Europe and Central Asia Region

How Resilient is the Energy Sector to Climate Change?

June 2008

The World Bank
Acknowledgements

This review has been based on information from a variety of sources including publicly available information and information available to the World Bank as a result of studies commissioned by the Bank, undertaken by Bank staff or otherwise provided to the Bank. The Bank has used the most up to date data that was available to it in preparing this review. More recent data may well change some of the analysis.

The review was prepared by a team from the Sustainable Development Department of the Europe Central Asia region of the World Bank comprising Jane Ebinger, Bjorn Hamso, Franz Gerner, Antonio Lim and Ana Plecas. The report benefited from review, comments and input from within the World Bank from: Christophe Bosche; Demetrious Papathanasiou; Gabriel Ionita; Gevorg Sargsyan; Helmut Schreiber; Joseph Melitauri; Ksenia Mokrushina; Henk Busz; Kari Nyman; Marat Iskakov; Marianne Fay; Nijat Valiyev; Pekka Salminen; Peter Johansen; Sameer Shukla; and Varadan Atur.
### Abbreviations and Acronyms

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>°C</td>
<td>Degrees centigrade</td>
</tr>
<tr>
<td>$</td>
<td>Dollars</td>
</tr>
<tr>
<td>%</td>
<td>Percent</td>
</tr>
<tr>
<td>A1B Scenario</td>
<td>IPCC Climate Scenario assuming rapid economic growth, slow population growth and very high but cleaner energy use</td>
</tr>
<tr>
<td>AFR</td>
<td>Africa region of the World Bank</td>
</tr>
<tr>
<td>CHP</td>
<td>Combined heat and power</td>
</tr>
<tr>
<td>CIS</td>
<td>Commonwealth of Independent States</td>
</tr>
<tr>
<td>cm</td>
<td>Centimeters</td>
</tr>
<tr>
<td>CO₂e</td>
<td>Carbon dioxide equivalent</td>
</tr>
<tr>
<td>EAP</td>
<td>East Asia and Pacific region of the World Bank</td>
</tr>
<tr>
<td>ECA</td>
<td>Europe and Central Asia region of the World Bank</td>
</tr>
<tr>
<td>EE</td>
<td>Energy efficiency</td>
</tr>
<tr>
<td>EU</td>
<td>European Union</td>
</tr>
<tr>
<td>EU ETS</td>
<td>EU Emissions Trading Scheme</td>
</tr>
<tr>
<td>GDP</td>
<td>Gross Domestic Product</td>
</tr>
<tr>
<td>GHG</td>
<td>Greenhouse Gases</td>
</tr>
<tr>
<td>GW</td>
<td>Giga Watts</td>
</tr>
<tr>
<td>HP</td>
<td>Hydropower</td>
</tr>
<tr>
<td>IEA</td>
<td>International Energy Agency</td>
</tr>
<tr>
<td>IPCC</td>
<td>Intergovernmental Panel on Climate Change</td>
</tr>
<tr>
<td>Km</td>
<td>Kilometers</td>
</tr>
<tr>
<td>Km²</td>
<td>Square kilometers</td>
</tr>
<tr>
<td>LAC</td>
<td>Latin America and Caribbean region of the World Bank</td>
</tr>
<tr>
<td>m</td>
<td>Meters</td>
</tr>
<tr>
<td>m/s</td>
<td>Meters per second</td>
</tr>
<tr>
<td>M³</td>
<td>Cubic meters</td>
</tr>
<tr>
<td>MENA</td>
<td>Middle East and North Africa region of the World Bank</td>
</tr>
<tr>
<td>NP</td>
<td>Nuclear power</td>
</tr>
<tr>
<td>OECD</td>
<td>Organization for Economic Co-Operation and Development</td>
</tr>
<tr>
<td>ppm</td>
<td>parts per million</td>
</tr>
<tr>
<td>RE</td>
<td>Renewable Energy</td>
</tr>
<tr>
<td>SAR</td>
<td>South Asia region of the World Bank</td>
</tr>
<tr>
<td>SE</td>
<td>South east</td>
</tr>
<tr>
<td>SEE</td>
<td>South Eastern Europe</td>
</tr>
<tr>
<td>tCO₂e</td>
<td>Tonnes of carbon dioxide equivalent</td>
</tr>
<tr>
<td>TP</td>
<td>Thermal power</td>
</tr>
<tr>
<td>TPP</td>
<td>Thermal power plant</td>
</tr>
<tr>
<td>TWh</td>
<td>Terawatt hour</td>
</tr>
<tr>
<td>US</td>
<td>United States</td>
</tr>
</tbody>
</table>
Table of Contents

Executive Summary

1 Introduction............................................................................................................... 10
2 What Do We Mean by Energy and Adaptation? ...................................................... 11
3 A Framework for Understanding Vulnerability and Adaptation ....................... 12
4 Energy Outlook in ECA............................................................................................ 13
5 Climate Projections.................................................................................................. 15
6 How Could This Affect the Energy Sector? ........................................................... 19
7 How Can We Reduce Vulnerability?........................................................................ 36
8 References................................................................................................................. 42

Annex 1 Carbon Intensity in Select Countries of ECA and Developing Countries Worldwide
Annex 2 Energy Priorities, Installed Capacity and Constraints
Executive Summary

While the Europe and Central Asia (ECA) region is resource rich, large scale oil and gas resources in particular are concentrated in a limited number of countries (Russia, Azerbaijan, Kazakhstan, Uzbekistan, and Turkmenistan) and transit infrastructure hampers delivery particularly in south eastern parts of ECA. Much of the region is dependent on Russian gas imports raising concerns about energy security and cost. Hydropower is a mainstay in south Eastern Europe, the Caucasus and central Asia but this has been dogged by drought conditions, and water resource allocation issues.

Energy demand has been rising with economic growth and consumer expectation for higher living standards and services. A significant increase is anticipated in coming decades and will require large scale investment in new generation capacity and rehabilitation of existing assets that are over designed and poorly maintained, if at all. Abundant indigenous coal resources are likely to be further exploited together with nuclear power to meet rising demand. Carbon emissions in the case of the former will be a challenge for industry. Renewable resources represent a small part of generation capacity today but will rise in importance with growing awareness and commitment to climate change policies. There is significant scope for energy efficiency and demand side management across the region.

Against this backdrop the region is experiencing changes in weather patterns; including variations in mean conditions and extremes. Greenhouse gas emissions are driving change, and their accumulation in the atmosphere is expected to rise in coming decades. In the period 2030-50 ECA is projected to see increased warming across the region, particularly in Arctic and Siberian Russia. There will be changes in precipitation (means and extremes) with increases expected in northern regions and significant reductions in southern and eastern parts of ECA. Water availability (run-off) will decline significantly in southeastern Europe and central Asia that will increasingly experience heat wave and drought conditions. Flash flooding is a particular concern for central Europe due to a combination of drought and heavy precipitation conditions. Wind strength will rise particularly in northern parts but there will also be increased variability. Solar radiation will increase especially around the Mediterranean.

Supply-demand challenges and energy security concerns will be affected on a number of fronts by projected changes in climate.

First, energy demand will change. It will increase in summer months across ECA due to rising cooling needs, particularly for cities that will see enhanced temperatures due to heat island effects. Consumption profiles will likely flatten across the year due to expected reductions in winter heat demand. SEE, Turkey, and Central Asia will be more vulnerable to these changes since supply is already constrained.
Second, generation capacity will be affected. Hydropower in southeastern parts of Europe (including Turkey) and central Asia will see changes in the timing and volume of flow to storage systems. Run-off will significantly decline (in some parts up to 25%) but in the near term may be balanced by glacial melt in the Alps, Caucasus and Central Asia that will initially increase stream flow but is expected to decline over time by up to 50%. Changing conditions will affect generation efficiency (sedimentation), reservoir management (storage and use, mudflows, lake outbursts), and seasonal water availability. There may be increased competition with other sectors and/or neighboring countries for scarce water supplies. However, northern parts of Europe and parts of Russia will see increased hydropower capacity.

The operation of thermal and nuclear power facilities will be challenged by water availability and temperature concerns due to their dependence on significant volumes of water for cooling. For example, lack of water or restrictions on cooling water intake or discharge can constrain facilities’ generation capacity. Impacts are likely to be less significant than for hydropower requiring operational management strategies and consideration in design.

Third, impacts on power transmission will be negative but manageable. Transmission capacity, constrained already in parts of Russia, SEE and parts of the Caucasus and Central Asia, will be hampered by load management issues particularly for summer peak demand. Efficiency will decline with rising temperatures due to issues such as line sag, and extreme events including heavy snowfall, precipitation, and icing that could affect line integrity.

Fourth, rising temperatures in Arctic and Siberian Russia could open up major economic opportunities offshore but will have negative impacts particularly in zones of discontinuous permafrost. The structural integrity of buildings, key infrastructure and pipelines is already being negatively affected by freeze-thaw processes, and operations are adversely impacted by the reduced number of access days for transit routes and operations sites. In offshore areas, reduced sea ice and longer navigation seasons will allow exploration and exploitation of as yet untapped mineral resources and cost savings to industries that rely on shipping for transit. However sea ice and increased storm surge may increase risks to shipping, enhance coastal erosion process and bring a risk of increased pollution.

Fifth, opportunities for renewable energy will open up with increased potential for solar and wind power generation.

Sixth, energy security will remain a concern. While reduced winter heating demand will bring positive benefits for those reliant on gas imports, anticipated water resource management concerns particularly in summer months may increase the focus on energy diversification, regional interconnections and trade.
Going forward it will be important to tackle climate change on two fronts: mitigation to manage the unavoidable, and adaptation to avoid the unmanageable. From an adaptation perspective, the key question for regulators and industry alike is how much to invest in adaptation today given the inherent uncertainties in climate forecasting, and the build up and impact of greenhouse gases in the atmosphere in coming decades. There is a growing consensus that a risk based and flexible approach to adaptation that focuses on no regrets and win-win adaptation solutions and combines infrastructure investment with operational management solutions and further monitoring, research and development provides a strong basis for development.

Even allowing for uncertainty ECA’s energy sector will undoubtedly be affected by climate change although impacts on northern European areas may be negligible if not slightly positive. That being said, the sector is quite resilient to change. The oil and gas industry has a long history of working in harsh environmental conditions and seeking innovative technical solutions to operational challenges. The power sector has vast experience in day to day grid management operations that are based on short term climate forecasting. Most adaptation measures are already known and the key issues are likely to be related to economics and political will rather than technology.

North American experience offers potential solutions for issues facing Russian Arctic and Siberian permafrost zones today. Energy saving and demand side management measures provide a cost effective win-win solution for mitigation and adaptation concerns surrounding rising demand and supply constraints. Water resource and flood management techniques are well known and will be important for those regions suffering increasing drought conditions and regional cooperation, integration and trade (for energy and water) can offer potential solutions to some of the concerns. Lastly the anticipated large investment in ECA’s energy infrastructure in coming decades provides a window of opportunity for smart climate resilient design. Regulatory support, incentives for change, investment in design standards that reflect projected changes, and most importantly outreach to key stakeholders will need to underpin these efforts to be able to harness this opportunity.
1 Introduction

The energy sector is sensitive to changes in seasonal weather patterns and extremes – e.g. floods, droughts, fire, storm, and landslide – that can affect the supply of energy, impact transmission capacity, disrupt oil and gas production, and impact the integrity of transmission pipelines and power distribution. Much infrastructure, built to design codes based on historic climate data, will require decisions in coming years regarding rehabilitation, upgrade or replacement. This poses both a challenge and an opportunity for adaptation.

