes to electricity access through urbanisation and grid extension are now complemented by the potential for off-grid and mini-grid solutions. Falling costs, new business models, and technological innovations are making these increasingly cost-effective. In addition to finance and policy, more innovation and experimentation are needed, not least to ensure these solutions prove their ability to supply low-carbon electricity as demand grows beyond lighting and low-power appliances. There is also a need to accelerate the pace of providing access to better cooking facilities.[90] **To advance these efforts, the Commission recommends launching a platform for public-private collaboration for innovation in distributed energy access.**

Another large opportunity involves improving in energy efficiency and productivity (the economic value created per unit of energy input), which effectively provides the world with an additional fuel. In developed countries, energy efficiency improvements have cut the effective demand for energy by 40% in the last four decades.[91] No other source of energy has contributed as much.

Focusing on energy efficiency as the "first fuel" has large benefits in terms of balance of payments (from avoided fossil fuel imports), growth potential, local air pollution, greater levels of energy services, and lower carbon emissions. It can also be highly cost-effective compared to increasing the supply of energy. Even with "rebound" effects, efficiency thus is an essential contributor to meeting energy needs. Exploiting efficiency opportunities will be particularly important to emerging economies, as they rapidly grow their energy demand. India's energy requirements in 2030, for example, are 40% greater in a scenario of low energy efficiency than in one with high energy efficiency.[92]

On a global scale, the energy required to provide energy services in 2035 could vary by the amount of energy used today by the OECD, depending on whether a high or low efficiency path is struck.[93] And large untapped efficiency opportunities remain—across buildings, vehicles and industry. Yet energy efficiency is held back by a combination of ineffective energy pricing, policy distortions, lack of awareness, poorly aligned incentives within key markets such as housing, and low prioritisation of energy efficiency by many businesses. **Thus, the Commission recommends that governments develop national roadmaps to identify and capture the potential for energy demand management measures.** These should include specific targets and sector-based opportunities, as well as policy measures addressing the barriers that prevent the development of energy-productive economic activity and energy-efficient end use.

Conclusion

The shift towards a low-carbon, climate-resilient path of growth and development will not be easy, and governments will need to commit to a just transition. Not all climate policies are win-win, and some trade-offs are inevitable, particularly in the short term. Although many jobs will be created, and there will be larger markets and profits for many businesses, some jobs will also be lost, particularly in high-carbon sectors. The human and economic costs of the transition should be managed through support for displaced workers, affected communities and low-income households. Strong political leadership and the active participation of civil society will be needed, along with far-sighted, enlightened business decisions.

The wealth of evidence presented by the report shows that there is now huge scope for action which can both enhance growth and reduce climate risk. Leading businesses, cities and countries are showing how this can be done. The world's economic leaders face a remarkable opportunity to set the world on the path to sustainable prosperity. The prize is immense, and the moment of decision is now. We can achieve both better growth and a better climate.

Endnotes

1 Please refer to the complete report for all footnotes: http://newclimateeconomy.report/TheNewClimateEconomyReport.pdf.

News (FROM PAGE 4)

an individual. Scarlett has been advancing natural resources science, policy, and publication for 25 years. She works actively on landscape-scale conservation, ecosystem services, biodiversity protection, climate, and energy issues.

From 1985 until 2001, Scarlett developed and implemented strategies for citizen stewardship of natural resources at the Reason Foundation in Los Angeles, initially as a research director and policy analyst, and briefly as its president, before joining the George W. Bush Administration.

In 2001, Scarlett was appointed assistant secretary and subsequently deputy secretary of the U.S. Department of the Interior. She created an administrative framework to guide the department's public outreach and public-private partnerships for the purpose of enhancing conservation at landscape scales to address land, water, and wildlife conservation challenges. She is widely recognized as the primary author of the idea, policy, and practice of "cooperative conservation."

