UNECE

# Global Tracking Framework:
## UNECE Progress in Sustainable Energy

**The current rate of progress is insufficient to achieve the three pillars of SDG7 by 2030**

**Despite advances in electricity access, challenges of energy affordability and quality persist**

**Improving energy efficiency is the most important enabler for sustainable energy**

**The uptake and investments into renewable energy vary vastly across the UNECE region**

**Indicators need to be refined to reflect the real imperatives of energy for sustainable development**

GTF

UNITED NATIONS

UNITED NATIONS ECONOMIC COMMISSION FOR EUROPE

# Global Tracking Framework:

# UNECE Progress in Sustainable Energy

## UNECE ENERGY SERIES No. 49

UNITED NATIONS

New York and Geneva, 2017

# Note

The designations employed and the presentation of the material in this publication do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations concerning the legal status of any country, territory, city or area, or of its authorities, or concerning the delimitation of its frontiers or boundaries.

Mention of any firm, licensed process or commercial products does not imply endorsement by the United Nations.

UNECE/ENERGY/108

| UNITED NATIONS PUBLICATION |
| --- |
| Sales No. E.17.II.E.23 |
| ISBN 978-92-1-117147-1<br>eISBN 978-92-1-362889-8<br>ISSN 1014-7225 |

United Nations publication issued by the Economic Commission for Europe

Copyright © United Nations, 2017

All rights reserved worldwide

# Foreword

The attainment of the sustainable energy targets in the 2030 Agenda for Sustainable Development (2030 Agenda) is not on track, either globally or in the United Nations Economic Commission for Europe (UNECE) region. Unless there is a significant acceleration of efforts and outcomes to ensure quality access to energy that is affordable and that meets the environmental, social, and economic imperatives of the 2030 Agenda, the international community will fall short of its ambitions and its commitments.

These are the blunt conclusions of the 2017 Global Tracking Framework report prepared by the World Bank and the International Energy Agency with the support of a host of organizations and UN agencies, including the five UN Regional Commissions. UNECE has cooperated with our sister Regional Commissions to prepare analyses for our respective regions and to elaborate a more detailed regional report as a complement to the global report.

The analysis for the UNECE region shows that progress differs from the global results, but that attainment in the region still falls short and solutions need to be adapted to national circumstances. Moving beyond the global results allows a more detailed assessment of national and regional conditions. While progress is insufficient in the UNECE region, the report presents case studies and examples showing that member States contributed significantly in proposing solutions to global problems.

There is not a single pathway to the future energy system, as each country has its own starting point and distinct options for how to proceed. It is essential for countries to develop their options, to consider both unilaterally and collectively how the objectives of energy for sustainable development might be achieved, and to establish an early warning system signalling if the objectives are likely not to be met. This report is a first step in that process, and a first alert has been issued.

This report sets forth the case for a holistic approach that countries must adopt to ensure a sustainable energy future that reconciles a tight emissions pathway with sustainable development aspirations. The approach will involve pursuing synergies and partnerships between low carbon alternatives and traditional fuels in terms of technology, policies, and market structure. Framework conditions are needed to mobilize investments that align with the objectives of the 2030 Agenda and that enable the needed transition. Rational economics and systemic improvements in efficiency throughout the energy chains lie at the heart of transformation to a sustainable energy system.

Decision-makers are offered a broader range of forward-looking indicators that cut across the 2030 Agenda from an energy perspective. Energy is intrinsically linked to the success of the 2030 Agenda, and progress needs to be tracked beyond SDG 7 across all energy-related goals.

**Olga Algayerova**

Executive Secretary
United Nations Economic Commission for Europe

# Acknowledgements

This report was made possible through funding from the Sustainable Energy for All Initiative. Country data for SDG 7 indicators were provided by the World Bank and the International Energy Agency (IEA) and their partners. The World Bank oversaw the development of the five regional chapters within the 2017 Global Tracking Framework report. The production of this report was coordinated by UNECE. It could not have been prepared without the support of experts and reviewers from across the UNECE region.

**UNECE Coordination:**

Lisa Tinschert

**Authors:**

Lead authors: Robert Tromop, Lisa Tinschert

**Supplementary authorship:**

Stefanie Held, Michal Drabik, and Harikrishnan Tulsidas of the UNECE Sustainable Energy Division. Further support was provided by Annukka Lipponen and other staff from the UNECE Environment Division, as well as Ilona Gremminger (Universität St. Gallen).

**Contributors and Reviewers:**

Through virtual consultation and exchange taking place between 12 December 2016 and 15 July 2017, responses were received from the following reviewers: Mariela A. Stefanllari, President, Human Environment Culture Foundation, Albania; Olga Dovnar, Deputy Chairperson, International Cooperation Unit, National Statistical Committee, Belarus; Andrei Miniankou, Head of Department, Department for Energy Efficiency, State Committee on Standardization, Republic of Belarus; Aleksandr Snetkov, Head of Industrial Statistics Department, National Statistical Committee, Belarus; Vladimir Zui, Professor, Belarusian State University, Belarus; Valentina Ilieva, Official, Energy Strategies and Policies for Sustainable Energy Development Directorate, Ministry of Energy, Bulgaria; Zlatko Pavicic, Independent Expert, Croatia; Matija Vajdic, Senior Researcher, Energy Institute Hrvoje Pozar, Croatia; Sigurd Heiberg, Chairperson, Petronavit A.S., Norway; Margalita Arabidze, Head of Energy Efficiency and Renewable Energy Division, Ministry of Energy, Georgia; Anna Sikharulidze, Technical Manager, Sustainable Development Centre Remissia, Georgia; Gogita Todradze, Deputy Executive Director, National Statistics Office, Georgia; Dr. Dr. h.c. Manuela Troschke, IOS Institute for East and Southeast European Studies, University of Regensburg, Germany; Vincent Duijnhouwer, Associate Director, Product & Business Development – Energy Efficiency and Climate Change Team, European Bank for Reconstruction and Development, Russian Federation; Hannes MacNulty, Development Manager, Sustainable Energy Solutions, BG Consulting and Energineers, Switzerland; Tahmina Mahmud, Independent Expert, Tajikistan; and Maksym Chepeliev, Research Economist, Center for Global Trade Analysis, Department of Agricultural Economics, Purdue University, United States of America (for Ukraine), Denis Hicks Director / Management Advisor, High Delta Limited, United Kingdom of Great Britain and Northern Ireland.

In addition, the following UNECE country representatives participated in the technical workshop organized by ESCAP in Bangkok, Thailand on 16 January 2017: Hayk Harutyunyan, Deputy Minister, Ministry of Energy Infrastructures and Natural Resources, Armenia; Vugar Jabbarov, Adviser, Ministry of Energy, Azerbaijan; Margalita Arabidze, Head of Energy Efficiency and Alternative Energy Division, Ministry of Energy, Georgia; Bekbergen Kerey, Deputy Director of Department of International Cooperation and Economic Integration Processes, Ministry of Energy, Kazakhstan; Aleksey Ponomarev, Vice President, Industrial Cooperation and Public Programs, Skolkovo Institute of Science and Technology, Skolkovo Innovation Center, Russian Fed.; and Ulugbek Agzamov, Head of Division of the Department for UN and International Organizations Affairs, Ministry of Foreign Affairs, Uzbekistan.

A workshop on "Tracking Progress on Energy for Sustainable Development: Data and Indicators" was organized with the other Regional Commissiones at the launch of the global 2017 GTF report in Astana, Kazakhstan on 14 June 2017 with participation of the following stakeholders: Olga Dovnar, Belarus; Mikhail Malashenka, Vice Chairman of the Committee Director of the Department, State Committee for Standardization Department for Energy Efficiency, Belarus; Andrei Malochka, Chief of Department of General Energy, State Enterprise Beltei, Belarus; Andrei Miniankou, Belarus; Ina Yeliseyeva, Head of Information and Analysis Section, Department for Energy Efficiency of the State Committee on Standardization, Belarus; Gogita Todradze, Deputy Executive Director, National Statistics Office of Georgia (GEOSTAT); Hamid Sherwali, Chairperson, Libyan Authority of Renewable Energy, Libya; Ahmad Saleh Abdelkarim Karaki, Project Management Unit, PRCS Hebron, Palestine; Oafa Quteineh, Electrical Engineering Technical Department, HEPCO, Palestine; Dr. Hazir Farouk Abdelraheem Elhaj, Head, Biofuel Research Group, Aeronautical Research Centre, Sudan; Ahmed Muna, Agricultural Technology Transfer Society, Sudan; Nafaa Baccari, Deputy Director of Renewable Energy, ANME, Tunisia; Dhamir Mannai, Executive Director, Mannai Energy, Tunisia; Professor Nickolas J. Themelis, director of the Earth Engineering Centre, Columbia University and chair of the global WTERT Council; Claire Morel, Statistics Programme Manager, IEA for EU4Energy, International Energy Agency, France; Kim Roseberry, Consultant, Energy Security and Water Resources Section, Environment and Development Division, UN ESCAP; Radia Sedaoui, Chief, Energy Section, Sustainable Development Policies Division, UN ESCWA; Mongi Bida, First Economic Affairs Officer, Energy Section, Sustainable Development Policies Division, UN ESCWA.