This review is one of a series of sector-based papers commissioned as background to the report “Managing Uncertainty: Adapting to Climate Change in ECA Countries” targeted at internal World Bank audiences as well as counterparts in client countries.

Approach – The review takes a look at what is known about climate change and the energy sector: how average temperature rise and increased climate variability are likely to impact the production, transmission and distribution of energy resources and affect end users. It takes a look at uncertainties regarding climate projections and flags knowledge/ information gaps of relevance to the energy sector. Where possible it identifies and prioritizes issues and/ or locations requiring particular focus for the development of strategies to improve the sector’s resilience to climate change.

It is a first step towards understanding the nexus between climate adaptation and the energy sector. The review has been based on relevant available literature and draws upon experiences and world-wide analysis of climate change, vulnerability and adaptation measures of relevance to oil and gas production, the coal sector, power generation and distribution, and energy use. To the extent possible, the review has been tailored to countries in the Europe and Central Asia Region. This has been achieved by supplementing the literature review with interviews with energy sector specialists at the World Bank that work in countries across the ECA region. The interviews have focused on existing constraints within the sector and present or increased vulnerability to changes in climate.

A risk assessment framework developed for the Australian Greenhouse Office (Australian Government 2005, 2006) has been employed to assess and present vulnerability and risk.
Organization – the review discusses energy and adaptation through 6 sections devoted to:

- A discussion of the energy sector and climate change mitigation and adaptation (section 2);
- Presentation of a framework for understanding energy and adaptation (section 3);
- A brief overview of ECA’s energy sector and constraints – section 4, supported by Annex 1;
- A discussion of climate projections for 2030-50 (section 5);
- A review of potential impacts and the vulnerability of ECA’s energy sector – section 6, supported by Annex 2 and 3; and
- A review of adaptation options (section 7).

2 What Do We Mean by Energy and Adaptation?

Perhaps the most important question to start with is: what do we mean by adaptation in the energy sector? Much of the discussion on climate adaptation naturally focuses on water resource availability, impacts on agricultural production, the spread of disease or the vulnerability of coastal communities to rising sea levels. These issues and impacts are perhaps more obvious but no less relevant when considered in an energy context. From an energy perspective, mitigation and adaptation can be viewed as two sides of the same coin.

Mitigation or ‘managing the unavoidable’ – as a primary contributor to global greenhouse gas (GHG) emissions the energy sector will need to deliver significant cuts by 2030 and beyond to support stabilization of carbon dioxide (CO₂) concentrations in the atmosphere¹. ECA’s energy sector has high energy and CO₂ intensity and has an important role to play. The European Community has taken a lead in this area with the introduction of the EU Emission Trading Scheme in 2005 and in 2007 an energy policy² targeting by 2020 a 20 percent reduction in CO₂ emissions, a 20 percent increase in energy efficiency and an increase in the share of renewable energy to 20 percent. At an international level, results of the ongoing negotiations on a post-2012 climate-change

¹ The Stern review commissioned by the UK Government in October 2006 made the case that “the benefits of strong and early action far outweigh the economic costs of not acting”. To avoid the worst impacts of climate change, greenhouse gas (GHG) levels in the atmosphere need to be stabilized at around 500 ppm of carbon dioxide equivalent (CO₂e); they are currently at 430 ppm and rising at a rate of 2 ppm per year. This requires emissions to be at least 25% below current levels by 2050. Actions taken in the next one to two decades will be crucial for achieving this target and have been estimated to carry a cost of around 1% of global GDP per year.
agreement to replace the Kyoto Protocol will influence mitigation policy and strategy in coming years.

*Adaptation or ‘avoiding the unmanageable’* – the primary focus is the energy sector’s vulnerability to the adverse effects of climate change, including climate variability and extremes; and the ability of the sector to adjust to moderate potential damages, to take advantage of opportunities, and / or to cope with the consequences. The degree of mitigation going forward will determine the level of adaptation needed.

To ensure the resilience of energy infrastructure to projected climate change, enable the continued provision of basic services to the public and industry, and enhance the quality of decision making, governments will need to understand the inherent vulnerabilities in their energy sector and develop flexible adaptation strategies for existing and planned infrastructure. Consideration will need to be given to the capacity of energy systems to sustain cumulative impacts; the sensitivity of regulators to climate change pressures on infrastructure and the possible need for redundant capacity at peak periods; and demand management and energy conservation strategies. This will support policies and projects that are robust in the face of climatic uncertainty while ensuring security of energy supply. For example, energy efficiency measures will reduce GHG emissions and energy demand – a mitigation strategy – but are also a key adaptation option in tackling growth in demand for summer cooling and winter heating especially when energy supply might be constrained due to, for example, drought conditions in the case of hydropower.

3 **A Framework for Understanding Vulnerability and Adaptation**

This review has drawn upon an approach proposed by the Australian Greenhouse Office to guide businesses and the Government in managing their risk through an assessment of their sensitivity to climate change, review of inherent vulnerabilities and analysis of their ability to adapt. Figure 1 illustrates the approach taken and looks at the factors influencing climate risk.

In reviewing a sector or business the model looks first at potential impacts. Potential impacts are based on projected changes in climate and are defined as a function of *exposure* – the climatic conditions within which the sector/ business operates – and *sensitivity*, or the degree to which a sector is affected by climate-related variables. Sectors can be affected positively or negatively. For those sectors that are already sensitive to changing climate conditions, these effects are likely to be further enhanced.

3 IPCC Fourth Assessment Report: Climate Change 2007, Appendix 1 Glossary, pgs 883
4 IPCC Fourth Assessment Report: Climate Change 2007, Appendix 1 Glossary, pgs 869
A sector’s vulnerability is a function of the potential impacts and its adaptive capacity — the capacity to moderate risks or realize benefits. Systems already operating close to their limits or that are poorly managed, will have less capacity to adapt and likely be affected by smaller changes in climate.

Adaptation actions can be planned or autonomous and can include a range of options. With the uncertainties surrounding the earth’s response and modeling tools, it is important to look for flexibility and consider actions that are ‘no-regrets’ or ‘win-win’ options, to avoid those that constrain future response, or to look for solutions such as risk insurance, technical or procedural changes to prevent effects, regulatory or institutional measures to prevent or mitigate effects, actions to avoid or exploit change, and to complement these with education, outreach and research/development.

Figure 1 A framework for understanding climate vulnerability

![Vulnerability Framework Diagram]


4 Energy Outlook in ECA

Before examining issues surrounding climate change it is important to take a brief look at the current energy outlook in ECA and sector challenges and constraints.

The ECA region has 10 percent of the World’s energy demand, but 5 percent of world GDP and remains the most energy-inefficient region in the world both in terms of consumption and production of energy (Figures 2 and 3). Energy and carbon intensity are high and electricity and heat production account for over 50 percent of the Region’s CO₂ emissions. Sector assets employ old and outdated technologies, many running beyond design life; the average age of power generation facilities is 35-40 years with nearly 80 percent installed prior to 1980. A lack of investment in major maintenance

---

5 World Bank 2008
throughout the 1990s has compounded the issue leading to inefficient, unreliable and polluting operations.

**Figure 2 ECA has the World’s Highest Carbon Intensity**

![Graph showing carbon intensity over time for EAP, ECA, OECD, LAC, MENA, AFR, and SAR.](image)


**Figure 3 ECA’s Energy Intensity is Significantly above that of the EU**

*(Total primary energy supply in Ktoe per GDP in millions of US$, 2004 prices)*

![Graph showing energy intensity for Russian Federation, ECA, Central Europe, and European Union.](image)


Demand is expected to rise in the period to 2030 – electricity consumption grows at an average annual rate of 3.7 percent – and fossil fuels are expected to remain the most dominant source of energy. Future gas and electricity shortages are possible in several sub-regions (South-eastern Europe, Central Europe, Turkey and Russia) threatening rapid growth. Together with rising gas prices and concern about reliance on Russia for fuel, the Region is tending towards a growth pattern that is based on more polluting but locally available coal and resistance to shutting down aging nuclear reactors.
By 2030 nearly 50 percent of generation capacity (as of 2005) is projected to be rehabilitated; 40 percent retired from service and around 726 GW of new generation capacity is projected, mostly thermal (72 percent). Coal-fired and nuclear generation are both projected to increase over 2006-30 to 35 percent and 20 percent respectively. Overall, investment costs are estimated at US$1.2 trillion (2008). While significant advances will be required in clean-coal technologies, including carbon capture and storage, the renewal of sector assets in the period to 2030 provides a window of opportunity to curtail the carbon footprint and increase the resilience of the sector to climate change.

Strategies proposed to ensure energy security and address the demand-supply gap have increased emphasis on efficiency of supply and consumption, the development of local renewable energy resources and improved regional cooperation and trade (Annex 2). Most countries face issues of tariffs that remain below cost-recovery levels, hampering sector investment and encouraging inefficient patterns of consumption. To enhance sector investment, tariff subsidies (explicit and implicit) will need to be phased out to improve the sector’s financial viability.

5 Climate Projections

Global climate projections used by the IPCC in its fourth assessment report rely on a suite of general (global) circulation models. The models are inherently uncertain both in terms of future level of greenhouse gas (GHG) emissions and their accumulation in the atmosphere, as well as the earth’s climatic response.

The ability to make accurate projections at a regional or country level – ‘downscaling’ – is even more difficult. The European Union has invested in regional models to provide projections on a smaller spatial scale. While temperature and precipitation modeling has been improved, there is a tendency to overestimate the inter-annual variability of summer temperatures in southern and central Europe. Regional models for Central Asia are less developed and modeling is more difficult here and in the Caucasus due to sub-regional topography.

For the purpose of this review, the IPCC’s A1B scenario – based on an assumption of rapid economic growth, slow population growth and very high but cleaner, energy use – has been used to provide an indication of climate trends for sub-regions of ECA [World

---

6 The remainder is projected to be in nuclear power (15%), hydro power (9%) and renewable energy sources (4%).
7 Hydropower and gas fired generation decline to 12% and 29% respectively over the period 2006-30.
8 Energy efficiency policies could contribute to 80% of avoided GHGs and substantially increase supply security (G8 Summit, 2007)
Bank 2008a], Trends have been presented on a sub-regional basis (Table 1). Where available, this has been supplemented by country-level projections obtained through available literature.

The science is likely to improve over the next decade, but climate projections will still remain subject to uncertainty. That being said, there is information today on expected trends that allow a qualitative review of potential vulnerabilities and constraints to facilitate risk-based planning going forward.

What trends have been observed in ECA? Looking at historical trends for the past century, it is already possible to observe significant increases in warming across parts of Russia, Central Europe, the Caucasus and Central Asia as well as increased wetness in many regions of Russia. There has been a sharp rise in temperature across the Arctic region over past decades, particularly in the winter (ACIA 2004).