Since leaving the department in 2009, Scarlett has taught courses on climate change and landscape conservation at UC Santa Barbara's Bren School of Environment Science and Management as a Zurich Financial Services Distinguished Visiting Lecturer. She has also served as co-director at Resources for the Future's Center for Management of Ecological Wealth, providing strategic planning and policy research on climate change, energy, ecosystem services, and land conservation.

Currently, Scarlett serves as The Nature Conservancy's managing director for public policy. She oversees all of The Nature Conservancy's conservation policy and government relations internationally, nationally, and at state and local levels.

Pictured standing (L-R): Whitford Remer (American Society of Civil Engineers), Howard Rosen (Society of Wood Science and Technology), Dick Engberg (American Water Resources Association), Alison Mize (Ecological Society of America), Roxanne Blackwell (American Society of Landscape Architects), Nancy Somerville (American Society of Landscape Architects), Tom Chase (American Society of Civil Engineers), Karen Paczjowski (Geological Society of America), Julie McClure (American Society of Agronomy, Crop Science Society of America, Soil Science Society of America), Robert Day (RNRF), Melissa Goodwin (RNRF); seated (L-R): Jennee Kuang (RNRF), Lynn Scarlett (The Nature Conservancy), Sarah Gerould (Society of Environmental Toxicology and Chemistry).

Round Table on Ecosystem Services

The RNRF Washington Round Table on Public Policy met with Lynn Scarlett, The Nature Conservancy's managing director for public policy and recipient of RNRF's 2014 Sustained Achievement Award, on September 23, 2014. The round table convened at The Nature Conservancy's headquarters in Arlington, Virginia. Scarlett spoke about the concept of "ecosystem services," why it has recently gained traction in the scientific community, and how it is being incorporated into the work of federal agencies.

Ecosystem services are benefits provided by ecosystems for people and nature. Recreational and provisioning services have long been recognized. More recently, ecosystem services has focused on the idea that ecosystems can work in conjunction with the built environment. Examples of services include natural landscapes that help purify air and water, forests that sequester carbon and help regulate temperature, and oyster reefs that provide effective wave attenuation.

Scarlett identified five reasons for the burgeoning interest in ecosystem services: 1) there is a continual search for new public and private revenue streams, 2) ecosystem services provide potential cost savings for services, 3) ecosystem services may support more cost-effective environmental performance, 4) there are costs associated with ecosystem losses, and 5) there have been efforts to enhance resilience in the context of changing conditions, especially in light of climate change.

Federal agencies manage about 700 million acres in the United States, and have many opportunities to incorporate ecosystem services into land management decisions. Numerous federal statutes and regulations already allow for this. For example, the National Environmental Policy Act (NEPA) sets forth a framework that allows for the integration of ecosystem services into its analysis. The Department of Defense (DOD) has conceptualized ecosystem services in developing infrastructure in the southeast. In an effort to preserve source water, DOD has considered ecosystem services in place of, or in addition to, built infrastructure.

Despite its utility, the language and application of ecosystem services introduce a suite of challenges. The Nature Conservancy has found that the term ranks at the very bottom of conservation-related terms used and recognized by the public. As a result, the organization uses "value of nature" or "nature's solutions" to convey the concept. Also, metrics need to be developed to measure ecosystem services to satisfy regulatory requirements. Finally, promoting and generating ecosystem services requires a systems approach featuring cross-jurisdictional and cross-agency coordination.

The concept of ecosystem services offers a promising framework for natural resources management that benefits both humans and nature. Many opportunities exist for the application of ecosystem service programs, though challenges must be addressed for truly effective results.

Round Table on Science Communication

The RNRF Washington Round Table on Public Policy met with Dr. Donald Boesch, professor of marine science and president of the University of Maryland Center for Environmental Science, on November 13, 2014. The round table convened at the American Geophysical Union headquarters in Washington, D.C. Boesch discussed the importance and methods of effective science communication and its application to climate change and water management and policy issues.