**Design:**

Lucille Caillot (UNECE), Luciana Matei (UNECE), Nathalie Loriot (UNOG Printing Section)

**World Bank Coordination:**

Vivien Foster, Alejandro Moreno, Niki Angelou

# Contents

## List of figures

# List of tables

# Executive Summary

If the world is to develop in line with the 2030 Agenda for Sustainable Development, it will be necessary to ensure access to affordable, reliable, sustainable, and modern energy services while reducing greenhouse gas (GHG) emissions and the carbon footprint of the energy sector. The Sustainable Development Goal for energy (SDG 7) has three principal objectives: ensure universal access to modern energy services; significantly increase the share of renewable energy in the global energy mix; and double the global rate of improvement in energy efficiency.

Unfortunately, the energy sector's support for the 2030 Agenda is at risk of faltering. On global scale the current pace of progress toward the SDG 7 targets will not meet 2030 targets. Energy is crucial to the success of the 2030 Agenda and there is a clear imperative for profound and immediate changes in how energy is produced, transformed, traded, and consumed of the objectives of the 2030 Agenda are to be attained. The rate of improvement in energy efficiency, the deployment of net low carbon energy solutions, and the provision of sustainable access to modern energy services are insufficient. Concrete measures are needed to improve energy productivity, rationalize energy use, optimize energy resources, and deploy sustainable energy technology and infrastructure.

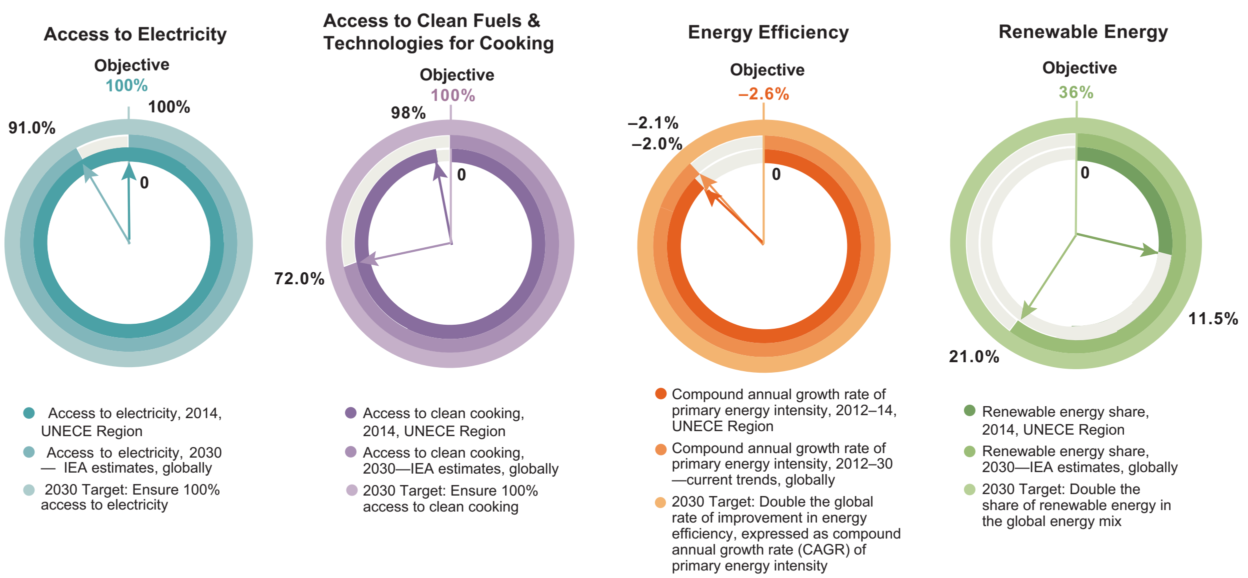
This report has been prepared by UNECE to complement the global analysis presented in the third edition of the Global Tracking Framework (2017 GTF), published by the World Bank and its partners.[1] It explores the global findings in a regional context to offer further insights into regional developments, projects and concerns. Already the 2017 GTF results are a wake-up call for greater effort on a number of fronts. Increased financing, bolder policy commitments, and a willingness to embrace appropriate technology on a wider scale are urgently needed. This is no different in the UNECE region with its 56 member States located in the northern hemisphere. While examples for progress exist, overall countries need to accelerate their efforts, as there remain only 12 years to meet the 2030 Agenda.

This UNECE regional report point to the extraordinary potential that the UNECE region offers with regards to energy efficiency and renewable energy development and deployment, but notes as well the regions reliance on fossil fuels.

## Attainment of the objectives of SDG 7 in the UNECE region.

Attainment of the objectives of SDG 7 is falling short in the UNECE region. While many of the energy challenges in this region are similar to those elsewhere in the world, the region has specific climatic, economic, environmental and political circumstances and the implications are found in inefficient use of energy, power cuts, increasing energy costs, and unsustainable and unaffordable heating in winter. Interpreting the global data on a regional basis has led to valuable insights about country contributions and needs.

**FIGURE 1:** *Summary of Attainment of Sustainable Energy Targets in the UNECE Region.*



At present, some countries export large quantities of fossil fuels as part of their economic model and feature some of the world's highest levels of energy intensity. The number of countries and the number of people whose national incomes and livelihood depend on fossil energy is important and will remain so over the outlook period. This feature has consequences for attainment of SDG 7 across the region.

### ➢ Global Target: Universal access to electricity and clean cooking fuels and technologies: 100% in 2030

Although the region has universal household electrification in terms of physical access, ageing infrastructure, a lack of supply diversity and increasing tariffs lead to poor power quality and, for some, energy poverty. This situation is particularly acute during the cold winter months in the Northern hemisphere, and disproportionately affects poor and rural populations. As a result, some consumers have reverted to local sources of solid fuels for cooking and heating, and others to electricity with off-grid diesel generators.

Further, human comfort and safety depend on substantial heating services in most UNECE countries. This dependence is not reflected in the statistics on electricity network access. A significant challenge exists to upgrade older, uninsulated housing stock with locked-in fossil fuel dependence. Low-income households throughout UNECE make tradeoffs between heat, food, and other needs, and there is a measurable proportion of households that spend more than 10% of their income on energy. Addressing greenhouse gas (GHG) emissions without improving energy efficiency would worsen energy poverty. The region achieved 98% access to clean fuels and technology for cooking in 2014, up from 95% in 2000, but 23.3 million people in remote regions still relied on traditional fuels for cooking in 2014.

### ➢ Global Target: Double the rate of improvement in energy efficiency: -2.6% per year (Compound annual growth rate - CAGR)

The region achieved an aggregated energy intensity of 5.1MJ/USD in 2014, with wide ranges at the sub-regional level from 3.7 MJ/USD in Western and Central Europe to 7.2 MJ/USD in Caucasus, Central Asia, Eastern Europe and the Russian Federation. The growth rate from 2012-14 was -2.0% per annum, almost equal to the global rate of -2.1%. Decomposition analysis shows that changes in energy intensity since 1990 result from decoupling energy consumption from economic growth through efficiency gains.

Energy intensity changes differed across sectors. While energy intensity in the industry and agricultural sector declined continuously between 1990 and 2014, the residential and service sector showed only modest declines in 2012-2014 (-0.9% and -0.4%, respectively) after a sharp decline in 2010-2012 (-3.1% and -3.4%, respectively).

Most countries in the region have developed National Energy Efficiency Action Plans but show limited progress in their implementation. Improving building energy performance is slow, though there has been solid appliance efficiency progress in North America and the European Union. A largely untapped potential for industry energy productivity improvement exists across the region. With the exception of the member countries of the European Union, vehicle fuel economy is not progressing.

Efficiency in fossil fuel power generation is another important indicator as improving conversion efficiencies would reduce the inputs (coal, gas, and oil) required to produce the same electrical output. In the UNECE region, average fossil fuel power plant efficiency improved from 36% in 1990 to 41% in 2014, compared to a lower global rate of 39%. The improvements in supply side efficiency in electricity generation in the region were driven primarily by investment in high efficiency combined cycle gas turbines, while the overall number was dampened by continued use of less efficient coal-fired power plants. Average gas-fired generation efficiencies in the region improved from 37% in 1990 to 49% in 2014, the highest globally. Electricity transmission and distribution losses declined from 8.2% in 1990 to 7.2% in 2014 (8.9% globally), the least among all world regions, while natural gas transmission and distribution losses fell from 1.2% to 0.6%.