Parts of the region have been significantly impacted by natural disasters – a function of both the climatic event and vulnerability – and place in the top 3 deciles for the global distribution of economic losses per unit of GDP for: (i) flooding – all areas with the exception of Caucasus and Central Asia; (ii) landslide – all except the Baltics and SE Europe; and (iii) drought – most with the exception of Southern Siberia, Caucasus and Central Asia. These trends and vulnerabilities may be exacerbated by projected climate change.

What are the projections going forward? The following discussion is based on projected trends for the period 2030-50, summarized in Table 19.

**Temperature** – In the period 2030-50 the region will experience warming with milder winters and hotter summers. The number of frost days10 will decline (especially in Central Europe) and the number of heat wave days11 will increase in all countries (particularly the Western Arctic and SE Europe). The mean annual average temperature is expected to increase across the Region and is particularly pronounced in higher latitudes.

Warmer temperatures will manifest themselves through glacier retreat, increased risk of flooding and, when combined with reduced mean summer precipitation, could enhance the occurrence of heat waves and drought. Within the region, summer temperature variability is projected to increase together with the incidence of heat waves and drought in Europe. Central Europe will see a similar number of hot days as parts of

---

9 Adapted from World Bank 2008a
10 Days with an absolute minimum temperature below zero degrees C
11 Heat wave duration index is used as a proxy and is defined as the maximum period greater than 5 consecutive days where the maximum temperature is greater than 5 degrees C above the 1961-90 maximum daily normal temperature
southern Europe does today, and droughts in Mediterranean regions will start earlier and last longer. The eastern Adriatic seaboard is among the areas that could be most affected (IPCC 548). Albania, Macedonia and southern parts of Bosnia, Serbia and Montenegro will see high increases in temperature across all seasons but particularly in summer (MCCR 2008).

Precipitation – The region will be wetter in northern areas with significant increases in mean annual precipitation projected for the Western Arctic, all parts of Siberia and the Far East of Russia. Precipitation will increase in northern Europe, with mean winter precipitation rising in most of Atlantic and northern Europe.

Southern areas of Europe will be drier with some models projecting a decline in precipitation of up to 20 percent in parts (IPCC 545). Annual mean precipitation is projected to decrease 10-20 percent along the Adriatic coast and some areas of the southeastern tip of the western Balkans including Albania and Macedonia. The greatest decline would be in summer months (Van der Celen 2006).

Both rainfall intensity and the intensity per extreme event are projected to increase in all areas apart from the Northern Caucasus, while SE and Central Europe and the rest of the Caucasus will all experience longer intervals between wet days. Together with a rise in temperature, the Western Balkans will experience reduced and variable precipitation and a higher frequency of extreme events (flood, drought, heat wave).

Water availability – Run-off is used to provide a measure for water availability12. Significant increases in water availability are projected for the Western Arctic, Baltic Russia, Siberia and the Far East; Northern Europe will also experience an increase. Particularly significant increases will be experienced in central Volga regions; projected at 60-90 percent in winter and 20-50 percent in summer.

Run-off will decline in southern and central Europe (-25 percent and -13 percent respectively). Summer flows from rivers in southern Europe could contract by up to 80 percent (IPCC 558). Southern Siberia will experience a decline in spring run-off of 10-20 percent (Roshydromet 2005) and similar effects will also be felt in the Caucasus and Central Asia.

Glaciers in Central Asia have been melting faster in recent years than previously thought. Associated changes in glacial run-off and the frequency of glacial lake outbursts have caused an increase in mudflows and avalanches (IPCC 478).

---

12 Surface water courses and river systems
<table>
<thead>
<tr>
<th>Sub-region</th>
<th>Western Arctic</th>
<th>Baltic</th>
<th>Central &amp; Volga</th>
<th>N Caucasus</th>
<th>Siberia &amp; Far East</th>
<th>S Siberia</th>
<th>Urals &amp; W. Siberia</th>
<th>Baltic</th>
<th>Central Europe</th>
<th>SE Europe</th>
<th>Caucasus</th>
<th>Central Asia</th>
<th>Kazakhstan</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Historic Trends (20th century)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Significant warming</td>
<td>√</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Significant wetting</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Disasters (top 3 deciles for global distribution of economic losses per GDP)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flood</td>
<td>√</td>
<td>√</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landslide</td>
<td></td>
<td></td>
<td>√</td>
<td>√</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drought</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Average Projected Trends (2030-50)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean annual temperature change (ºC)</td>
<td>2.6</td>
<td>1.9</td>
<td>1.9</td>
<td>1.6</td>
<td>2.4</td>
<td>2.4</td>
<td>2.2</td>
<td>1.6</td>
<td>1.7</td>
<td>1.8</td>
<td>1.7</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Winter</td>
<td>3.4</td>
<td>2.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Summer</td>
<td>2.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frost days</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat-waves</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean annual precipitation (%)</td>
<td>+10</td>
<td>+6</td>
<td>n.a.</td>
<td>+11</td>
<td>+8</td>
<td>+9</td>
<td>n.a.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intensity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extreme event</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interval between wet days</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Run-off (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes** – √ – decreasing trend; ∨ – increasing trend; n.a. – not available; *Western Arctic* – Heat wave increase greatest in ECA; *Baltics* – Runoff southern parts of the region projected to experience decreases and the northern parts increases; *Central Europe* – Decrease in frost days is greatest in ECA; *SE Europe* – Maximum consecutive dry days projected to increase by 5 days.
Sea level change/ Sea ice retreat – Arctic sea levels have risen 20-30 cm in the past 100 years and are projected to continue rising this century; between 10 and 90 cm. In Arctic areas summer sea ice has continued to retreat – the average extent of summer sea ice cover has declined 15-20 percent in the past 30 years. This trend will accelerate and near total summer sea ice loss is projected for the end of the century (ACIA 2004). Rising sea levels and reduced sea ice cover will increase coastal erosion rates as higher waves and storm surges reach the shore.

Sea level rise is also a growing problem in low-lying coasts of the Adriatic and Black Seas. The Caspian Sea has also experienced extreme changes13 caused by variations in river run-off and visible evaporation (HDR 2008), and a significant downwards trend in sea level is expected.

Wind – High wind speeds have been observed in coastal regions of the Russian Far East (up to 34 m/s) and the Arctic (38 m/s); they are also common in the southern zone of European Russia (34-36 m/s) along the border with Kazakhstan (Novosibirsk and Kemerovo regions) (Kattsov 2008). Mean annual wind speeds are expected to increase in northern Europe (around 8 percent) with largest increases in winter and early spring. Wind strength is expected to decline in the Caucasus.

Extreme events – there will be a rise in the number and intensity of extreme events, including more frequent and larger floods, more frequent and longer droughts, more frequent very hot days (heat waves), more frequent and intense rainfall and storms, higher peak wind speeds and storm surge. In particular, flood risk is projected to rise in northern, central and Eastern Europe as well as in Asian Russia. Intense short term precipitation will rise across most of Europe as will the risk of flash flooding. Southern Europe will experience an increase in drought and heat waves and further aridition is expected in Central Asia due to pressures on water resource availability.

6 How Could This Affect the Energy Sector?

The warming trend that is projected, especially for higher latitudes, has potential to impact the entire energy chain: from production, through transmission and distribution, to end use. Increased flood and drought risk, as well as other extreme events such as heat waves, cold snaps and storm intensity could impact energy supply. This section takes a look at the potential impact on demand and follows with a discussion of the impact on electricity and oil and gas supply. A review of vulnerability for sub-regions of ECA follows.

13 In coming 10-12 years this is expected to vary between -27.08 m and -27.58 m and show a downward trend (average rate of around 4 cm/year). Moscow 2005.
**Heating demand declines, cooling demand rises**

Most areas will experience reduced demand for heat energy\(^\text{14}\) in the winter and increased demand for cooling and air conditioning, particularly in summer months. Changes in the level and timing of peak demand are likely to result in a flattening of the electricity consumption profile across the year. While ECA specific projections are not available, European data is indicative: heating demand is projected to decline by 2-3 weeks per year and cooling demand to rise between 2-3 weeks (in coastal areas) and 5 weeks (in inland areas) by 2050. Overall this represents up to a 10 percent decrease in heat energy demand and up to 28 percent increase in cooling needs in 2030 for southeast Mediterranean (IPCC 543).

Reduced heating seasons could bring energy savings and alleviate peak winter load concerns although climate variability may make supply-demand management (e.g. energy generation, fuel stockpiles) difficult and costly\(^\text{15}\). The Baltics (including Poland, Belarus) and the Caucasus may have reduced demand for power and gas imports. The efficiency of Poland’s cogeneration may be slightly impacted by reduced winter heat demand; although this is likely minor.

A rise in the number of very hot days – above 35°C and 40°C – will place additional burden on electricity production, challenge system reliability, and possibly impact load management. This could increase the unit cost of electricity – due to investment needs driven by changing peaks – raising prices for residential, industrial and commercial users alike.

Electricity systems that are over stretched will be particularly affected by warming trends and some are already experiencing impacts. Many regions of Russia are struggling with supply side capacity constraints either not meeting demand, or projected not to in the near future. In the absence of back up, supply shortages could lead to issues of affordability of energy for some segments of the population. In 2008 in Tajikistan a “…major hydropower plant had been affected by falling water levels as rivers froze, threatening production, while energy supplies from neighboring countries had also been reduced. Price of fuel wood doubled to $20, out of range of many people” (DPA, 2008). Continuing rapid coastal and tourism development in southern areas (Turkey, Croatia, and Albania) could add pressure on supply as could urban centers; the heat island effect\(^\text{16}\) leading to

\(^{14}\) Winter heat demand in Hungary and Romania is expected to decrease by 6-8% (IPCC 556).

\(^{15}\) While a reduction in the number of very cold days is expected on average, this may not be consistent year on year, for example, there may be 10 less frost days in one year, and 5 more the following year.

\(^{16}\) Temperatures are higher due to heat trapped by buildings; waste heat generated by vehicles, air conditioners and industrial facilities; and greenery displaced by buildings. This can result in increased energy demand and potential health impacts for those living in poorly adapted housing located in zones prone to heat wave.
higher temperatures and increased cooling demand in cities when compared with rural areas.

**Hydropower generation will be threatened by changes in the water cycle**

Rising temperatures will impact the timing of snow melt, stream flow and water availability. Across Europe hydropower generation potential is projected to decline by an average of about 6 percent by the 2070s, with marked declines in the Mediterranean region (20-50 percent). Northern Europe is expected to see an increase of water availability of around 9-22 percent in the same period (with around 5-15 percent to 2020) with a commensurate increase in hydropower potential (15-30 percent). Hydropower production in western and central Europe will remain stable (IPCC 550). Turkey has been experiencing water shortages and for the first time has drawn on reservoir storage for winter power generation and is cooperating with Syria for water supply. Increased emphasis is being placed on energy diversification particularly wind power.

Increased precipitation in Russia (apart from north Caucasus) will generally have a positive impact on hydropower production. However some areas will be negatively impacted by reduced mean annual inflows to reservoirs (Roshydromet 2005) including: Volga-kama chain (-10 to -20 percent); NW federal district (-10 percent); Angara-enisei reservoirs (up to -15 percent); Vilui-Kolyma-Zeya reservoirs (up to -15 percent); and Tsimlyanskiy, Krasnodar and Novosibirsk reservoirs (-5 to -15 percent).