Scientists and "scientific boundary" entities, such as professional organizations and nonprofits, play a critical role in influencing public opinion and sound policymaking in today's political climate. Sophisticated communication strategies are essential. Boesch recommended that scientists work with journalists and the popular media to convey complex scientific concepts to a general audience. Most people, including those

Dr. Donald Boesch

with an understanding of science, often receive and retain the majority of their information from the media. He cited this as a more effective approach to sway public opinion than the top-down approach traditionally applied by scientists approaching government officials.

In this "era of climate responsibility," successful climate change adaptation and mitigation is particularly contingent upon effective scientific communication. Skepticism regarding scientific findings can often arise not from a distrust of science itself, but because expected solutions can be initially unattractive. To convey the same message to different audiences, scientists must reframe problems and solutions. They must learn to simplify technical language and use metaphors and storytelling to connect with individuals outside of the scientific community.

American Geophysical Union

AGU Launches Free Science News Website

AGU announced on December 9, 2014 the transformation of its flagship print newspaper, *Eos*, into a robust, dynamic and openly accessible online publication—Eos.org. The new site will focus on providing the latest Earth and space science news, continuing *Eos*'s 35-year tradition of excellence. Eos.org will also provide expanded feature and opinion content, as well as blogs and special series, and extensive coverage of trends and other issues influencing the Earth and space sciences.

In keeping with AGU's mission to promote discovery in Earth and space science for the benefit of humanity, Eos.org will not be targeted solely to AGU members. Instead, it will be written for all members of the Earth and space science community, including those working in academia, and the government and private sectors, as well as those in related and allied fields. As such, the site will be accessible free of charge

For more information, contact AGU, 2000 Florida Ave NW, Washington, DC 20009; (202) 462-6900, www.agu.org.

American Meteorological Society

23/5 Talks Give #AMS2015 New Angle

At the annual meeting in Phoenix, AMS premiered a new series of TED-styled conversations called "23|5 Talks," which brought together some of the leading voices in the weather, water,

and climate community. The first 23|5 Talk was given by Sheldon Drobot, who works at UCAR on providing up-to-the-minute weather information for drivers. Sheldon spoke about the dangers of driving in bad conditions and solutions to these problems. See the AMS's YouTube page for other 23|5 Talks with Marshall Shepherd, Kristen Averyt, and David Kenny.

For more information, contact AMS, 45 Beacon Street, Boston, MA 02108; (617) 227-2425, www.ametsoc.org.

American Society of Civil Engineers

Infrastructure Report Card Android/iOS Tablet App Offers New State Information

On December 11, 2014, ASCE released an update to its 2013 *Report Card for America's Infrastructure* Android/iOS app for tablets and website featuring new state data and graphics. The update is available for free download in the Apple App Store, Google Play Store and at www.infrastructurereportcard.org, and includes new video content, graphs, charts, and 20 new case studies or "success stories" that underscore the benefits of investing in infrastructure.

The Report Card, originally released in March 2013, graded the nation's infrastructure at a D+, highlighting the need for further investment in the 16 categories documented in the report, including roads, dams, and drinking water. This app update does not change the grades or evaluation from the 2013 report, but does update the state-level data to provide the most current information for each state's infrastructure.

For more information, contact ASCE, 1801 Alexander Bell Drive, Reston, VA 20191; (800) 548-2723, www.asce.org.

American Society of Landscape Architects

ASLA Launches New Website

ASLA launched a redesign of its website on November 7, 2014. The redesign will educate the general public about landscape architecture with engaging content while still offering ASLA members a wealth of information and resources.

The website redesign features new "Learn What Landscape Architects Do" sections, which provides people eager to learn about the profession with a high-resolution, full-screen portfolio of what ASLA and its members create. The website also displays ASLA's current projects and advocacy campaigns.

For more information, contact ASLA, 636 Eye Street NW, Washington, DC 20001; (202) 898-2444, www.asla.org.

ASLA to Renovate Chinatown Building into Center for Landscape Architecture

ASLA has embarked on a $4 million plan to renovate its headquarters building to create a Center for Landscape Architecture.