### ➢ Global Target: Significantly increase the share of renewable energy in total final energy consumption (TFC): 36% in 2030

The UNECE region was the only region in the United Nations system to increase the share of renewable energy in TFC from 2012 to 2014 to 11%. The reasons for this outcome include strong support mechanisms. In addition, the increased application of more flexible market-based support mechanisms such as auctions, the overall decrease of installation costs, and increased awareness of the feasibility of renewable energy projects across most of the region all contributed.

While growth of renewable energy output in the region accelerated over the period, progress on sub-regional level varied significantly. Looking beyond the share of renewable energy in TFC, a more detailed picture emerges. Taking the share of renewable energy in total primary energy supply (TPES), for the UNECE region as a whole, renewable energy from wind, solar, and geothermal accounted for only 1.6% of TPES in 2014. If hydropower, biofuels and waste are included, this figure rises to 9%, compared to a global share of 14%. The numbers show that modern renewable energies are still lagging. Solar and wind power had a share of 2.1% in TPES in Western and Central Europe, the highest share among UNECE sub-regions.

Investments in 17 countries from the Caucasus, Central Asia, Eastern and Southeast Europe and the Russian Federation fell from USD 700 million in 2013 to USD 400 million in 2015, despite tremendous untapped potential. This figure represents only about 0.2% of the global total investment, a decrease from 0.5% in 2014. An absence of new investment is notable in the Caucasus, Central Asia, and South East Europe.

## Sustainable energy needs to be tracked differently, more holistically

There is no common view in the UNECE region nor globally of what sustainable energy is or how to attain it. Apart from the global challenges regarding the implementation of the 2030 Agenda and other pledges that countries have made, countries in the UNECE have divergent economic development, resource availability and energy mixes embedded in today's national energy strategies. As a consequence, multiple national approaches and outcomes can be found. Choices must be economically and socially rational for each country and be made in the broader context of an economy as a whole. The integration should consider quality of life.

From a mere tracking progress on SDG 7, this report has moved towards tracking progress beyond SDG 7. It has become evident in the preparation of this report that the current approach would benefit from refinements. Relevant indicators should reflect a holistic approach and address the challenges that countries face as systems become more complex and needs more urgent. Taking such a holistic approach leads to the application of a broader concept of "energy for sustainable development" which seeks to measure progress towards all energy-related SDGs to reflect the cross-cutting interconnections among the SDGs.

This report highlights the high dependence on fossil fuels of many countries of the UNECE region, combined with a high carbon-intensity of the energy sector. Therefore, tracking the rate of fossil fuels in the energy mix in addition to the existing indicators will provide useful information about the real state of transformational systems change. To assess if targets linked to SDG 13 on climate can be achieved, it would be useful to provide information on the carbon intensity of the energy sector. As mentioned above, SDG 7 targets 7A and 7B need to be monitored closely to track mobilisation of funding, investment in energy efficiency, and foreign direct investment in infrastructure and technology.

Current indicators have been derived from the existing data gathering and reporting infrastructure that emerged from the energy system of the past. In order to inform policies to accelerate the transition to an energy system that can meet the 2030 Agenda objectives and targets, it will be necessary to develop appropriate indicators for the system of the future, adapt data gathering systems and build the required capacities to collect, analyse, track and report new data and indicators.

## Practical solutions from countries show a changing face of energy

Each country sets its national energy strategy based on its unique perspective, so multiple national approaches and outcomes are found. Country case studies included in this report highlight the changing face of energy towards a service industry. For example, to address energy poverty, the United Kingdom introduced a community led programme to develop renewable energy for self-sufficiency (case study 5). To improve appliance energy efficiency, Turkey fostered market transformation by introducing legislation for minimum energy performance standards (case study 8). The potential of solid biomass and its increased application for combined heat and power (CHP) generation is highlighted for Croatia (case study 15), while Germany's introduction of auctions for off-shore winds provides insights towards the shift to economically feasible applications of variable renewable energy (case study 16). Also addressed in this report are the (Intended) Nationally Determined Contributions ((I)NDCs) by UNECE member States to address climate change mitigation challenges (case study 20), as well as case studies from Poland and the Ukraine on the recovery of coal seam methane (case study 21).

The existing infrastructure, including the physical, regulatory, policy, and organizational infrastructure of the energy industry, is shaping policy approach and national energy decision making. There is evidence in the UNECE region of challenges in heating service affordability, reliability of aging systems and future resilience needs. Truly transforming the energy system will require a creative shift in policy and regulation to unleash innovation, investment, and improved energy productivity. Yet, in many countries in the region, the current political, regulatory, and industrial infrastructure is not yet ready for such a transformation.

## Moving ahead: Key challenges for the UNECE region

- Energy security: These concerns impede improvements in technical, environmental, and economic efficiency, but can be interpreted in different ways. Some countries and sub-regions seek to promote energy independence or self-sufficiency while others strive for efficient integration of energy markets. Promoting mutually beneficial economic-interdependence would accelerate attainment of the 2030 Agenda through integrative, nexus areas that the notion of sustainable development offers. For energy, it is critical to think in terms of a wholly interconnected, complex system in which supply, demand, conversation, transport and transmission interact freely and flexibly.

- Fossil fuel dependency: Fossil fuels dominate the region's energy mix and underpin today's energy access and economic development. The locked-in dependency on fossil fuels is neglected in conversations about energy efficiency and renewable energy, which slows attainment of objectives. The TPES of UNECE countries is just over 80% fossil energy. Less than half the fossil energy used to generate electricity is converted to usable energy, with the remainder lost during conversion. Even under a climate change scenario that meets a 2°C target, fossil energy will still represent 40% of the energy mix in 2050. The underlying tension between achieving SDG 7 and the impact on other SDGs is immediately apparent.

- **Climate commitments:** Given the regions dependence on fossil fuels, meeting the 2030 Agenda's climate objectives must be integrated with the remainder of the agenda to achieve the aspired decarbonisation of future energy systems. Integrated solutions require clear understanding of the climate-related impacts of energy in connection with the development-related opportunities that energy represents. The two most relevant GHGs from the energy sector are $CO_2$, mainly from the combustion of fossil fuels, and methane ($CH_4$) emissions along the coal and gas value chains. This report suggests three additional indicators to track progress towards a less-carbon intensive energy sector: GHG intensity of TPES, GHG intensity of TFC, and per capita GHG intensity of energy. The UNECE region also is falling short on these relevant indicators.

- **Constrained optionality:** Certain options for improving the overall performance of today's energy system are excluded in the formulation of some national sustainable energy strategies for reasons of public perception, politics, imposed market distortions, or legitimate but possibly solvable concerns of safety or environment. These options include nuclear power, carbon, capture, use and storage (CCUS), shale gas, natural gas in transport, among others. Including them in the future would change potential to meet the 2030 Agenda.

- **Energy as a service, not energy as a commodity:** The energy industry has succeeded in raising quality of life around the world, most notably in the advanced economies but even in the developing world. The energy industry today is a commodity business in which players earn returns by producing and selling more. The existing infrastructure, including the physical, regulatory, policy, and organizational infrastructure of the energy industry, is shaping decisions about the future inasmuch as today's structures are expected to persist in the future. And yet consumer energy services are inadequate. There is evidence in the UNECE region of challenges in heating service affordability, reliability of aging systems and future resilience needs. What is needed for true sustainability is to reconceive the energy industry as a complex of service industries. Such a reconfiguration would unleash innovation, investment, and improved energy productivity. Truly transforming the energy system will require a creative shift in policy and regulation, yet in many countries the current political, regulatory, and industrial infrastructure is not yet ready for such a transformation.

# I. Introduction

The third edition of the Global Tracking Framework (2017 GTF) assessed progress on the three pillars of sustainable energy: energy access, energy efficiency, and renewable energy. The findings in this report clearly portrayed that the pace of progress on meeting the objectives and targets of the 2030 Agenda on Sustainable Development (2030 Agenda) is falling well short of what is needed to meet global objectives by 2030.

The 2017 GTF provides regional analyses of progress on sustainable energy that delve into regional trends to explain the global results and to highlight individual country experiences. The regional analyses were prepared in collaboration with the five United Nations Regional Commissions (UNRCs): the Economic Commission for Africa, ECA; the Economic and Social Commission for West Asia, ESCWA; the Economic and Social Commission for Asia and the Pacific, ESCAP; the Economic Commission for Europe, UNECE; and the Economic Commission for Latin America and the Caribbean, ECLAC.

This report has been prepared by UNECE to complement the regional analysis presented in the 2017 GTF to explore the global findings in a regional context, to consider alternative and additional data sources that may offer further insights into regional concerns, and to reflect on alternative indicators for a more robust assessment of progress toward energy for sustainable development in the future.