In the South Caucasus, Georgia has ample hydropower resources however water reservoirs are located in relatively narrow gorges and storage capacity does not and will not meet winter power demands. Milder winters will modestly help mitigate the problem. Reduced run-off may constrain spring and summer hydropower production. However, expected changes in the timing and volume profile of run-off are unclear, making climate change’s directional impact on Georgian hydropower production uncertain. Armenia has mismatched generation with excess capacity in summer, and thus is likely to positively benefit from projected changes (flatter demand profile).

Central Asia’s semi-arid and arid zones will experience more aridition and given the strong link with energy supply, harmonization of water management will increase in importance. While water resource management is an issue across the entire central Asia region, Kyrgyz Republic and Tajikistan that supply water to neighboring (water constrained) countries including Kazakhstan, Uzbekistan and Turkmenistan are more likely to be impacted by glacier melt\(^{17}\), lake outbursts, flooding and mudflow at least in the short term. While declining summer rainfall could be offset in the near term by

\(^{17}\) Europe and parts of the CIS are experiencing glacier retreat. In the short term, summer water flows have increased, but these will diminish in coming years by up to 50 percent as glaciers shrink in size (IPCC 550).
increased river flows due to glacial melt, reservoir management - reinforcement of dams, storage, flood protection, sedimentation- could become more challenging.

**Thermal and nuclear power plant operation may be affected by water shortages and hotter temperatures**

The availability of cooling water is a particular concern for thermal and nuclear plants; plant cooling accounts for about a third of European water abstraction. South eastern parts of Europe and parts of Central Asia are projected to see a significant decline in run-off (in some parts up to 25 percent by 2030-50).

Plant operation can be negatively impacted by a decline in available water for cooling and/or when water levels in rivers or lakes drop below the intake piping of nuclear or thermal power facilities. There could be other or additional restrictions due to the temperature of the cooling water itself which may be too hot for intake or above discharge temperature levels. As a result, power plants could be required to cut back or shut down operations, increasing the risk of blackouts and/ or leading to price increases as alternate sources of power are sourced (where available). With rising ambient air temperature the efficiency of thermal power generation may decline, including less efficient heat absorption systems and stop-start operations mentioned above. Increased evaporation from cooling towers could add to cooling water supply concerns.

“August 2007, Browns Ferry Plant Alabama shutdown for a day because cooling water too hot to discharge” (CNN 2008)

Lake Norman, NC – “nuclear reactors across SE could be forced to throttle back or temporarily shut down this year because drought is drying up rivers and lakes that supply power plants with the cooling water they need to operate…….’shockingly’ higher electric bills” (CNN, 2008)

Europe – 2006 heat wave – “French, German and Spanish utilities were forced to shutdown some of their nuclear plants and reduce power at others because of low water levels, some for up to a week” (CNN 2008)

**Network management will be complicated by higher summer peaks and extreme weather**

Rising temperatures may make load management more problematic especially for aging infrastructure and networks; networks located in areas with summer-time power constraints; or for energy systems dependent on hydropower where drought and heat wave are a risk (e.g. south east Europe). Thermal expansion of transmission and distribution lines tends to increase line sag and reduce transmission volume. Systems experiencing high loads could see increasing congestion (US Climate Change Science Program 2007) and network faults. Turkey has experienced summer peak load
problems in recent years and transmission networks in Azerbaijan (Baku) and Kazakhstan (Almaty, Astana) have also been strained in summer months.

Overhead power transmission lines may also be affected by increasing heavy precipitation\(^\text{18}\). Changes in wind load, depending on the direction of change, can have positive or negative effects on transmission lines linked to the frequency that design parameters are exceeded. Areas in the Northern Caucasus, Murmansk, Archangelsk, Leningrad regions, and coastal zones of Khanty-Mansi and Evenki autonomous areas will see a 1.2 fold increase in wind load by 2010-15, raising the number of electric power incidents but possibly opening opportunities for wind power generation. In contrast, European Russia is projected a decrease in wind load (by a factor of 1.1 by 2015) compared with today (Roshydromet 2005).

**Extractive industries in the Russian Arctic and Siberia will experience both positive and negative effects from global warming**

Oil, gas and mining impacts are largely confined to Arctic Russia and Siberia and will be both positive and negative. Zones of discontinuous permafrost are particularly vulnerable to rising temperatures; energy infrastructure and communities located in these areas are potentially at risk. Industries relying on offshore access are likely to see some benefits.

**Offshore exploration, production and transport** - the central Arctic Ocean is projected to experience the largest warming in the period to 2090 compared with other arctic sub-regions; up to 7°C annually and 10°C in winter. The consequent reduction in sea ice is very likely to lengthen the navigation season\(^\text{19}\) through the northern sea route – by 2100 a projected increase to 120 days per year from the present 20-30 days – opening up access for exploration and production of offshore oil and gas reserves that are currently not viable and potentially bringing significant economic opportunities. Coal mines in Siberia that export by ocean will likely experience savings due to reduced sea ice and the longer navigation season.

Seasonal (summer) opening of the North Sea route is also likely within decades bringing benefits for trans-Arctic shipping. However, increasing ice movement and wave action in some channels of the Northwest Passage could make shipping difficult initially due to

---

\(^{18}\) 250,000 people were left without power in the North-Rhine Westphalia, Germany and 19,000 households lost electricity in France’s Vendee region when sudden snow storms gripped northern Europe in November 2005 (BBC 2005). The Hubei province of China this winter experienced heavy snow, sleet and ice that led to 56 energy-intensive industries cutting power consumption so that household demand could be met. Transmission facilities were also knocked out paralyzing the rail lines (Red Cross 2008).

\(^{19}\) Sea ice concentration below 50%
sea ice and storm surge; hindering access to oil and gas resources and increasing the risk of pollution.

Onshore exploration, production and transport - discontinuous permafrost melt and reduced access of arctic lands will have the largest impact on onshore oil and gas exploration and production, coal mines in Siberia, and other energy facilities that rely on land transport.

By the 2090s an additional average annual warming of 6°C is projected for NW Russia, with a larger increase near the coast. Warmer climates will result in degradation of permafrost observed through an increase in temperature and seasonal thaw depths and a northward shift of the southern permafrost limit20 – several hundred km by 2100 (ACIA 2004). As a result, various impacts will increase, such as landslides, a slow down-slope flow of melting ground, significant hummocky topography in frozen ground caused by melting ice (Roshydromet 2005). This can lead to failure of pilings, reduced bond strength between permafrost and piles, heaving of pilings and structures, shoreline and riverbank erosion and mobilization of pollutants. Areas of discontinuous permafrost are most at risk, and larger facilities such as tank farms could be affected first (US Arctic Research Commission 2003).

Resultant ground settling is already impacting the structural integrity of buildings, roads, power/ nuclear facilities, coal mines and oil and gas transmission lines. A review by the US Arctic Research Commission concluded that Russia has more settlements and infrastructure in higher risk areas of the Arctic than other countries, with major settlements in areas of moderate or high hazard potential in western Siberia (Yukutsk). Collapsing ground in Yakutsk has already affected several large residential buildings, a power station and runway at Yakutsk Airport. Most power facilities, including extensive networks in south central Siberia, are located in areas of moderate risk, although the Bilibino nuclear power station and grid is located in an area of high hazard potential. Other (future) concerns include the weakening of the walls of open-pit mines and pollution threats as tailing disposal sites experience thaw, releasing excess water and contaminants into ground water systems.

Transportation routes (e.g. road, rail) located on land are being disturbed by thawing ground. The period during which ice roads and tundra are frozen, allowing access for operational purposes (e.g. oil and gas production facilities, mining, pipeline maintenance) or delivery of supplies, is shrinking. In the Alaskan tundra the number of days under which travel is allowed by the US Department of Natural Resources has dropped from 200 to around 100 over the past 30 years resulting in a 50 percent reduction in the number of days that oil and gas exploration and extraction equipment can be used (ACIA 2004). This will increase overall exploration costs and may make

---

20 The boundary between seasonal thawing and freezing of ground
some regions unattractive for investors to carry out exploration and production activities. Communities in these areas are also affected. In 1997-98 the Manitoba Government in Canada spent $15-16 million to airlift supplies to communities normally services by ice roads due to extreme warm weather conditions (Infrastructure Canada 2006).

Furthermore, a large portion of ECA’s oil and gas reserves are located in ice-rich regions of the Arctic, such as western Siberian, that are vulnerable to freeze-thaw processes (US Arctic Research Commission 2003). Many of the existing and anticipated pipeline routes cross extensive areas of continuous and discontinuous permafrost. They will require special technical design consideration due to their unique interaction with the surrounding environment resulting from large differences between operating temperatures and ambient conditions. Transmission of oil through pipelines usually takes place at high temperatures to limit viscosity and pumping costs. Conversely, natural gas transportation takes place at temperatures below freezing to increase gas density and throughput. Some effects are already being seen: the Messoyakh-Norilsk pipeline recorded sixteen pipeline breaks in 2003-04; and the Khanty-Mansi autonomous district reported 1702 accidents involving spills and resulted in the removal or disallowance of use of more than 640 km² of land area from use in a single year due to oil contamination (ACIA 2004).

That being said, the oil and gas industry has a long history of working under harsh weather conditions both upstream and downstream and considerable engineering experience has been accumulated to construct and operate pipelines under different climate and weather conditions. Techniques to address warming and thawing of oil and gas pipelines are already commonly used in North America and Scandinavia. In most cases, engineering solutions are available, thus the issue is likely to be more economic than technological.

**Renewable energy may benefit from the changing climate**

Wind power potential is projected to grow in northern Europe; mean annual wind speeds increasing by around 8 percent with particular impacts in winter and early spring. Generation increases of about 7 percent are expected in typical production zones and 10-15 percent annually from the period 1961-90 to 2021-50 for offshore wind power (based on a change in mean wind speed) (IPCC 548). On the other hand, wind power production efficiency could suffer as a result of changing wind patterns and increasing variability; the latter affecting both production and turbine load (life time). Increased and variable precipitation patterns can affect turbine efficiency; light rainfall by -20 percent and ice by -50 percent without anti- or de-icing technology. Kattsov (2008) predicts a decline in wind production in the Russian Far East, Arctic, and the southern
zone of European Russia along the border with Kazakhstan\textsuperscript{21} due to changing circulation patterns despite wind speeds of 34 m/s or more.

More solar energy will be available in the Mediterranean in coming years although this will be vulnerable to cloud cover and hence reduced insolation\textsuperscript{22}.

\textbf{Energy infrastructure could be affected by flooding and changing sea levels}

Changes in the water cycle are projected to increase the risk of flooding (IPCC 550) in northern, central and Eastern Europe and permafrost-free areas of the Arctic; potentially threatening energy infrastructure located in coastal zones or flood plains. When vast areas are impounded, deformation and weakening of structural foundations and pressure on energy supplies may result. Western Balkan countries have experienced flooding along the Serbian section of the Danube River (2002) as well as increasing heat waves (e.g. summers of 2003 and 2007) – conditions for flash flooding. In 2005 “\textit{Romania ... suffered six consecutive waves of flooding....power cuts were widespread}” (International Federation of the Red Cross 2005). In Russia, Kattsov (2008) reports an increased flood risk for Saint Petersburg\textsuperscript{23}.