The Society purchased the 12,000 square foot building located at 636 Eye Street, NW, in 1997 for $2.4 million, just as D.C.'s Chinatown neighborhood was being revitalized. After 17 years of occupancy, any building would be in need of renovation. However, ASLA leaders saw the opportunity to do much more.

"Today, our headquarters is in a vibrant neighborhood and the building is valued at $6.9 million—a 189% return on our investment," said Mark A. Focht, FASLA, immediate past president of the ASLA, in presenting the renovation plan to the Society's Board of Trustees for approval in late November 2014. "This is an opportunity to create a facility to reflect the image and ethic of our profession—a world-class Center for Landscape Architecture that will inspire and engage our staff, our membership, allied professionals, public officials and the general public."

Gensler was selected through a request for proposal process to lead the design team, which includes landscape architecture firm Oehme, van Sweden, to ensure the profession's values will be well-represented. The building will be designed to LEED Platinum and WELL™ building standards.

Conceptual drawings are available on the Center for Landscape Architecture website, along with a list of donors, naming rights opportunities, and information on making a donation to the project. Currently, construction is planned to begin in fall of 2015.

For more information, contact ASLA, 636 Eye Street NW, Washington, DC 20001; (202) 898-2444, www.asla.org.

American Water Resources Association

Wigington to Head Journal of the American Water Resources Association

AWRA is pleased to announce that Dr. Parker J. Wigington, Jr. has been named the new Editor-in-Chief of the Journal of the American Water Resources Association (JAWRA) effective January 1, 2015. Wigington has an extensive publication record dealing with the influence on human activities and natural processes on watersheds and associated aquatic ecosystems. During his 28 year career with the U.S. Environmental Protection Agency Office of Research and Development, Wigington led a wide range of interdisciplinary research efforts ranging from the effects of acidic deposition on aquatic ecosystems to connectivity within stream and river systems. He is currently a research and consulting hydrologist residing in Redding, CA. He is also a courtesy faculty member in the College of Earth, Ocean, and Atmospheric Sciences at Oregon State University.

For more information, contact AWRA, P.O. Box 1626, Middleburg, VA 20118; (540) 687-8390, www.awra.org.

Geological Society of America

New GSA Book on 2011 Virginia Earthquake Goes Online First

"Online First" is a new method of delivery for The Geological Society of America that provides online publication ahead of print for book chapters as the volume is being assembled. One of the first books to make this jump is *The 2011 Mineral, Virginia, Earthquake, and Its Significance for Seismic Hazards in Eastern North America,* online at http://specialpapers.gsapubs.org/online-first/509. This volume takes a detailed look at the 2011 magnitude ~5.8 earthquake centered in Mineral, Virginia, USA.

Soon to be a collection of 23 chapters, this GSA volume brings together important new seismologic, engineering, geologic, hydrologic, and geophysical data that contribute to the understanding of earthquakes in eastern North America and contribute toward better assessment and mitigation of seismic hazards. Online First makes these results available as quickly as possible to geoscientists, engineers, and decision makers interested in understanding earthquakes and seismic hazards in eastern North America and other intraplate settings.

For more information, contact GSA, P.O. Box 9140, Boulder, CO 80301; (303) 357-1806, www.geosociety.org.

Society of Environmental Toxicology and Chemistry

Reviewer Rewards Program

SETAC is delighted to announce the launch of the Reviewer Rewards Program. SETAC publishes high quality research thanks to the diligence and keen eye of the journals' editorial board members and reviewers that have helped to shape book chapters and journal articles. Reviewing manuscripts can be time consuming, and there is often little tangible reward for the work. It is seen as a "pay it forward" labor, since reviewers themselves benefit from the process of peer-review when they are authors. SETAC would like to recognize that effort by offering a points system that tracks individual contributions to the SETAC publications

For more information, contact SETAC, 229 S. Baylen Street, Pensacola, FL 32502; (850) 469-1500, www.setac.org.