The report takes a system perspective on energy in the UNECE region. It highlights interconnections along the energy value chain, and explores the policies and pricing mechanisms that shape the ability to deliver society's energy needs. Energy is undergoing a paradigm shift away from the commodity business that society has been comfortable with for two centuries. The human needs for comfort, health, shelter, mobility and the like are more properly thought of as services. It is the demand for these energy services that leads to investment throughout the energy value chain from delivery to transformation and ultimately development of primary energy resources. A reorientation of the energy industry from commodity production to service provision will drive the innovations and efficiency improvements that are at the heart of the 2030 Agenda.

The challenges faced by all governments are to understand which policy choices and options can deliver improved sustainability, consumer utility, productivity and economic resilience in their energy system and to connect these efforts to the greening of their economies. The adoption of a holistic and cross-sectoral approach to energy policy-making will enable synergies with other sectors, and integrate energy-water-food nexus benefits. This report explores these issues and highlights successful applications of best practices.

This report is not intended to present a complete dataset for all proposed indicator categories. The interpretation of data on regional and sub-regional level shows the need to develop regional and country-specific solutions. A broader perspective on energy for sustainable development is further required to measure success more comprehensively and point out more specifically the challenges for the diverse UNECE membership.

## 1.1. Sustainable Energy and the Sustainable Development Agenda

On 1 January 2016, the 17 Sustainable Development Goals (SDGs) of the 2030 Agenda for Sustainable Development (2030 Agenda) officially came into force.

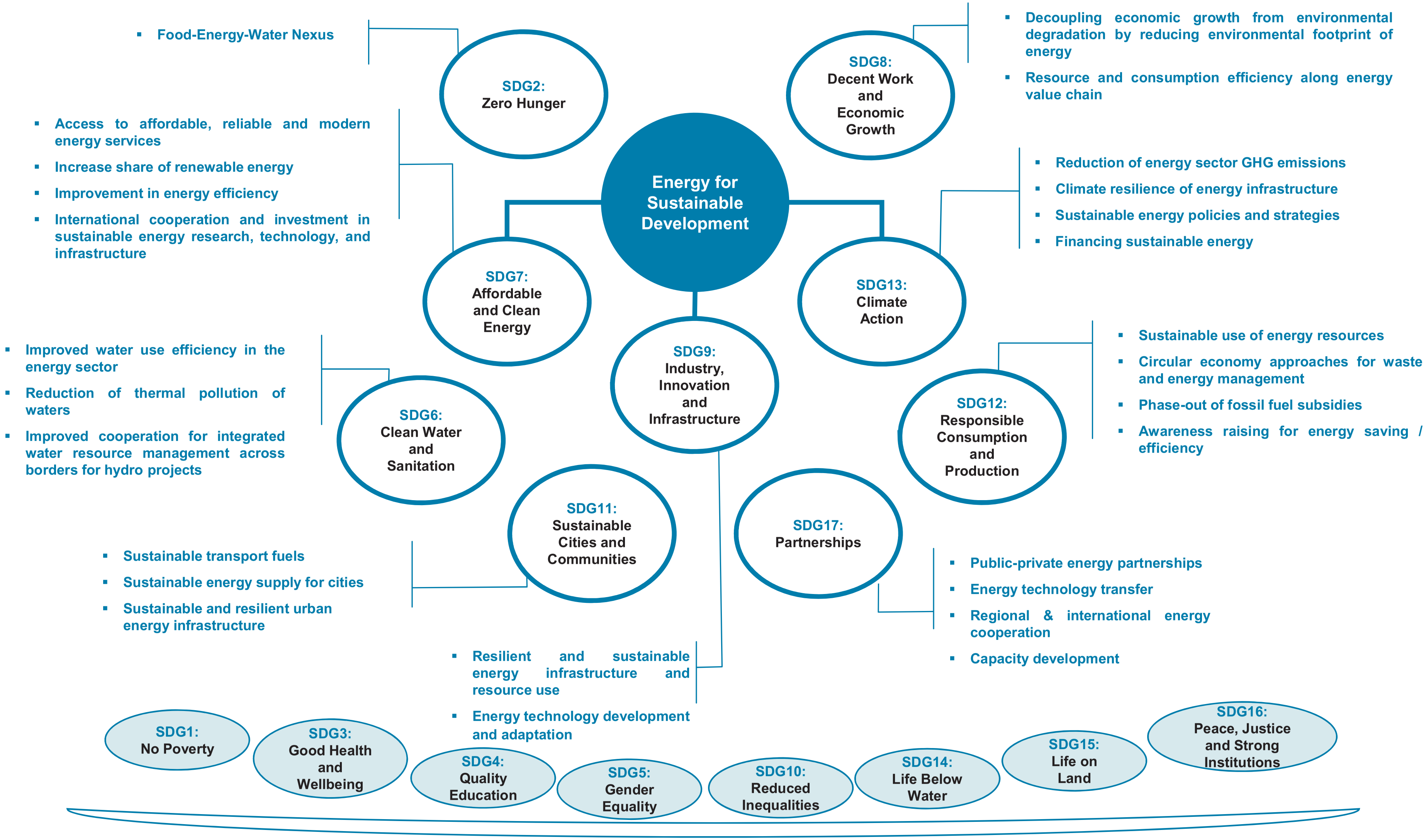
The SDGs call for action by all countries to promote prosperity while protecting the planet. They recognize that ending poverty goes hand-in-hand with economic growth, addressing social needs, and tackling climate change and environmental protection. They are also inter-related in that achieving one goal invariably impacts on one or more of the other goals.

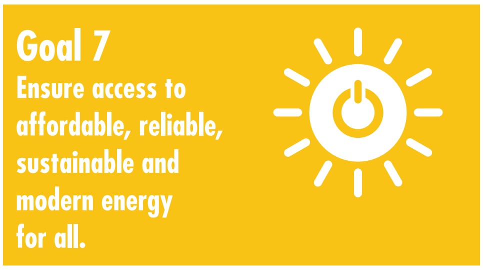
If the world is to develop in line with the 2030 Agenda, it will be necessary to ensure access to affordable, reliable, sustainable, and modern energy services while reducing energy's environmental footprint. Energy is crucial to the 2030 Agenda. It is the golden thread that weaves together all our aspirations and implies an imperative for profound and immediate changes in how energy is produced, transformed, traded, and consumed.

Energy is a fundamental need as it provides the essential services of modern life including cooking, heating, cooling, lighting, and mobility. It enables the operation of appliances, information and communications technology (ICT), and machines in every sector of every country. Doctors use energy to provide healthcare services in clinics, it provides lighting for children to study, and when it is unavailable women (most often) are obliged to gather wood to burn for cooking (which then degrades indoor air quality).

"Sustainable energy" is about providing the energy services that promote sustainable development of a country. Energy was not included explicitly as one of the Millennium Development Goals but has assumed a prominent place in the 2030 Agenda. SDG 7 - the energy goal - aims to *ensure access to affordable, reliable, sustainable and modern energy for all*, and links sustainability in energy to the other 16 goals.

FIGURE 1.1: *Mapping of Energy-Related Sustainable Development Goals.*






**SDG 7 has five targets[2]:**

**7.1** By 2030, ensure universal access to affordable, reliable and modern energy services,

**7.2** By 2030, increase substantially the share of renewable energy in the global energy mix,

**7.3** By 2030, double the global rate of energy efficiency improvement,

**7.A** By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology,

**7.B** By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small-island developing States, and land-locked developing countries, in accordance with their respective programmes of support.

The targets focus on renewable energy, energy efficiency and access without addressing fossil fuels or nuclear. The targets also do not connect to nexus-sectors (e.g., climate, food, water, or agriculture).

## 1.2. "Energy for Sustainable Development" in the 2030 Agenda

While the SDG 7 targets are central to energy's role in the 2030 Agenda, a broader perspective on the contribution energy will make to sustainable development is needed. Energy considerations are important for attainment of many of the SDGs, and a wide set of indicators is needed for the broader picture.

Figure 1.1 maps how Sustainable Energy underpins the 2030 Agenda. SDG 7 should not be seen in isolation but as enabling the attainment of the wider set of SDG goals with improved energy productivity, lesser emissions and sustainable access to energy services. The figure highlights those SDGs with higher relevance for "energy for sustainable development". Beyond the direct link with SDG 7, a particularly strong relationship exists with two further goals: SDG 9 and 13. Without the supply of affordable and clean energy these SDGs cannot be achieved. A progressively complex relationship exists with other SDGs, notably SDGs 2, 6, 8, 11, 12 and 17. The success of the remaining SDGs is either indirectly linked to energy, or energy acts as an enabler. As the success of one goal depends on another, a complex system of dependencies emerges. This complexity is crucial to understand in assessing progress to sustainable energy, and to develop global, regional and national solutions to attain the set targets.