Changes in sea level are a growing problem in low lying coastal areas of the Adriatic and Black Seas. In Arctic areas coastal erosion will increase with changing sea levels and reduced sea ice as higher waves and storm surges reach the shore. Sea levels have already risen 20-30 cm in the Arctic in the past 100 years and are projected to continue rising this century; between 10 and 90 cm. Energy infrastructure and communities on low lying coasts are potentially vulnerable to this change and some communities and industrial facilities face relocation or increased risks and costs (ACIA, 2004). For example, the Russian oil storage facility that was built on a barrier island at Varandei, Pechora Sea is already under threat; and the village of Kivaline in Alaska was relocated in 1998 at a cost of $54 million.

In contrast the Caspian Sea, a major oil and gas production area, is experiencing a large decline in sea level. Limited information is available in published literature on the potential vulnerability of offshore infrastructure, refining and support facilities located on Caspian coastlines (supply, ports, rail, refining, etc).

\textsuperscript{21} Novosibirsk and Kemerovo regions
\textsuperscript{22} The amount of electromagnetic energy (solar radiation) incident on the surface of the earth.
\textsuperscript{23} Kattsov 2008 projects an increased risk of floods of more than 3 m water level rise in Saint Petersburg in the coming 5-10 years; the last flood of this magnitude occurred in 1924. A flood protection system is underway.
Climate change raises regulatory and policy issues

Climate change may add to existing regulatory and policy concerns such as energy security, pricing and demand management. Areas facing supply constraints and rising cooling demand may require new or revised policy/ regulation to encourage energy efficiency and diversify supplies. New or improved building codes, contingency planning and compensation mechanisms, as well as urban development can help reduce the adverse effects of heat exposure, the increased demand for cooling, and exposure to flooding and other extreme events.

Regulators may be faced with decisions linked to price increases for consumers as energy suppliers source alternate fuels, face increased costs, or reduced efficiency due to changing climate conditions. In Australia local regulators have already been faced with these concerns due to a prolonged period of drought and water shortage: “Electricity futures have doubled so far this year [May 2007]….Sydney Futures Exchange – ranks as biggest commodity price increase ever seen and not driven by market speculation (convergence of negative trends and water shortage). State regulators are in dilemma” (Sydney Morning Herald 2007).

There may be increased competition for scarce water resources from other sectors and industries. In Victoria, Australia “3 giant coal fired power plants have an annual water entitlement from the Government equal to about 20 percent of Melbourne annual water use but water shortages have forced them to buy water elsewhere to meet capacity” (Sydney Morning Herald 2007). Areas affected by drought will likely experience more widespread stress on water supply and/ or availability and groundwater recharge may also be reduced. Harmonization of water management, combined with measures to reduce losses and manage demand will be required as will systems to monitor and project water flows.

The decline in arctic sea ice and opening of historically closed sea passages, are likely to raise questions of sovereignty over shipping routes and seabed resources. Issues of security and safety could arise as new and increased offshore developments require revised and/ or new national and international regulations for marine safety and environmental protection in arctic seas. Other potential conflicts include competition between users of arctic waterways and coastal seas, including commercial fishing, oil and gas exploration and production, and hunting of marine wildlife by indigenous people. Increased access to shipping routes and mineral resources will raise the risk of environmental degradation from for example oil spills or industrial accidents. Coordination on services including ice-breaking will be required to manage access.
### ECA’s energy sector, a review of sub-regional vulnerability

**1 Central Europe - Czech Republic, Hungary, Moldova, Romania, Slovakia, Ukraine**

<table>
<thead>
<tr>
<th>Exposure</th>
<th>Temperatures will rise (particularly in winter). The region will see the same number of hot days as SE Europe today. Rainfall patterns will change and become more intense increasing the risk of flash flooding. Intervals between wet days will be longer. Run-off will decline significantly.</th>
</tr>
</thead>
</table>
| Sensitivity | - **Romania** – production constraints projected in coming 3-5 years due to closure of TP facilities (EU *Acquis*). Dependence on NP will increase. Rising summer cooling demand, reduced water availability and rising temperatures could potentially impact NP and TP operation (cooling water, meeting demand). Romania is sensitive to flash flooding due to a lack of storage for run-off.  
- **Moldova** - 100 percent gas and electricity import dependent; trade balance is an issue. Moldova is sensitive to increasing drought conditions and competition for water resources (e.g. agriculture) could present issues for TP operation.  
- **Ukraine** - gas import dependent; relying largely on NP (~50 percent). HP contributes 6-7 percent. Peak loads currently occur in winter. Summer peaks are suppressed compared to 1990s and substantial room remains for an increase in demand. There could be potential impacts on NP and TP operation due to cooling water restrictions/ availability and these will need to be taken into account for the planned nuclear expansion. |
| Adaptive Capacity | The region is highly energy intensive and there is substantial scope to improve energy efficiency. This could help alleviate energy constraints linked to increased cooling demand in summer. Moldova has an action plan under preparation to improve energy efficiency. |
| Adverse Implications | - HP potential could be reduced in Romania with less hours per day for peak services  
- TP may be less efficient (e.g. warmer cooling water) and cooling water availability could be an issue in some countries  
- There could be competition for water resources in drought prone areas  
- Flash flooding could affect energy supply |
| Potential to Benefit | In general reduced demand for winter heat will improve energy security, and provide some cost benefits. In Moldova, reduced winter heat demand and increased demand in summer will likely lower the cost of supply to cheaper summertime electricity imports |
### (2) South Eastern Europe - Albania, Bosnia, Bulgaria, Croatia, Kosovo, Macedonia, Serbia, Slovenia, Turkey, Montenegro

<table>
<thead>
<tr>
<th>Exposure</th>
<th>Significant warming and an increase in the number of heat wave days is projected. Mean rainfall will reduce especially in summer. Rainfall will be more intense with longer intervals between wet days (maximum number of consecutive dry days increases by 5 days). Run-off will decline significantly. Extreme events will increase e.g. flooding, landslide, and drought (particularly along eastern Adriatic seaboard).</th>
</tr>
</thead>
</table>
| Sensitivity | Dependence on HP with a rise in TP and NP in future. Regional cooperation for power and this is proposed for gas. TP and NP facilities will be sensitive to cooling water needs and water availability as will the HP.  
- **Albania** - 90 percent HP dependent and supply constrained. With increasing demand, supply security is likely to be an issue. Construction growth is linked to tourism but limited building codes or enforcement of energy efficiency measures. Increased TP and more investment in HP are proposed; these could be sensitive to declining run-off.  
- **Turkey** – relies on HP for 20-25 percent (in poor – average years) of supply; water supply constraints exist. Diversification to coal, NP, gas and wind is proposed. Summer peak constraints already (higher than winter peak in 2007) and rapid growth in cooling demand. Turkey is vulnerable to rising temperature and drought and could experience summer blackouts. A new energy efficiency Law has been introduced and tariffs raised to dampen demand. Energy regulations and active load management measures in place.  
- **Croatia** - Tourism and residential demand for cooling is growing rapidly. The network is regulated with HP (25-30 percent but declining rapidly); alternatives mostly TP (coal and gas).  
- **Bulgaria, Montenegro and Macedonia** – likely to be affected by water availability. Bulgaria is energy intensive with limited incentives to conserve energy. HP is significant in energy mix (including new investment). Reliance on NP and lignite will increase. Montenegro has inefficient TP. HP is the main supply and there is significant use of solar. Imports make up to 30 percent. Building codes (including energy efficiency) are being enforced. Macedonia uses electricity (25 percent HP, lignite and imports) for heating and has a large winter peak. Prices have not been liberalized in the residential sector. Limited energy efficiency incentives. |
| Adaptive Capacity | Winter peak demand is higher than summer demand so raising the summer peak would not necessarily stress energy supply in Bulgaria. This is not necessarily the case for HP dependent countries such as Albania. Demand side management and energy efficiency could relieve some stress on supply. Regional cooperation (gas and power) will improve resilience overall but additional constraints could be experienced due to the closure of some NP and TP facilities. |
| Adverse Implications | Reduced HP generation potential exacerbated by increased urbanization and cooling demand. Power shortages (already in Turkey in summer). Rising energy prices: while TP can meet summer peak demand it will come at a higher |
Benefit: Potential impacts and implications of rising temperatures on the energy sector.

### Potential to Benefit
Possible increased opportunity and demand for renewable energy sources including solar and geothermal energy. Incentives to improve energy efficiency would increase resilience in summer. Winter demand for electric heat will decline.

### Exposure
In the Baltic region the energy sector will be exposed to rising temperatures, changing and more intense patterns of rainfall, and an increase in extreme events e.g. flooding. Run-off will decline in southern regions but increase in the north.

### Sensitivity
Capacity constraints linked to increased demand for summer cooling, and reduced demand for winter heat are likely to be minor. Within the region, Belarus while natural gas and electricity import dependent has an extensive energy efficiency program (energy intensity has been decoupled from GDP growth). Poland has significant domestic lignite resources and a small level of gas imports (Russia). A supercritical lignite plant is proposed for development. Latvia is mostly hydropower and import dependent but effects are likely to be limited given increasing run-off. Across the region adverse impacts on the operation of thermal and nuclear facilities are expected to be limited since increased water availability is projected particularly in the north.

### Adaptive Capacity
Rising summer demand could be addressed through energy efficiency programs and revising building codes targeting the commercial and housing sector in Belarus, and Poland. Strategies for improving supply side energy efficiency are underway in Belarus and an energy efficiency strategy is proposed in Latvia to 2016 tackling end users in public and private sectors.

### Adverse Implications
The efficiency of Poland’s co-generation will be slightly impacted by a reduction in winter heat demand. Increased flood risk could have temporary impacts on generation and transmission.

### Potential to Benefit
- General – flattening of power demand curve over year
- Belarus potential savings on reduced gas and power imports
- Poland potential winter energy savings
- Latvia’s energy sector is hydropower dependent and projected increases in run-off could provide added benefits
### Exposure

In the Caucasus the energy sector will be exposed to significant warming and increase in the number of heat wave days. There will be more intense patterns of rainfall and longer intervals between wet days. Run-off will decline. The region is already exposed to extreme events including landslide and drought.

### Sensitivity

Georgia and Armenia will be sensitive to the projected trend of warmer winters and hotter summers as well as reduced run-off, but impacts mostly positive.

- **Georgia** is 70 percent HP dependent with the remainder being TP. HP storage capacity is insufficient for summer run-off (too high) at present and gas supply constraints are experience in winter (although more as a diversification and cost issue than a matter of physical access to gas).

- **Armenia** has a nuclear base load (remainder HP, TP) and replacement/expansion of NP is planned. Electricity swaps are conducted with Iran due to mismatched generation. Armenia has excess capacity in summer. Appropriate siting of the proposed NP facility in Armenia will be important for cooling water management.