SETAC Vancouver Session Recordings Now Available

A select number of sessions were recorded at the SETAC North America 35th Annual Meeting in Vancouver, British Columbia, and they are now available online free of charge. Session recordings let you catch up on what you missed and make great training tools. Review best practices presented by leading experts in your field and stay current on the trends affecting your industry. For an overview of all annual meeting presentations, you can download the presentation grid from the meeting program. Visit vancouver.setac.org for a list of recorded sessions.

For more information, contact SETAC, 229 S. Baylen Street, Pensacola, FL 32502; (850) 469-1500, www.setac.org.

Society of Wood Science and Technology

Renewable Materials and the Bio-Economy: SWST 2015 International Convention June 7-12, 2015

SWST is evolving quickly to meet the fast-changing research and education landscape of its members. It has held four International Conventions outside of North America. The 2014 Convention in Zvolen, Slovakia was a huge success. Heavy participation from across Europe helped increase SWST membership by over 10%. In 2015, SWST continues developing the Society by introducing a host of firsts to the International Convention.

This year, SWST is holding its first North American Convention that is a full week, scientific learning and networking event. Its success in internationalizing the society is clearly illustrated by the diverse geographical coverage of those submitting abstracts for the convention. SWST has over 230 abstracts from 31 different countries. Nearly half of these are from early stage researchers – students on up to someone within three years of receiving their PhD.

Tuesday, June 9 of the Convention is a day dedicated to early stage researchers. SWST created this day to focus on future leaders of SWST and provide extra time for them to present their work. As part of this day, two mini-workshops that focus on publishing SWST journals will be held.

Business and marketing focused abstracts represented nearly one of every five submitted.

The remainder of the day will include 18 different presentations with topics such as: GIS applications in marketing, supply chain mapping, lean thinking, illegal timber trade, and consumer reactions to wood in the built environment.

Early bird registration deadline is March 1.

For more information, contact SWST, P.O. Box 1655, Monona, WI 53716; (608) 577-1342, www.swst.org.

International News

United Nations Environment Programme

First of its Kind Guide Launched to Enable True Valuation of Ecosystems in Some of the World's Smallest and Most Vulnerable Economies

A new manual that will enable policymakers to calculate the true value of ecosystems for a transition to a green economy across the world's 52 small island developing states (SIDS), was launched today by the United Nations Environment Programme (UNEP) at a ceremony celebrating the end of the International Year of SIDS.

The manual highlights the strong interdependency between the natural environment and the economy of SIDS and the importance of accounting for the contribution of ecosystem services to human well-being in order to be able to quantify and manage those benefits.

It is revealed, for example, that in the Federate States of Micronesia the contribution of fisheries to GDP amounts to 10 per cent, and in Antigua and Barbuda, Anguilla, Seychelles and Vanuatu the tourism industry accounts for over 50 per cent of GDP. Exports are also largely supported by local ecosystems. Fifty-two per cent of the exports of the Caribbean island of Grenada are nutmeg, tuna, frozen albacore and cocoa beans. While in Trinidad and Tobago petroleum and natural gas represent 54 per cent of exports.

The *Guidance Manual on Valuation and Accounting of Ecosystem Services for Small Island Developing States* is seen as a timely and critical tool for mainstreaming island ecosystem services in conventional economic decision-making frameworks, and ultimately supporting policymakers' ability to achieve sustainable development.

The guidance manual is being launched at an event to mark the close of what was a momentous year for SIDS and attended by Under-Secretary-General Wu Hongbo, the Chair of the Alliance of Small Island States, and the Champions of the International Year of SIDS.

"Rio+20 emphasized that SIDS have unique vulnerabilities and require special attention during the evolution of the sustainable development agenda in order to achieve the gains required to lift people out of poverty, create green jobs and provide sustainable energy for all," said UN Under-Secretary-General and UNEP Executive Director Achim Steiner.

"For example, these 52 nations, home to over 62 million people, emit less than one per cent of global greenhouse gases, yet they suffer disproportionately from the climate change that global emissions cause."