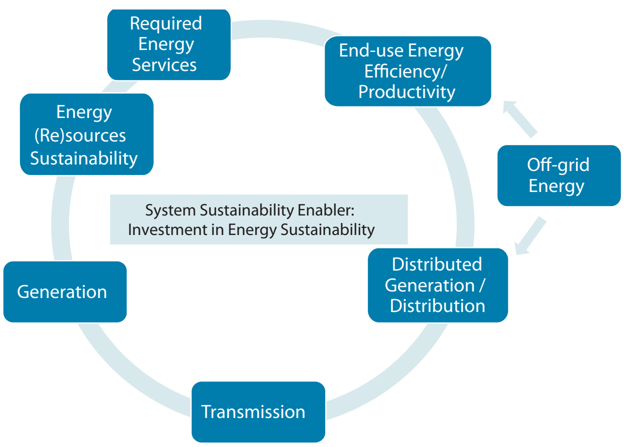
## 1.3. A System Perspective on Sustainable Energy

National energy systems are complex, inter-connected networks that require well-developed policies to function efficiently. The current energy system needs to change significantly to provide affordable energy services, to achieve security of supply and to reduce greenhouse gas emissions. This shift requires deployment of affordable low-carbon technologies and energy efficiency measures, the costs and benefits of which are often highly uncertain.

Moreover, energy systems consist of stakeholders who often have conflicting objectives. The actors and their technologies interact through physical and social networks governed by institutional and political structures whose evolution is also uncertain. Agenda 2030 imposes additional externalities on the energy system, increasing the complexity and uncertainty inherent in policy development.

Figure 1.2 provides a simplified overview to the energy system with its inter-connected parts. Inefficiencies in each stage of the value chain wastes energy. Efficiencies achieved throughput the chain reduce costs for consumers. Typically demand for energy services is moderated by competitive offers, the costs of technology, cost-reflective prices and clear information. The demand to improve energy efficiency is driven by a need for both improved or increased service and the need to manage energy costs.

**FIGURE 1.2:** *A System Perspective on Energy Sustainability.*



Energy efficiency policies and measures deliver both improved services and a reduction in demand for energy; the balance between these is based on consumer's utility-maximising response to the energy efficiency intervention.

This approach improves the adaptability and resilience of the energy system with a diversity of distributed and centrally supplied energy as well as off-grid energy supplies consumers. The supply system (primary energy production, transformation, generation, and transmission / transportation) and its capacity to adapt to changing environmental pressures, technology and resource options, will drive investments in both demand and supply. The result should be an improvement in the supply, reliability and costs of energy.

## 1.4. UNECE Region Overview

The UNECE region is important in the global energy picture. In 2014, the region accounted for 42% of the world's GDP[3], 40% of the world's total primary energy supply (TPES)[4], and 34% of the world's $CO_2$ emissions from fossil fuel combustion.[5]

The UNECE region is very diverse. It comprises 56 countries with a total population in 2015 of 1.3 billion people, representing 18% of the world's population[6] and the majority of the Northern Hemisphere (see figure 1.3). The seven UNECE sub-regions[7] include Caucasus, Central Asia including Turkey, Eastern Europe including Israel, Southeast Europe, North America, the Russian Federation, as well as Western and Central Europe.

The diversity of the region is shown by its history of economic development and the ranges of size of country, population density, national income, climate and access to indigenous energy sources.

The UNECE region has been shaped predominantly by the reconstruction and development that followed World War II that established the infrastructure and technology that persists in today's energy, industrial and transport systems. The development resulted in a level of industrialisation and technological progress ahead of other regions but also created an enduring legacy that is the starting point for future evolution.

Almost half a billion people live in Western and Central Europe, with another 356 million people in North America. The remaining third of the UNECE population resides largely in the Russian Federation (144 million) and Central Asia (including Turkey, 146 million). Eastern Europe has 67 million people. The smallest sub-region in terms of population is the Caucasus with 16 million.

Population density per km$^2$ varies widely across the region. Iceland and Canada have low population densities (3.3 and 3.9 people per km$^2$, respectively), whereas San Marino (530 people per km$^2$), Malta (1349 people per km$^2$), and Monaco (18,865 people per km$^2$) have much higher densities.

In terms of GDP per capita, Western and Central European countries enjoy the highest per capita GDP, for example, Luxembourg (USD 101,449 (current), Switzerland (USD 80,945), and Ireland (USD 61,133). The countries of Caucasus, Central Asia, and Eastern Europe have much lower per capita GDP's including Tajikistan (USD 926), Kyrgyzstan (USD 1,103), and Moldova (USD 1,848).

The climate in the UNECE varies from Mediterranean in the South, to Arctic in the North.

For energy supplies, some sub-regions are net energy importers, such as Western Europe, while other, such as North America and the Russian Federation, are net energy exporters.

This diversity across the UNECE region results in countries having different policy priorities based on wealth and perception of affordability of policy options, climate, availability of energy resources and the stage of economic development.

A more complete set of socio-economic data for the region are presented in Annex I, Table A.1.

### Member States of UNECE Region clustered in seven sub-regions

#### Caucasus

Azerbaijan, Armenia, Georgia

#### Central Asia

Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan, Turkey

#### Eastern Europe

Belarus, Republic of Moldova, Ukraine, Israel

#### North America

Canada, United States of America (United States)

#### Russian Federation

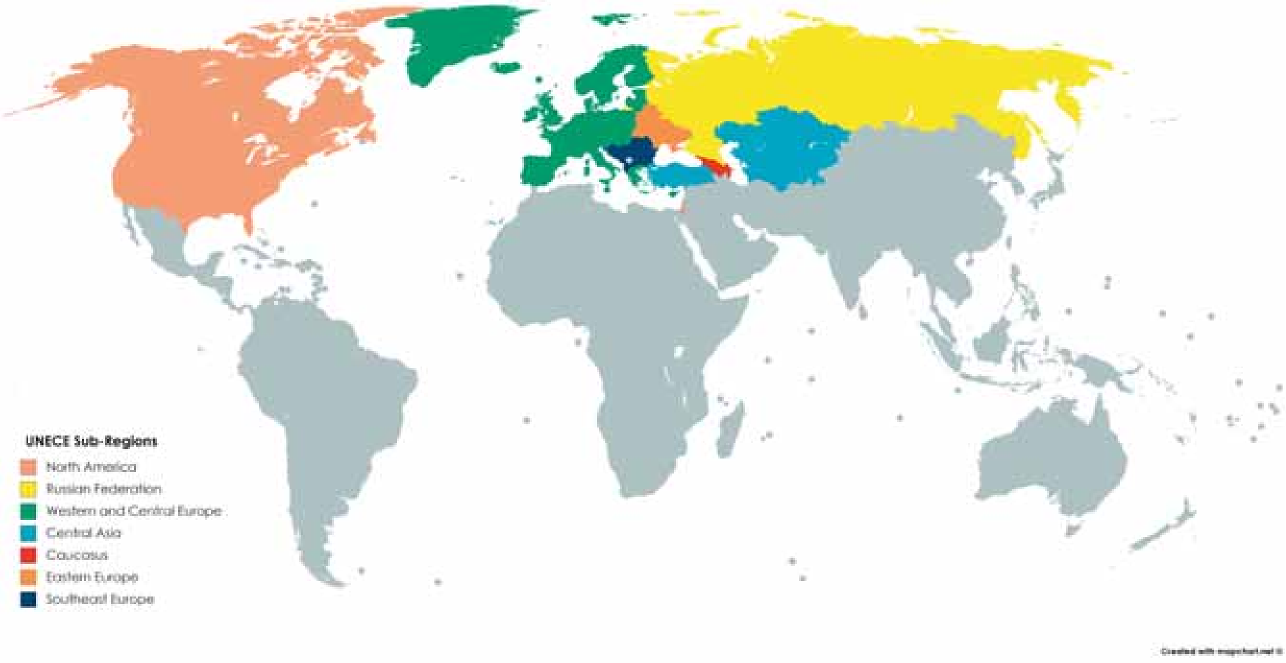
#### Southeast Europe

Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Montenegro, Romania, Serbia, The former Yugoslav Republic of Macedonia (FYR of Macedonia)

#### Western and Central Europe

Andorra, Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Monaco, Netherlands, Norway, Poland, Portugal, San Marino, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, United Kingdom of Great Britain and Northern Ireland (United Kingdom)

**FIGURE 1.3:** *Map of 56 UNECE member States and Sub-Regions used in this Report.*



# II. Tracking Sustainable Energy Progress in UNECE

## 2.1. Overview

On a global scale, the current pace of progress on the SDG 7 targets (universal access to electricity, growth in the share of renewable energy and improvements in energy intensity) will not meet the objectives of the 2030 Agenda targets[8]:

- **The rate at which people are getting access to electricity is slowing.** While UNECE officially has achieved 100% access to power networks, there remain significant quality and affordability challenges. Issues related to access to alternative energy networks such as natural gas also need to be considered.
- **It is estimated that annual renewable energy investments need to double or triple in order to achieve the 2030 target.** Even though the UNECE region is the only region with an increasing share of renewable energy in TFC, sub-regions with extremely low and declining investment rates remain a challenge.
- Only energy intensity improvements have been progressing towards objectives, with global energy savings during the 2012-2014 GTF reporting period enough to supply Brazil and Pakistan combined. **Nevertheless investments in improvements in energy efficiency will need to increase by a factor of 3 to 6 in order to achieve the 2030 target.**

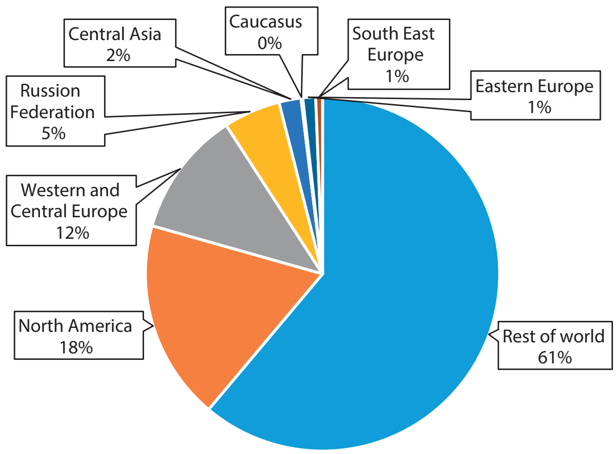
The 2017 GTF results are a wake-up call for greater effort on a number of fronts, including increased financing, bolder policy commitments, and a willingness to embrace new technologies faster and on a wider scale.[9]

### 2.1.1. Energy in the UNECE Region

The following sections give an overview of the energy situation in the UNECE region, including information on its energy mix, energy trade, and infrastructure.[10]

Figure 2.1 shows the share in the UNECE sub-regions[11] of global TPES as compared to the rest of the world in 2014. The UNECE region uses 39% of global TPES. North America has the main share (18% globally), followed by the 33 countries of Western and Central Europe with 12%.

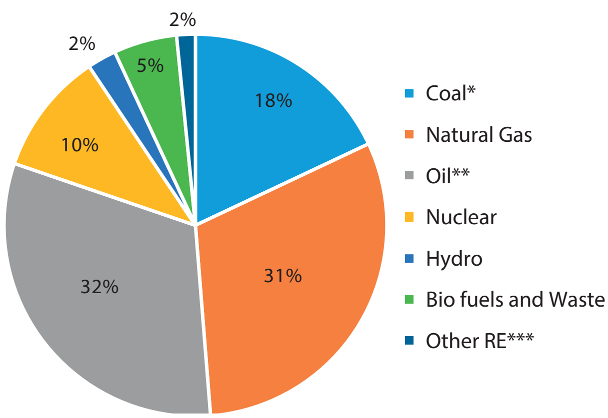
**FIGURE 2.1:** *UNECE Regional Share of Global TPES (in %, 2014).*




*Data Source: International Energy Agency (IEA) World Energy Balances.*

Similar to the global value of 81%, the UNECE region's share of fossil fuels in TPES is 80%. Of this 18% is coal, 31% natural gas, and 32% oil. Figure 2.2 gives the overview of the full energy mix of the UNECE region.

**FIGURE 2.2:** *UNECE Energy Mix (% of TPES, 2014).*




**Includes Coal, peat and oil shale*
*** Includes Crude, NGL and feedstocks and secondary oil products*
****Geothermal, solar/wind/other, heat, electricity*
*Data Source: IEA World Energy Balances.*

**TABLE 2.1:** *UNECE Regional Ranges for Own Production Indices.*

| 2014 | Caucasus | Central Asia | Eastern Europe | Southeast Europe | Western and Central Europe |
|---|---|---|---|---|---|
| **Average** | 2.81 | 1.22 | 0.55 | 0.73 | 0.60 |
| **High** | Azerbaijan (4.10) | Turkmenistan (2.29) | Ukraine (0.73) | Albania (0.86) | Norway (6.83) |
| **Low** | Armenia (0.29) | Turkey (0.26) | Moldova (0.10) | FYR of Macedonia (0.48) | Average Lowest 5 (0.11) |

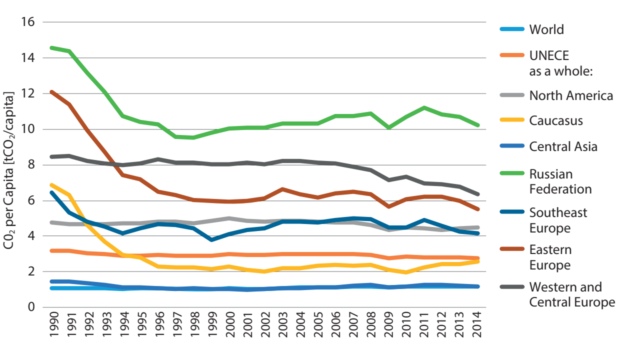
*Data Source: IEA World Energy Balances. within the table, can you please always move the number to the row below (e..g FYR of Macedonia (0.48), and Turkmenistan (2.29))*

Each country's TPES, energy intensity (TPES/capita), and "own production index" are shown in Annex II, Table A.2. The Own Production Index is calculated by dividing total energy consumed in a country by that produced from TPES. It is a simple indication of a countries energy balance: below 1 represents a net energy importer and above 1 represents a net energy exporter. A country can increase its index by reducing energy use by improving energy efficiency or economic restructuring or by increasing energy production. A summary of the countries with the highest and lowest own production index values in the UNECE sub-regions is provided below (Table 2.1). The table shows that the different UNECE sub-regions vary significantly between net energy importers and exporters. Norway has a high index of 6.2 due to its high domestic use of hydropower and significant oil exports, followed by Azerbaijan. Azerbaijan's oil exports result in an index of 4.1.

The sub-regions Eastern Europe, Western and Central Europe, and Southeast Europe are net energy importers. Over the past decade, North America has gradually increased its exports, so that it is expected to become a net exporter between now and 2025, mainly due to the reduction of petroleum liquid imports and the increase in natural gas exports.[12] The Russian Federation, and Central Asia sub-region are net energy exporters.

The Caucasus sub-region became a net energy exporter in 1998, mainly driven by Azerbaijan's oil and gas exports. Georgia and Armenia have an index below 1.

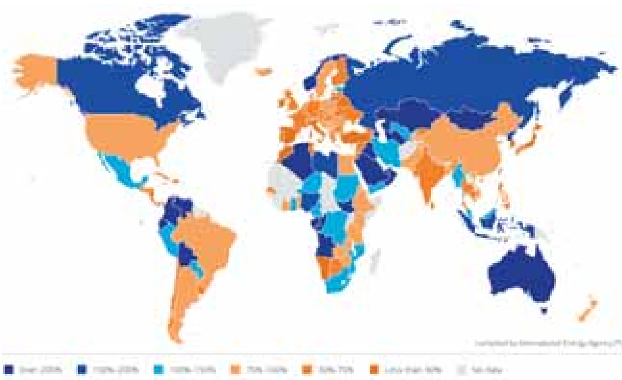
**FIGURE 2.3:** *Own Production Index for UNECE Sub-Regions (1990-2014).*




*Data Source: IEA World Energy Balances.*

Figure 2.4 highlights the own production index values. Countries with an index over 1 are shaded blue, while countries with an index below 1 are shaded orange.[13] Western, Central, Eastern and Southeast Europe which are all net importers with the exception of Norway. Within Central Asia, Kyrgyzstan and Tajikistan are net importers, even though the sub-region is overall an energy exporter.