- **Azerbaijan** has experienced winter energy cuts due to worn down power production capacity that is mostly based on TP (~90 percent). However, major capacity additions undertaken have remedied the situation, and more generation capacity is under construction. Energy consumption is high in summer. Energy supply could be sensitive to water availability/cooling water constraints. Rising summer demand could stress the transmission network. Siting of new TP, HP and possible NP will require consideration of water resource management issues. Offshore oil and gas exploration and production facilities and related infrastructure located in coastal regions (refining, port, etc) could be sensitive to changing sea levels in the Caspian (expected downwards trend).

In all countries energy use is inefficient and there has been limited focus on energy saving; transmission and distribution losses for power and gas are high but improving. Collection rates are high in Georgia and Armenia, and are improving in Azerbaijan, thus providing incentives for residential energy saving but insufficiently so due to limited access to credit for energy efficiency investments.

### Adaptive Capacity

There is significant potential for energy efficiency and demand side management in all countries but limited focus at present. In Georgia TP facilities are air cooled, reducing sensitivity to water availability. Ongoing gas transmission rehabilitation in Georgia will reduce risks to pipelines from landslips.

### Adverse Implications

- Availability of cooling water for current and planned TPs and NPs; siting of new facilities to ensure adequate water supply
- Potential to stress transmission network in summer in Azerbaijan
- Heat impacts on poor households without air conditioning or well designed housing
- Add structural stress to the oil/ gas transmission network (Georgia, Azerbaijan)

### Potential to

- Supply – smoothing effect on generation profile (Georgia, Armenia)
<table>
<thead>
<tr>
<th>Benefit</th>
<th>- Energy security – less reliance on winter gas (all), lower costs</th>
</tr>
</thead>
</table>

(5) Central Asia - *Kazakhstan, Turkmenistan, Tajikistan, Uzbekistan, Kyrgyz Republic*

| Exposure | Significant warming and increasing number of heat wave days. Mean annual rainfall will increase and be more intense. Run-off will decline apart from Kazakhstan where there will be an increase in parts. Already affected by extreme events (e.g. flood, landslide, and drought). Further aridation likely due to pressure on water resource availability. High wind speeds have been observed in Kazakhstan near Russian border. Glacier retreat is occurring faster than expected; short term increase in run-off, increased risk of mudflow/avalanche. |
| Sensitivity | - **Kazakhstan** is water constrained and availability will be linked to evaporation and precipitation levels\(^{24}\). Water availability will be determined by evaporation and precipitation levels. Energy sector is fossil fuel based; planned base load is NP and coal that may be vulnerable to cooling water availability/constraints. The power market is progressive and liberalized. Energy efficiency law is under development. There is significant mining and 23 small/medium HP plants (600 MW) are under construction; potentially sensitive to changes in run-off. Infrastructure in SE is vulnerable to flooding but adaptive measures have been taken.  
- **Kyrgyz and Tajikistan** – Kyrgyz and Tajikistan supply water to neighboring countries and are more likely to be impacted by glacial melt, flooding and mudflow rather than water constraints.  
- **Turkmenistan** – water constrained; the Amy-Daria River is the main water source (including for Tajikistan and Uzbekistan). There is competition for water and huge losses in irrigation systems. The energy sector is gas based and could be sensitive to cooling water availability in future.  
- **Uzbekistan** – water availability is a key issue. The energy sector is fossil fuel based and could be sensitive to cooling water availability in future. |
| Adaptive Capacity | - Improvements in energy efficiency and demand side management could improve resilience as could trans-boundary and local water resource management measures, including demand side management. |
| Adverse Implications | In general, reduced HP potential (in longer term due to glacial melt), HP needed for frequency regulation. Water management issues; competition for water from agriculture/irrigation and power generation; cooling water constraints for TP generation in Region.  

**Kazakhstan** – Power network loads are significantly higher in summer (due to cooling) and this is an issue for Almaty/Astana. Spot shortages of power occur in winter. **Tajikistan, Kyrgyz** – landslide, mudslides and flooding impact the integrity of HP dams and related infrastructure. Reservoir sedimentation can also reduce HP generation capacity. This is particularly problematic for Nurek Reservoir in Tajikistan (Kokorin 2008). |

Potential to Improvement in water management in Kyrgyz can increase HP generation.

---

\(^{24}\) National water resources are predominantly surface water (24,000 m\(^3\) per km\(^2\), Kokorin 2008).
**Benefit**

capacity. Rehabilitation of Tajikistan’s HP generation capacity and improvement in water management have potential for energy trade with southern neighboring countries.

---

### (6) Arctic Russia and Siberia

<table>
<thead>
<tr>
<th>Exposure</th>
<th>The energy sector is likely to be directly affected by significant warming, melting permafrost; reduced sea ice; increased and more intense patterns of rainfall; and natural disasters including landslides, and flooding. Runoff will increase significantly.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>The region is highly sensitive to these changes, particularly in areas with major population centers and infrastructure, oil and gas exploration and production zones, and areas of discontinuous permafrost subject to freeze-thaw patterns. Some areas are already experiencing impacts. Siberia is generally self sufficient and well balanced in terms of energy supply. However large power deficits exist in parts (Central Krasnoyarsk, Omsk, South Kuzbass, Altai, etc).</td>
</tr>
<tr>
<td>Adaptive Capacity</td>
<td>Extractive industry already used to working in harsh environments and technology responses are available to address many concerns as demonstrated by reduced vulnerability of the oil and gas sector in Alaska, Canada, Scandinavia however this will come at a cost; awareness and financing are likely to be potential issues in Arctic Russia and Siberia.</td>
</tr>
</tbody>
</table>
| Adverse Implications | **Onshore:** (i) electric facilities and extensive networks in south-central Siberia are in areas of moderate risk (US Arctic Research Commission 2003); (ii) Bilibino nuclear station and its grid occupy an area of high hazard potential (US Arctic Research Commission 2003); (iii) oil and gas pipelines are located in areas vulnerable to freeze-thaw processes; potential for accidents and spills; (iv) reduced access time to facilities (oil, gas, mining) dependent on sufficiently frozen ice roads and tundra. Related increase in maintenance costs or areas become less attractive for economic for developers; (v) potential for structural failure of infrastructure. Heavy, multi storey buildings in northern Russia already experiencing problems; (vi) weakening walls of open pit mines lead to pollutant effects from large mine tailing disposal as frozen layers thaw’ (vii) More electricity for cooling burdening capacity and potentially leading to peak connected load problems (summers may be extremely hot and dry even in Siberia due its continental climate). Summer peaks unlikely to outweigh winter ones.  
**Offshore:** (i) increased potential for coastal erosion due to melting sea ice and increased wave action; (ii) arctic oil and gas reserves – issues of sovereignty, security, safety, environment; (iii) trans-arctic shipping initially more difficult; (iv) pollution risks – oil spills at high latitudes last longer. |
| Potential to Benefit | Rising temperatures lead to reduced heat demand and costs; flattening of demand profile. Wind load reductions in some parts will relieve wind load on buildings and infrastructure. Melting Sea Ice brings significant economic... |

---

25 45 percent of Russia’s HP systems are located in Siberia, 77 percent oil stock, 80 percent coal and 85 percent natural gas resources.
opportunities: (i) North sea route opens for commercial shipping with navigation season increasing to 120 days from current 20-30 days by end of century; (ii) Increased marine access to offshore Arctic mineral resources; (iii) trans-arctic shipping during summer feasible in several decades; and (iv) coal mines in Siberia that export by ocean experience savings.

(7) Russia's Regions – North Caucasus, Central and Volga, Baltic Russia, Far East and Urals

| Exposure | Significant historical warming in Far East and wetting in N. Caucasus, Siberia, Far East and Urals. All regions exposed to flood risk; S. Siberia drought; landslides in N. Caucasus, Far East and Urals. High wind speeds observed in Far East and southern parts of European Russia. Warming increasing in all regions. Mean annual rainfall increasing significantly in Far East and Urals; and less significantly in the Baltics. Increased rainfall intensity and extreme events in all regions except N. Caucasus which will see a decline. Declining interval between wet days everywhere. Significant runoff increase in Far East and Urals; less significant in central and Volga regions, Baltics. Declining runoff in N. Caucasus. |
| Sensitivity | Everywhere - generation constraints and problems meeting demand due to rapid industrial growth and rising end user consumption; limited incentives for efficient consumption.  
- **Urals** rely on gas fired (75%) generation. Power shortage at peak demand.  
- **NW Russia** relies on HP (15 percent), CHP (37 percent), NP (29 percent) and condensation stations (20 percent). A 21-22 percent power shortage is forecast for 2020.  
- **Central Volga** network carrying constraints and severe power shortages in parts- e.g. Nizhegorods and Saratovskaya oblasts- despite adequate generation capacity (50 percent CHP, 26 percent HP, 17 percent NP). Shortages projected for 2010-11 linked to industrial growth and low water inflow to HP storage systems and cascades.
  - **Far East** is self sufficient. CHP (30 percent of supply). Shortages projected.  
  - **Caucasus** relies on CHP (55 percent), HP (31 percent) and NP (11 percent). Power shortages are projected. |
| Adaptive Capacity | Urals and Central Volga regions propose power system integration to address supply shortages. Energy efficiency and demand side management could reduce vulnerability during peak demand. |
| Adverse Implications | Cost savings could result from shorter heat seasons. Increasingly variable climate – e.g. heat season of -20 days in 1 year and +5 days the next – means generation capacity and fuel stockpiles need to be sized for a range of conditions, affecting costs and management. HP production could rise with precipitation but dam reinforcement and reservoir management may be more difficult (balancing storage with flood protection, Kokorin 2008). Glacial melt in N. Caucasus could reduce water availability in medium term. Extreme weather |

---

26 The Volzhsko-Kamskiy cascade was 20% below normal levels in spring 2006. In September 2006 Kuybyshevskoe storage pool lacked 7km³ of inflow and this alone caused 300 million kWh of electricity shortages.
- floods, strong winds, snowstorm and heavy rain - could adversely impact infrastructure. Catastrophic flooding is projected for the Don River Basin, North Caucasus and mountain zones in the Far East (Kokorin 2008).
  - **Ural** thawing permafrost may damage infrastructure.
  - **Baltic Russia** more power for cooling burdening capacity, potentially leading to peak connected load problems. Summer peaks unlikely to outweigh winter ones. Rising groundwater levels are impacting some cities particularly in European Russia (e.g. St Petersburg is exposed to catastrophic flood risk too). Potential adverse impacts on urban energy infrastructure (Kokorin 2008).
  - **Central and Volga** Potential issues for summer peak electricity consumption due to increased cooling demand. Winter peaks may remain a bigger issue.
  - **Far East Russia** – More electricity for cooling burdening capacity and potentially leading to peak connected load problems. Summer peaks unlikely to outweigh winter ones.
  - **N. Caucasus** – Summer peak connected load problems could arise due to cooling demand. Declining summer rain could be (partially) offset by increasing snow melt but could also aggravate capacity constraints leading to power shortages during summer peak load. Winter peak shortages could be alleviated by increased winter rain. Declining run-off will negatively impact HP generation.

| Potential to Benefit | Heating periods will reduce 3-4 days per year on average, up to 5 days in S. Far East, S. Kamchatka. Heat season could decline 5-10 percent by 2025 (Kokorin 2008). Wind generation potential will declined by a factor of 2 due to changing atmospheric circulation in the Baltics and Far East (Kokorin 2008).
  - **Urals** Warmer winters will smooth electricity consumption and cut the demand for heat.
  - **Baltic Russia** Increasing runoff, rising summer and winter precipitation will positively influence HP generation. Warmer winters will smooth out electricity consumption and reduce demand for heating.
  - **Central and Volga** Increasing runoff, rising summer and winter precipitation could alleviate low inflows to HP reservoirs and cascades, mitigating generation constraints. Winter peak consumption likely to be less problematic and annual electricity consumption profile could flatten.
  - **Far East** Rising summer and winter precipitation, glacial melt and runoff will positively impact HP generation. Warmer winters will flatten electricity consumption profile, reduce heat demand.
  - **N. Caucasus** winter peak shortages could be alleviated by increased winter rain. |
7 How Can We Reduce Vulnerability?