"Fortunately, studies demonstrate that we have the tools and capabilities to head off future developmental setbacks. It is up to the international community to support SIDS—not least through building momentum towards a robust climate agreement—to be agreed in 2015, which will cut emissions and minimize the threat of climate change for these nations," he added.

UNEP's *SIDS Foresight Report*, launched in 2014, identifies climate change impacts and related sea-level rise as the chief concern among twenty emerging issues impacting the environmental resilience and sustainable development prospects of SIDS—including coastal squeeze, land capacity, invasive alien species and threats from chemicals and waste.

In all SIDS regions, coral reefs, the frontline for adaptation, are already severely impacted by rising sea surface temperatures. The global net loss of the coral reef cover—around 34 million hectares over two decades—will cost the international economy an estimated US$ 11.9 trillion, with SIDS especially impacted by the loss.

In the insular Caribbean, for example, up to 100 per cent of coral reefs in some areas have been affected by bleaching due to thermal stress linked to global warming. Climate threats are projected to push the proportion of reefs at risk in the Caribbean to 90 per cent by 2030 and up to 100 per cent by 2050.

World Environment Day, held in Barbados on June 5th 2014, adopted SIDS in the broader context of climate change as its theme. The event garnered global coverage and helped build momentum towards the Third International Conference on SIDS, which took place from 1-4 September in Apia, Samoa. At the Samoa event, nearly 300 partnerships between governments, businesses and civil society organizations from all over the world were registered to support SIDS, bringing the total value of these commitments to over US $19 billion.

The manual includes many examples of accounting and valuation techniques in action, and is related to The Economics of Ecosystems and Biodiversity, which is a global initiative focused on attracting attention to the economic benefits of biodiversity and the growing cost of biodiversity loss and ecosystem degradation.

The full SIDS Guidance Manual can be accessed at http://issuu.com/unep/

docs/guidance_manual_sids_full_report.

United Nations and Climate Change

Lima Climate Conference Paves the Way Towards a Climate Agreement in Paris

The 194 countries attending the Lima Climate Conference reached agreement early Sunday on key decisions that provide the foundation for a climate change pact in Paris late next year.

"The decisions adopted in Lima pave the way for the adoption of a universal and meaningful agreement in 2015," said UN Secretary-General Ban Ki-moon in a statement issued at the conclusion of the two-week meeting.

Looking to Paris, he urged the parties to the Convention to enter into substantive negotiations, based on the Lima Call for Action, for the 2015 agreement at their first meeting, held in February in Geneva.

During the Conference, countries defined what they will need to prepare and present in their Intended Nationally Determined Contributions to the new agreement. These contributions, which will serve as the basic building blocks of the Paris accord, will contain information on the nature and scope of countries' projected actions to address climate change, above and beyond what they are now doing.

The Secretary-General also called on all countries, especially the major economies, to submit ambitious national commitments well in advance of the Paris meeting. At last year's conference in Warsaw, countries were urged to submit their contributions by the end of the first quarter of 2015.

Countries also finalized the institutional architecture for a new mechanism on loss and damage, an issue of great importance to the countries that are most vulnerable to the impacts of climate change. "Loss and damage" refers to measures that could be taken to alleviate suffering in instances where adaptation efforts do not suffice.

The Lima Conference was buoyed from the start by commitments made last September at the Climate Summit, which was held in UN Headquarters in New York, and then by a series of emissions-reduction announcements made by the European Union, China and the United States.

Countries had also pledged nearly US$10 billion for the initial capitalization of the Green Climate Fund, which will provide financing for projects to address climate change in developing countries. In Lima, announcements from several countries—developed and developing—pushed the pledge total beyond the initial US$10 billion goal.

The thousands of conferees did not need to attend the meetings to be reminded of the importance of their work. During the Conference, the World Meteorological Organization presented a provisional report showing that, based on data from the first 10 months of the year, 2014 was on its way to becoming the world's hottest year on record. And Typhoon Hagupit reminded them of the consequence of severe weather as it lashed the Philippines. It marked the third consecutive year that a deadly typhoon struck the Philippines during a climate conference.