**FIGURE 2.4:** *National Own Production Index for the World (2014).*



*Source: IEA (2017c).*

## Regional Energy Infrastructure

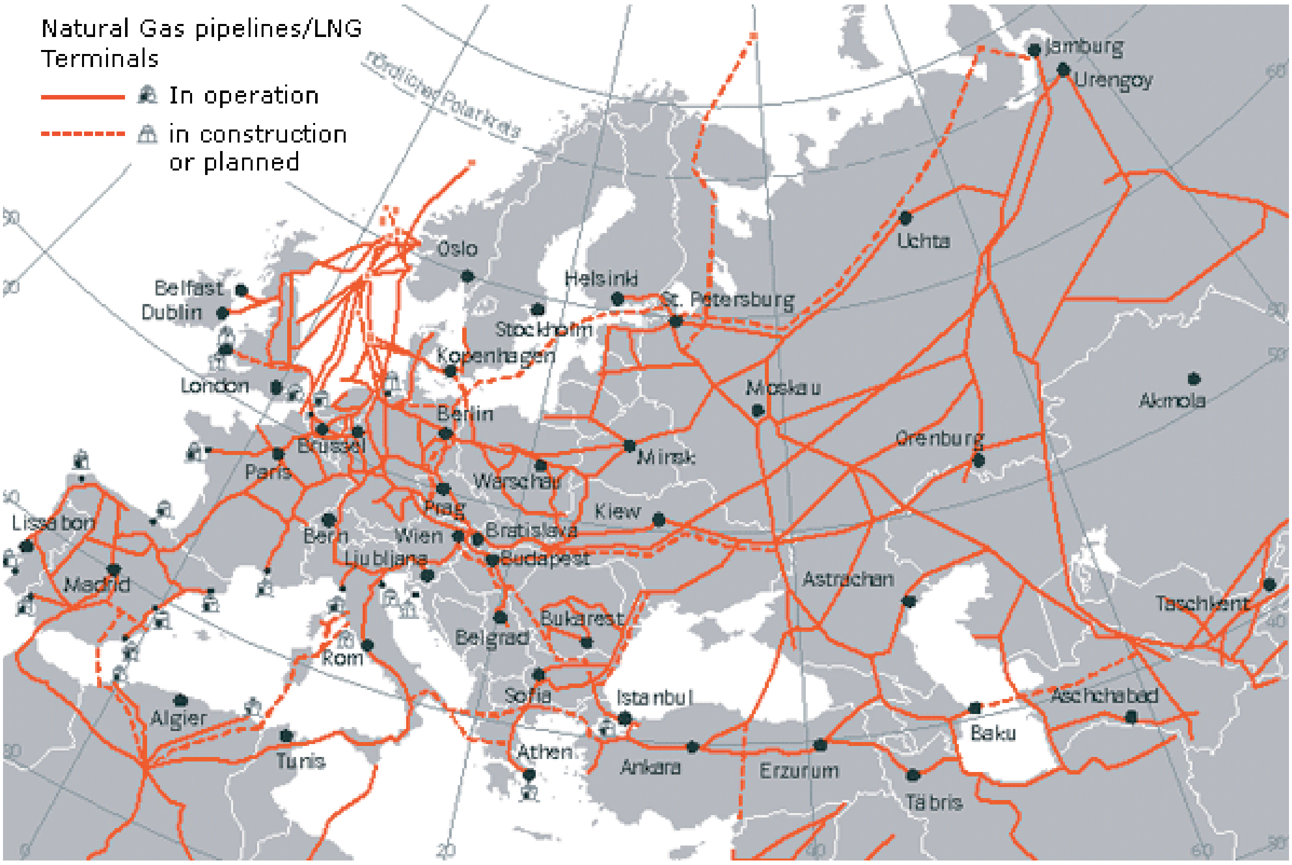
UNECE member States have a complex network of inter-connected energy infrastructure and trade. Figure 2.5 shows the natural gas distribution system in Europe, including the gas trade infrastructure across the Caspian and Black Sea region. The map highlights the issues of trade routes that cross multiple borders, with significant flows of gas from the Russian Federation to Europe. In 2013, 39% of gas imports to the countries of the European Union came from the Russian Federation; followed by Norwegian gas with 31% (year 2012).[14]

In order to diversify gas supply for countries in Central and Southeast Europe, the Southern Gas Corridor is currently being built, with operations expected to commence in 2019-2020. It aims to expand infrastructure for gas to be supplied to the EU from the Caspian Basin, Central Asia, the Middle East, and the Eastern Mediterranean Basin. Expected gas supply is in the range of annually 80 to 100 bcm of gas.[15]

With growing energy trade with Asia, the energy infrastructure in the region is extending towards the East. Figure 2.6 shows the natural gas and oil pipeline infrastructure goings eastwards from Central Asia.

The 3,666 km long Central Asia – China natural gas pipeline, built in several phases between 2003 and 2014 brings gas from mainly Turkmenistan, but also Kazakhstan and Uzbekistan, to China. By 2015, Turkmenistan exported

**FIGURE 2.5:** *Natural Gas Distribution System in Europe and the Commonwealth of Independent States (CIS).*




*Source: SManalysis (2009).*

**FIGURE 2.6:** *Central-Asia China Gas Energy Infrastructure.*


*Source: Strafor (2013).*

40 billion $m^3$ per year to China, which is set to be increased to 65 billion $m^3$ per year. China is further receiving 10 billion $m^3$ per year from Uzbekistan, and 5 billion $m^3$ Kazakhstan. From 2009 to 2015, Turkmenistan has already delivered 125 billion $m^3$ gas to China.[16]

Most of the natural gas that was previously exported to the Russian Federation is now going east. As a result, the 1960 to 1980s built infrastructure connecting Central Asia with Russian Federation, the 4,495 km long "Central Asia Centre" gas pipeline, is now heavily under-utilized.[17]

A majority of the existing power infrastructure in the Eastern stretches of the region date back to the early era of the former Soviet Union. Within Central Asia most of the existing power related infrastructure, including generation and transmission networks, is in disrepair or inefficiently operated. More than 77% of Kazakhstan's and 87% of Kyrgyzstan's power generation assets are at least 20 years old. The share of old equipment older than 20 years is 86% and 88% for Tajikistan and Uzbekistan, respectively.[18]

## 2.2. Progress across SDG 7 Targets

The following sections present indicators and data for the three SDG 7 targets on energy efficiency, renewable energy, and energy access.[19] Indicators and data from the 2017 GTF report included in this presentation are complemented with additional information beyond the core indicators[20].

Data presented here focus on the period from 1990-2014, including an interpretation of the tracking period 2012-2014. Many developments have occurred since 2014 and new trends may have emerged in the last three years. The interpretation of data in a regional context has led to introduction of additional data in this report. The intent is to enrich the analysis of progress for SDG 7 and to initiate a discussion on a broader set of indicators to track energy for sustainable development across the 17 SDGs.

A summary of indicators used in the 2017 GTF including information on the methodology is provided in Annex III. The list is complemented by recommendations from stakeholder consultations to provide the basis for further discussion on indicators to track energy for sustainable development in Annex V.

### 2.2.1. Energy Efficiency

According to the Sustainable Energy for All Initiative (SEforALL), a global initiative launched by Secretary-General Ban Ki-moon in 2011 to promote sustainable energy: "Energy efficiency can bring SDG 7's renewable and access objectives within reach if energy consumption can be stabilised at current levels through efficiency gains".[21]

Energy efficiency is defined as the relationship between the energy consumed and the output (energy service) produced by that energy. Increasing energy efficiency means using either less energy to provide the same output, or use the same amount of energy to produce more.[22] For example, it can be used on micro-level to express efficiency of energy in a sector, such as steel, as well as on product level, such as the energy efficiency of applications, or in terms of energy efficiency in power generation such as from coal, gas and renewable energy.

Energy efficiency is an enabler for many policies: reducing the energy required for economic output in the context of the capital, labour and other material resources in an economy improves energy productivity. Since a report by McKinsey it has been recognised as a low-hanging fruit to achieve global goals and targets, nevertheless implementation of energy efficiency measures could be improved.[23]

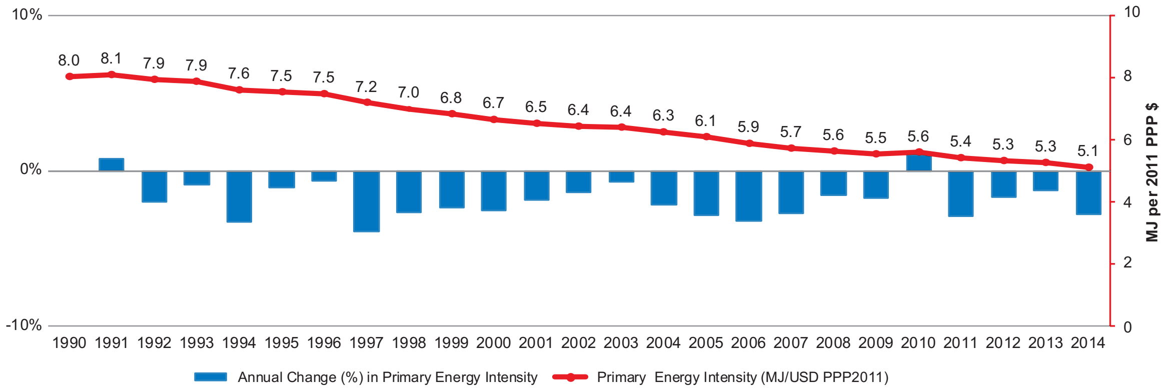
A commonly used measure for energy efficiency is energy intensity although the two are not equivalent and energy intensity, in itself, does not account for differing economic structures, availability of resources, activity levels or climatic drivers for energy use. Energy intensity is an indication of how much energy is needed to produce one unit of economic output. Lower ratio indicates that less energy is used to produce one unit of output. It is usually an indicator used on macro-economic level, defined in terms of energy rather than output.[24]

For example, high energy intensity may directly result from a country extracting and exporting energy intensive mineral products in a cold climate (e.g., Canada, Sweden, or the Russian Federation), and low intensity from high levels of service industries (e.g., Switzerland). In neither case does energy intensity offer insights into the underlying efficiency of the economy, historical development paths, and improvements in energy efficiency, or the opportunities for further energy efficiency improvements.