Adaptation strategies, in contrast to mitigation, need to be locally rather than globally based since there is great variation in the response of similar systems to climate change – linked to attributes such as geographic location, and sensitivity of receptors. While ECA’s energy sector will undoubtedly be impacted by climate change, the degree of impact is uncertain and will vary by sub-region. Based on historic patterns and projected trends impacts are likely to be negligible or maybe even slightly positive in northern parts of Europe that will see decreased heat demand and greater hydro and wind power production potential. In south Eastern Europe and parts of Central Asia systems dependent on hydropower or that currently suffer supply constraints are more likely to be vulnerable to the negative impacts of declining run-off and general warming. Permafrost zones in Arctic and Siberian Russia are also likely to be negatively affected although major economic benefits are expected due to increased access to offshore areas including untapped offshore mineral resources.

Many of the issues discussed in Section 6, are not new to the energy sector and technical solutions exist, albeit at a cost. The sector is also quite resilient. The oil and gas industry has much experience in working in harsh conditions and there are many examples of innovative technical solutions to adapt to challenging environments. For example, Alaska faces similar concerns to Arctic and Siberian Russia but has demonstrated increased resilience to changing climate. Construction standards have been adapted to reflect changing conditions and to reduce the vulnerability of infrastructure to melting permafrost, e.g. deeper pilings are used, air is allowed to circulate beneath buildings, thicker insulation is employed, and facilities are located on gravel pads or other insulated materials. Buildings and infrastructure are generally lighter weight and subject to regular repair and maintenance programs. The Trans-Alaska Oil Pipeline is an example of good adaption. Here a range of measures are employed to increase resilience including elevating the pipeline above ground level in areas of excess ice; using vertical supports with heat pipes to cool permafrost in winter, lower the mean ground temperature and prevent thaw in summer; and burying sections of the pipeline with thick insulation and refrigeration (US Arctic Research Commission 2003). Structural measures are complemented with routine monitoring, repair and maintenance programs.

The power sector also has significant expertise in managing day to day grid operations to adjust to and cope with short term weather changes when dispatching and pricing energy. While there is less awareness and planning for long term changes outside historic norms, the sector’s ability to adapt to change in the short term provides a basis for longer term management. Regional energy cooperation through trade and power swaps is also common strategy for managing supply-demand constraints and energy
security, e.g. southeastern Europe is presently increasing regional grid interconnections to improve supply and increase efficiency.

While the sector is resilient the key question facing both regulators and the private entities given the inherent uncertainties in climate modeling, and the extent and success of global mitigation efforts is how far and to what extent the energy sector should adapt today. There are many advocates of risk based and flexible adaptation strategies for existing and planned infrastructure. This could include no-regrets and/or win-win investments; the development of emergency plans for sudden and/or severe energy shortages; the deployment of monitoring systems to track and assess the degree of climate change and identify when parameters are exceeded that may influence adaptation decisions; and research and development of for example new technologies. Finadapt (2005a) for example advocates the use of underground power cables and improved construction and maintenance techniques to adapt to winter time cabling risks from heavy rain, high winds, icing or other events. While the EU supports learning by doing to improve knowledge and support commercialization of carbon capture and storage technology. And BP (2006) is supporting the development of alternate fuels and technologies with two pilot hydrogen power stations27 planned for Scotland and California.

It will be important to engage with a broad range of stakeholders to design effective adaptation strategies and ensure buy-in. Cities will be an important counterpart requiring cross sector adaptation solutions due to increasing urbanization trends and their rapid growth in energy demand. A number of cities have already taken steps to reduce their vulnerability (see Box overleaf).

In summary, many adaptation measures can be anticipated for ECA’s energy sector, but they will come at a cost; financing is likely to be an issue. Some common strategies to address vulnerabilities identified in Section 6 are discussed overleaf.

27 Coal and gas are separated into hydrogen and used to generate power while carbon dioxide is stored.
Urban Design and Land Use Planning

Cities are important and growing consumers of energy – around 75 percent of world population expected to be urbanized by 2030 (BP 2006) – policy and regulation, together with land use planning, design and construction standards will play an important role in reducing overall consumption and improving resilience. For example, clustering of high density residential and commercial land use can improve the efficiency of combined heat and power systems; streets can be laid out to optimize potential for solar energy use; and by minimizing paved surfaces and planting trees urban heat island effects can be mitigated together with demand for cooling (UNFCCC 2006). A number of cities have set climate goals or formed working groups to manage climate concerns.

In Portland, Oregon a task force was established in March 2007 that aims to reduce fossil fuel dependency and consumption, expand energy efficiency programs, facilitate emergency planning, and engage and build ownership in the community. While the Cool Communities program in New York City (NY 2000) combined landscaping (urban forestry) and design standards (high albedo surfaces on roofs and pavements) to reduce the heat island effect and save energy (by 3-35 percent).

A number of ‘Eco-cities’ have chosen low energy and/ or zero carbon growth paths; bringing mitigation and adaptation gains. Freiburg im Breisgan in Germany also known as the ‘solar’ city has a strong focus on energy efficiency and renewable energy and Dongian in China has adopted a zero-emission vision. In Wallington, South London (ETAP 2006) buildings have been designed to be energy-efficient. Design measures target heat loss reduction, installation of solar panels, increased insulation and laying out buildings specifically with north-south frontage (south-facing buildings take advantage of sun heating, north-facing workspaces avoid the need for cooling). Appliances installed in the buildings have been chosen for efficiency and full advantage has been taken of planting opportunities in communal open space, private gardens and green roofs.

Centralized district cooling systems are an alternative to traditional air conditioning and are growing in popularity particularly in Scandinavia (e.g. Sweden, Finland). In addition to reducing the electricity load at times of peak summer demand, they have the advantage of being 5-10 times more efficient than electric power air conditioning. WP 2007 estimates if 25 percent of Europe’s cooling demand were met through district cooling, there would be savings of 50-60 TWh electricity and 40-60 million tonnes CO2e a year.

Fortum runs a district cooling system in Stockholm, Sweden, that provides 7 million square meters of commercial area with district cooling. In Helsinki, Finland, the Salmisaari power plant transmits cooling energy via a pipe network to the districts of Ruoholahiti and Kamppi. Contrary to expectations, both networks provide cooling year round due to process cooling needs from electronic equipment and appliances (computers, refrigeration), and solar heat entering large windows.

Asset Refurbishment and Construction – significant investment is anticipated for energy sector assets (new and existing) in ECA over the coming decades. Given the typical lifespan of these assets, ranging between 30-50 years, this presents a unique window of opportunity to address climate mitigation– e.g. by reducing the overall carbon footprint and adopting cleaner technologies, such as super- and ultra-critical boilers, and integrated gasification combined-cycle plants – and climate adaptation, incorporating projected climate change in their design. To improve climate resilience
new design codes and construction standards28 may need to be developed with supporting regulation and enforcement to address for example permafrost melt in the far north or reduced water availability in southern and eastern sub-regions. Design and construction changes could also be complemented by an analysis of failures, routine maintenance, emergency planning, and improved climate data and forecasting.

In areas subject to permafrost melt, adaptation strategies are likely to combine upgraded or new building codes and construction standards (such as those deployed in Alaska); targeted rehabilitation of key assets located in high risk areas; emergency planning; and improved maintenance programs for key infrastructure and pipelines including monitoring, early warning systems for thermokarst, and regular inspection. Higher construction standards are likely to be required for ships navigating arctic waters together with ice breaking services, enhanced emergency response in dangerous areas and improved oil-ice clean up capacity. New regulations may also be required for ships, offshore structures, and port facilities to reduce oil spill risk and improved ice charting and forecasting.

In the case of hydropower systems the structure of existing dams may need to be enhanced to cope with more variable run-off and increasing precipitation, landslide, and mudslide. New facilities may require enhanced water storage and decisions may need to be taken regarding their location in areas with significant risk of declining run-off. Operational measures including contingency planning for load leveling and good reservoir management practices (e.g. storing water for use during high load periods, managing sedimentation in reservoirs to minimize impact on capacity) could also improve resilience.

**Water Resource Management** – Particularly in south eastern and eastern regions of ECA, as run-off declines and warming and evaporation rise, trans-boundary and inter-sector water management will be increasingly required to prioritize and optimize use and ensure that energy sector vulnerabilities are adequately addressed. Measures to reduce water losses, encourage water savings and improve the efficiency of water use across the economy will support adaptation29. Operational strategies for thermal and nuclear power facilities that ensure plants can operate under water stress, identify alternate and cost efficient solutions to meet demand when plants cannot operate, and maintain efficiency and safety during stop-start operations will also increase resilience as will the integration of water concerns into site selection and design of new facilities.

---

28 Some work has been initiated by the Engineering Institute of Canada, Canadian Council of Professional Engineers, and Canadian Standards Association (Infrastructure Canada 2006) to take a look at engineering design standards for a changing climate.

29 For example reduce losses from inefficient irrigation systems and poorly managed water supply networks, or target incentives for water conservation at high consumers.
**Flood Management** – central Europe in particular is vulnerable to flash flooding and landslide due to increasing heavy precipitation and drought conditions. Common measures to improve resilience include identifying high risk areas, sites and energy facilities; implementing a flood monitoring and early warning system; developing a program of regular inspections for key infrastructure located in high risk areas; modifying or developing construction standards and land use planning tools to address landslide or flood risk through for example limiting development on current or anticipated flood plain or landslide zones, or protecting energy facilities using physical barriers; emergency planning and disaster risk insurance. Finadapt (2005a) outlines an approach to flood management that includes: mapping and modeling; floodwall and dam upgrades; revisions to legal frameworks for land use and construction; and new standards for flood damage compensation from state funds. Other options identified by Infrastructure Canada in 2006 are: expanded floodplain areas, emergency flood reservoirs, preserved areas for flood water, and flood warning systems, especially for flash floods.

**Demand Side Management** – many parts of Russia, south Eastern Europe, and Central Asia face supply constraints that will only be exacerbated by climate change including increasing demand for summer cooling. Energy efficiency programs can provide a win-win solution addressing climate mitigation and adaptation at the same time as improving energy security and economic development. Buildings have the largest potential for energy efficiency improvements, and management strategies include:

(i) *building design* – insulation, efficient windows, building orientation to use sun for heating and lighting of buildings’ interior areas, minimize north facing window area, ventilation, energy saving building codes;

(ii) *codes and standards* – norms and standards for efficient air conditioning as well as building codes that target cooling needs

(iii) *equipment* – efficient lighting, efficiency standards for appliances, space heating and cooling;

(iv) *change consumption patterns* – to reduce demand notably at peak hours; flexible working hours, leave during hot periods,

(v) *low energy cooling* –district cooling, ceiling fans, gas air conditioning;

(vi) *energy cutoffs* – agreement with key industries that supply can be temporarily cut off at times of constrained supply in exchange of a reduction in tariffs;

(vii) *demonstration* – pilot programs, government energy efficiency measures;

(viii) *policy* – higher energy prices, financial incentives, taxation; and

(ix) *awareness* – training, education and outreach on options and benefits, energy audits and certification.