During the final hours of the Conference, negotiations stumbled over difficult issues, such as how to differentiate the obligations and responsibilities of developing and developed countries, and frustration grew among many here.

But the talks continued throughout Saturday, with Conference President and Peruvian Environment Minister Manuel Pulgar-Vidal holding a series of meetings and redacting the draft document to meet individuals' concerns.

"With this text, we all win," he said after finalizing the draft, adding that it was not only "more focused," but that "it takes into account the concerns of everyone, without exception."

In addition to sending the world a strong signal of hope and trust, "Lima has given new urgency towards fast tracking adaptation and building resilience across the developing world – not least by strengthening the link to finance and the development of national adaptation plans."

He added, "It is the way to show that we are mobilizing action from Lima to Paris."

The two weeks of the Conference proved "very, very challenging," said UNFCCC Executive Secretary Christiana Figueres, who nonetheless praised its outcome. "With this COP and moving on to Paris, we cement the fact that we will address climate change."

Governments leave Lima "with a range of key decisions agreed and action-agendas launched, including how to better scale up and finance adaptation, alongside actions on forests and education," she said.

Though concerns about technical issues slowed the progress of the Lima meeting, a sense of perspective among participants ensured they did not keep the participants from reaching their goal, French Foreign Minister Laurent Fabius told reporters. "Beyond these technical things there are lives and deaths of millions of people, and all of us are aware of that."

The action agenda during the 2015 meeting in Paris, slated to begin 30 November and to end 11 December, will include a day devoted to action by civil society, cities, regions, private companies, non-governmental organizations, "everybody," he said.

Quoting an oft-repeated phrase used by Mr. Ban, Mr. Fabius added, "We have to be successful because there is no Planet B. When we say that, we say nearly everything."

More information on the United Nations Framework Convention on Climate Change is available at http://unfccc.int/2860.php.

International Union for the Conservation of Nature

Underestimating the Ocean: New Evidence from IUCN Highlights the Carbon-Regulating Capacity of the Ocean

Protecting key carbon-absorbing areas of the ocean and conserving fish and krill stocks are critical for tackling climate change. This is one of the findings of a report released by the International Union for Conservation of Nature (IUCN) in which top marine scientists describe how atmospheric carbon is captured, stored and moves in the ocean.

The report, *The Significance and Management of Natural Carbon Stores in the Open Ocean*, underlines the significant role of the open ocean in absorbing, moving and storing carbon and, for the first time, using the latest science, looks in detail at its role in climate regulation. Over half of all absorbed carbon emissions end up in the ocean. The report suggests poor ocean management practices are putting this vital ecosystem service at risk.

At the heart of this report is the new concept of 'mobile carbon units' – animals such as plankton, fish and krill, which provide an important service that must be addressed in ocean management. The report defines the critical role that the food chain plays in basic ocean processes, including those that regulate climate. It also warns that the role of the ocean in storing and managing carbon must now be factored into policy and decision making at all levels.

"The world is at a crossroads in terms of ocean health and climate change," says the report's co-editor Dan Laffoley, Vice Chair, IUCN World Commission on Protected Areas. "Neglect the ocean and wonder why our actions are not effective, or manage and restore the ocean to boost food security and reduce the impact of climate change. The choice should be an easy one."

The ocean is already showing signs of stress, tending to more acidic conditions. It is also warming and holding less oxygen, which in turn is leading to dead zones.

"A sick ocean is one that loses its capacity to support planetary processes. As governments convene for climate talks in Lima in the hopes of getting an international carbon reduction agreement back on the rails, these results highlight the need for immediate action on ocean carbon, ensuring that it is taken into consideration in climate policies," said Carl Gustaf Lundin, Director of IUCN's Global Marine and Polar Programme.