Despite the benefits, and cost effectiveness of energy efficiency measures, the uptake has not been as broad as could be expected. There are a number of barriers, including a lack of awareness of the benefits, financing, and most importantly a principal-agent
problem that is ‘pervasive, disbursed and complex’ (IEA’s 2007 review of energy efficiency practice and barriers). Well designed and targeted policies will be required to address this issue in addition to the measures outlined above.

30 “The central dilemma investigated by principal-agent theorists is how to get the employee or contractor (agent) to act in the best interests of the principal (the employer) when the employee or contractor has an informational advantage over the principal and has different interests from the principal”, http://www2.chass.ncsu.edu/garson/pa765/agent.htm
8 References


Albania - Climate Change Programme/ Unit. *Albania and Climate Change*. http://www.ccalb.org/


BP. March 8, 2006. *Energy Trends and Technologies for the Coming Decades*. Address to Harvard University Center for the Environment by Iain Conn, Executive Director


Coal, Oil and Gas. European Fossil Fuels Forum Berlin 19th October 2006. *Coal in Europe.*

Coal, Oil and Gas. Energy Information Administration. *Central Asia.*
http://www.eia.doe.gov/cabs/Centasia/Background.html

Coal, Oil and Gas. International Herald Tribune. *In Russian Energy Plan, Coal is a Question Mark.*

Coal, Oil and Gas. Energy Information Administration. *Caucasus Region.*
http://www.eia.doe.gov/cabs/Caucasus/Background.html


Commission of the European Communities. 2007. *Adapting to Climate Change in Europe, Options for EU Action.* Green Paper, From the Commission to the Council, the European Parliament, European Economic and Social Committee and the Committee of the Regions


Deutsche Presse Agentur (DPA). February 1, 2008. *Severe Weather Knocks out Water and Power in Tajikistan*


ECO Cities. Wired magazine issue 15.05. *Pop-up Cities: China Builds a Bright Green Metropolis.*
http://www.wired.com/wired/archive/15.05/feat_popup.html

http://www.sacredearth-travel.com/articles/stockholm.php
http://www.guardian.co.uk/business/2005/nov/06/china.theobserver

http://news.bbc.co.uk/2/hi/business/6756289.stm


http://www.independent.co.uk/environment/green-living/carbonfree-living-chinas-green-leap-forward-435208.html

ECO Cities. The Independent, May 4th. Life, But Not as We Know It.  
http://www.independent.co.uk/environment/life-but-not-not-as-we-know-it-476751.html

http://www.seerecon.org/infrastructure/sectors/energy/oilgas.htm

EEF. District Cooling, A Sustainable Response to Europe’s Rising Cooling Demands.  

EIA. Balkans. Energy Information Administration. The Balkans - Background.  
http://www.eia.doe.gov/cabs/Balkans/Background.html

EIA. SE Europe. Energy Information Administration. South Eastern Europe - Background.  
http://www.eia.doe.gov/cabs/SE_Europe/Background.html

http://ec.europa.eu/environment/etap/pdfs/june06_ecocities.pdf


GCSI. 2005. An Overview of the Risk Management Approach to Adaptation to Climate Change in Canada

Government of Canada. 2004. Climate Change Impacts and Adaptation, A Canadian Perspective. (pp 139, Transportation)

Helsinginenergia. What is District Cooling?


Infrastructure Canada, Research and Analysis Division. December 2006. Adapting Infrastructure to Climate Change in Canada’s Cities and Communities, A Literature Review

International Federation of Red Cross and Red Crescent Societies. September 6, 2005. Europe’s Summer Floods and Fires. Information bulletin.

International Federation of Red Cross and Red Crescent Societies. February 2, 2008. China: Snow Disaster. Information bulletin no. 1

Kattsov, Vladimir. 2008. Climate Change Projections anl impacts in Russian Federation and Central Asian Countries
Kokorin, Alexey. 2008. Report No. 2 *Expected Impact of the Changing Climate on Russia and Central Asia Countries*

Kokorin, Alexey. 2008. Report No. 3 *Ongoing or Planned Adaptation Efforts and Strategies in Russia and Central Asia Countries*


Romanian Ministry of Environment and Water Management. *National Strategy on Climate Change in Romania 2005-07*


NY. June 19, 2000. *Climate Change and a Global City, An Assessment of the Metropolitan East Coast Region. Assessment Synthesis*

NY. 2000a. *Preparing for Climate Change in the Metropolitan East Coast Region: The Potential Consequences of Climate Variability and Change, Energy Sector*


Pew Center on Global Climate Change. February 2006. *Agenda for Climate Action*


Reuters Foundation. February 6, 2008. *Frozen Tajikistan Appeals for Aid in Winter Crises*

Science-ebooks. *District Cooling.*
 http://www.science-ebooks.com/ematrix2/districtcooling.htm


UK Climate Impacts Programme (UKCIP). 2003. Climate Adaptation: Risk, Uncertainty and Decision-making


UNDP. 2008. Energy and Climate Change in Europe and CIS. Climate Change Adaptation, Energy and Climate

UNDP. Albania - Climate Change.

UNDP. Turkey - Climate Change - Enhancing the Capacity of Turkey to Adapt to Climate Change.


Annex 1 – Carbon Intensity in Select Countries of ECA and Developing Countries Worldwide

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>million metric tons</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ECA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Azerbaijan</td>
<td>37</td>
<td>-9</td>
<td>76</td>
</tr>
<tr>
<td>Belarus</td>
<td>55</td>
<td>-10</td>
<td>69.4</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>47</td>
<td>-3</td>
<td>74.1</td>
</tr>
<tr>
<td>Croatia</td>
<td>22</td>
<td>4</td>
<td>73.8</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>112</td>
<td>-6</td>
<td>86.2</td>
</tr>
<tr>
<td>Hungary</td>
<td>56</td>
<td>-2</td>
<td>74.9</td>
</tr>
<tr>
<td>Kazakhstan</td>
<td>172</td>
<td>12</td>
<td>78.2</td>
</tr>
<tr>
<td>Poland</td>
<td>288</td>
<td>-10</td>
<td>81.1</td>
</tr>
<tr>
<td>Romania</td>
<td>95</td>
<td>-21</td>
<td>73.4</td>
</tr>
<tr>
<td>Russia</td>
<td>1685</td>
<td>0</td>
<td>76.9</td>
</tr>
<tr>
<td>Slovakia</td>
<td>38</td>
<td>-2</td>
<td>76.6</td>
</tr>
<tr>
<td>Turkey</td>
<td>212</td>
<td>53</td>
<td>58.9</td>
</tr>
<tr>
<td>Ukraine</td>
<td>364</td>
<td>-17</td>
<td>64.9</td>
</tr>
<tr>
<td>Uzbekistan</td>
<td>121</td>
<td>24</td>
<td>66.9</td>
</tr>
<tr>
<td>Developing Countries Outside ECA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brazil</td>
<td>337</td>
<td>26</td>
<td>15.1</td>
</tr>
<tr>
<td>China</td>
<td>4707</td>
<td>68</td>
<td>70.4</td>
</tr>
<tr>
<td>India</td>
<td>1113</td>
<td>53</td>
<td>56.8</td>
</tr>
<tr>
<td>Mexico</td>
<td>385</td>
<td>15</td>
<td>60.6</td>
</tr>
<tr>
<td>South Africa</td>
<td>430</td>
<td>25</td>
<td>81.2</td>
</tr>
</tbody>
</table>

Source

Growth and CO2 Emissions: How do different countries fare? Environment Department, World Bank, October 2007
## Annex 2 – Energy Priorities, Installed Capacity and Constraints

[Adapted from World Bank 2008]

<table>
<thead>
<tr>
<th>Sub-region</th>
<th>Priorities</th>
<th>Installed Capacity/ Future Additions</th>
<th>Comments and Constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Security/ Diversity</td>
<td>Competitiveness</td>
<td>Efficiency</td>
</tr>
<tr>
<td>Russia</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caucasus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>European</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Far East</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Siberia</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central Europe</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Czech Rep</td>
<td>Y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Latvia</td>
<td>Y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lithuania</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poland</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Slovakia</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slovakia</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SE Europe</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Albania</td>
<td>Y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bosnia</td>
<td>Y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bulgaria</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Croatia</td>
<td>Y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kosovo</td>
<td>Y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Macedonia</td>
<td>Y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Montenegro</td>
<td>Y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Romania</td>
<td>Y</td>
<td></td>
<td>Y</td>
</tr>
<tr>
<td>Serbia</td>
<td>Y</td>
<td></td>
<td>Y</td>
</tr>
</tbody>
</table>

Small, peak-load HP  
Replace inefficient gas-fired plants  
Energy efficiency program proposed  
Possible closure of NP  
Modernize coal sector; import from jointly developed NP in Lithuania; RE – biomass, wind  
Possible closure of NP  
Import fuel such as natural gas as infrastructure available  
Import fuel such as natural gas  
Extend working lives and upgrading key power/ heat plants  
See above  
Import fuel such as natural gas  
If new NP not commissioned in time, faces rapid increases in imports of power or natural gas (TP generation)  
Rehab/ upgrade HP
<table>
<thead>
<tr>
<th>Sub-region</th>
<th>Priorities</th>
<th>Installed Capacity/ Future Additions</th>
<th>Comments and Constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Security/ Diversity</td>
<td>Competitiveness</td>
<td>Efficiency</td>
</tr>
<tr>
<td>Armenia</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Belarus</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Georgia</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Moldova</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Turkey</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Ukraine</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
</tbody>
</table>

**Black Sea Regions**

- Armenia: EU pressure to close NP (40% of power supply). Possible RE – HP and wind- and gas-fired TPP, new NP. Russia possible main source for future potential power imports; may not be able to meet demand. Issues regarding power affordability and reliability (gas price) and impact on expansion plans.
- Belarus: Ukraine could source of imports. Concern gas price. Highly dependent energy import from Russia.
- Georgia: Russia possible main source for power but may not be able to meet demand. Concern gas price. Gas imports.
- Turkey: Gas-fired plants supply more than 50% of TP. Gas imports from Central Asia and Russia. Gas prices a constraint. RE not likely to contribute significantly in the near term.
- Ukraine: Large spare generating capacity, but significant loss also due to lack of investment and deferred maintenance. A major expansion of coal-fired and NP capacity planned; dependency on imports of gas and coal to drop from around 60% to below10% by 2030. Substantial power exports to Russia, Belarus, Slovakia, Poland, Hungary, Romania and Moldova.


- Azerbaijan: Power demand from resource industry increasing. Upgrade and expansion of power transmission.
- Kazakhstan: Progressive, liberalized power market.