Diatoms, the microscopic plankton that are a food source for many larger organisms, are estimated to transfer about 150 million tons of carbon per year to the deep ocean (at depths of more than 1,000 metres) – the equivalent carbon capture of about 250,000 square kilometres of restored tropical rainforest (as it grows), or an area the size of the United Kingdom. Krill are believed to capture about 22.8 million tons, but ongoing climate change due to human activities could undermine their carbon removal potential. Sargassum, a golden floating seaweed covering large tracts of the vast Sargasso Sea close to Bermuda, is a carbon sink of regional importance and a critical habitat for a number of endangered species, including turtles and eels.

The full report is available at https://portals.iucn.org/library/sites/library/files/documents/2014-049.pdf.

Meetings

See http://www.rnrf.org for additional meetings

Submit Meeting Notices to: info@rnrf.org

March 2015

GIS/CAMA Technologies Conference. March 2-5, 2015. Oklahoma City, OK. http://www.urisa.org/gis-cama-technologies-conference/

North American Wildlife and Natural Resources Conference. March 9-13, 2015. Omaha, NE. http://www.wildlifemanagementinstitute.org/index.php?option=com_content&view=article&id=348:north-american-conference-10&catid=37:NAWNRC&Itemid=61

Nexus 2015: Water, Food, Climate and Energy Conference. March 15-17, 2015. Chapel Hill, NC. http://nexus.unc.edu/

American Water Works Association, Sustainable Water Management Conference. March 15-18. Portland, OR. http://www.awwa.org/conferences-education/conferences/sustainable-water-management.aspx

National Groundwater Association Groundwater Summit. March 16-18, 2015. San Antonia, TX. http://www.groundwatersummit.org/

Global Science Conference: Climate Smart Agriculture 2015. March 16-18, 2015. Le Corum, Montpellier, France. http://csa2015.cirad.fr/

Environmental Film Festival in the Nation's Capital: Climate Connections. March 17-29, 2015. Washington, DC. http://www.dcenvironmentalfilmfest.org/

Geological Society of America Southeastern Section Annual Meeting. March 19-20, 2015. Chattanooga, TN. http://www.geosociety.org/Sections/se/2015mtg/

American Chemistry Society Spring 2015 National Meeting & Expo. March 22-26, 2015. Denver, CO. http://www.acs.org/content/acs/en/meetings.html

Arctic Technology Conference 2015. March 23-25, 2015. Copenhagen, Denmark. http://www.arctictechnologyconference.org/atc2015.cfm

Geological Society of America Northeastern Section Meeting. March 23-25, 2015. Bretton Woods, NH. http://www.geosociety.org/Sections/ne/2015mtg/

American Water Resources Association Spring Specialty Conference—Water for Urban Areas: Managing Risks and Building Resiliency. March 30-April 15, 2015. Los Angeles, CA. http://www.awra.org/meetings/LosAngeles2015/

2015 National Hurricane Conference. March 30-April 2, 2015. Austin, TX. http://hurricanemeeting.com/

April 2015

NACWA/WEF/WERF National Water Policy Forum & Fly-In. April 13-15, 2015. Washington, DC. http://www.nacwa.org/index.php?option=com_content&view=article&id=7&Itemid=4

American Planning Association 2015 National Planning Conference. April 18-21, 2015. Seattle, WA. https://conference.planning.org/conference/

Northeast Fish & Wildlife Agencies Annual Conference. April 19-21, 2015. Newport, RI. http://www.neafwa.org/

American Council for Energy-Efficient Economy, National Symposium on Market Transformation. April 20-22, 2015. Washington, DC. http://www.aceee.org/conferences/2015/mt

International Association for Impact Assessment, Impact Assessment in the Digital Era. April 20-23, 2015. Florence, Italy. http://conferences.iaia.org/2015/index.php

American Meteorological Society 2015 Washington Forum. April 21-23, 2015. Washington, DC.

Association of American Geographers Annual Meeting. April 21-25, 2015. Chicago, IL. http://www.aag.org/annualmeeting

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