**SDG 7 Indicator: Energy Intensity of Total Primary Energy Supply to GDP; Compound Annual Growth Rate (CAGR) of Primary Energy Intensity [25]**

Primary energy intensity is the ratio of TPES to GDP measured at Power Purchasing Parity (PPP) in constant 2011 USD (MJ/2011 PPP USD). Energy intensity in the region has been improving since 1990. Over the period 1990-2014, primary energy intensity[26] declined at the fastest rate globally (1.9% (CAGR), from 8.0 MJ/USD to 5.1 MJ/USD in 2014 (see figure 2.7)[27]. From 2012 to 2014, the UNECE region avoided 3.9 exajoules (EJ)[28] of TFC – about a third of avoided energy globally, and nearly equivalent to the 2014 TFC of Spain and the Czech Republic combined. The decline

**FIGURE 2.7:** *Steady Improvement in UNECE Primary Energy Intensity from 1990 to 2014.*




*Data Source: IEA and UN Statistics, quoted from World Bank et al. (2017a).*

of energy intensity within the tracking period was -2.01%, almost equal to the global rate of 2.1% but short of the 2.6% needed over 2010-2030 to meet the targets of SDG 7.

## Energy intensity by economic sector

Energy intensity in the UNECE region has declined across all sectors. In the industrial sector, energy intensity declined continuously across all periods. Energy intensity in the agricultural sector improved in recent years, dropping by 6.4% annually. Energy intensity in the services sector and the residential sectors dropped significantly from 2010-2012 before returning to more modest trends from 2012-2014.

Decomposition of energy end-use trends considers three main components over time: activity change, sectoral structure shifts, and the energy efficiency improvements. In the UNECE region there has been a relative decoupling of energy consumption from GDP growth in the region, which began in the early 1990s, as GDP increased and energy demand remained stable (see figure 2.8).

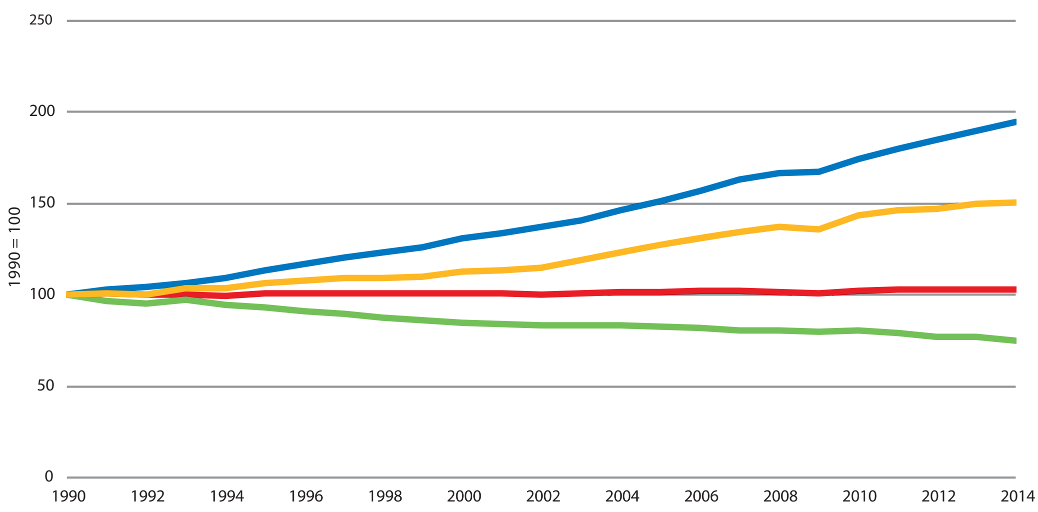
There was little change in the region's aggregate economic structure, except for the countries of the former Soviet Union.[29] Some of these countries saw a substantial shift away from heavy industry to lighter industry, agribusiness and services. For example, Belarus' share of manufacturing in total GDP fell from 42% in 1991 to 32% in 2000, and 24% in 2014, similar to the Ukraine's which fell from 44% in 1992 to 19% in 2000.[30]

## Sub-Regional Energy Intensity Trends[31]

Energy intensity has been declining in all sub-regions from 1990-2014, and the declines accelerated over the tracking period 2012-2014 except in North America (see figure 2.9) where the rate of decline slowed recently. There is a wide variance of energy intensities across the region from 18 MJ/USD in Iceland with its high reliance on geothermal energy[32] to about 2 MJ/USD in Switzerland with a large services industry and hydroelectric power.

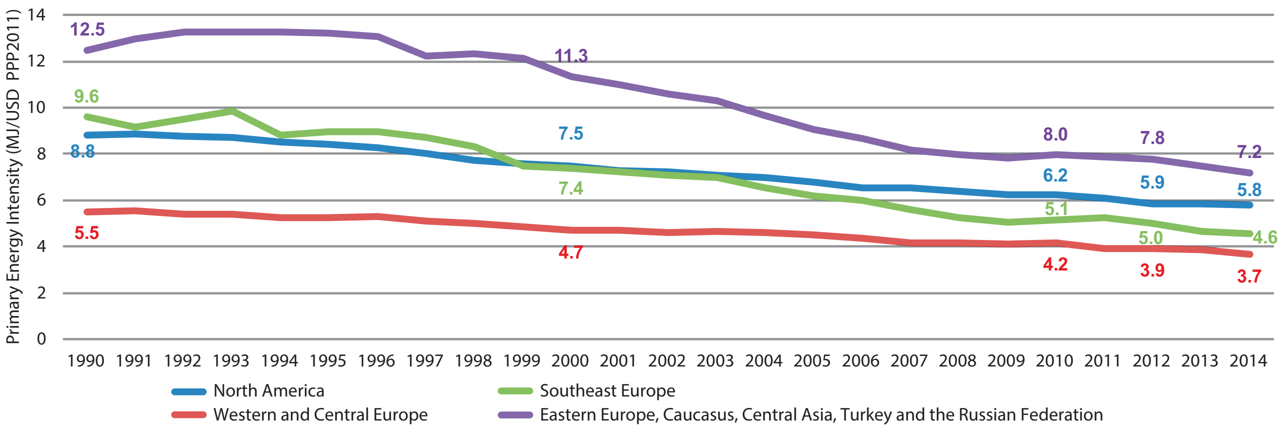
**North America** had the third highest energy intensity in 1990 at 8.8 MJ/USD, which fell to 5.8 MJ/USD by 2014 as economic growth decoupled from energy demand. In 2010–12, the pace

**FIGURE 2.8:** *UNECE Region Achieved Relative Decoupling of Energy from GDP Growth.*




*Data Source: IEA and UN Statistics, quoted from World Bank et al. (2017a).*

**FIGURE 2.9:** *UNECE Sub-Regions Achieved on-going Declining Energy Intensity from 1990-2014.*




*Data Source: IEA and UN Statistics, quoted from World Bank et al. (2017a).*

of improvement accelerated, driven by cost-reflective energy prices and energy efficiency policies. In the power sector, the shift to natural gas enabled efficiencies in new electricity and heat plants that displaced older coal-fired plants. Yet activity in energy-extractive industries recorded significant growth. Canada's cold climate and mineral extraction industry resulted in energy intensity of 7.7 MJ/USD, higher than the United States' 5.6 MJ/USD.

In **Western and Central Europe**, energy intensity also declined continuously between 1990–2014, from 5.5 MJ/USD, the lowest in the region, to 3.7 MJ/USD. This was driven by a combination of cost-reflective energy prices and consistent, comprehensive, and aggressive energy efficiency policies and commitments.

The European Union's Renewable Energy Directive 2009/28/EC set an energy efficiency target for 2020 of a 20% reduction in energy demand relative to a business-as-usual projection. All member countries of the European Union were mandated to shape National Energy Efficiency Action Plans (NEEAP) requiring durable efficiency improvements along the whole energy value chain. These plans should largely achieve the 2020 targets, in part due to the global financial crisis.[33] The European Union's 2020 target was originally set at 18.6% below projected primary energy consumption of 1,542 million tonnes of oil equivalent (Mtoe), or 64 EJ, but primary energy consumption was revised downward to 1,527 Mtoe (63EJ).[34]

Higher-productivity countries in Western and Central Europe reported very low energy intensity, but Iceland's was the highest in 2014 as its economy featured high energy-intensive aluminium smelters and a primary energy resource of low grade geothermal energy with high transformation losses.

In **Southeast Europe**, sharp improvements in energy intensity were made in the 1990s when conflict in Croatia, and Bosnia and Herzegovina caused energy demand to drop faster than economic output. During the 2000s, innovations in productivity contributed to further improvements.

The pace of energy intensity improvements in Southeast Europe picked up in 2012–14, and energy intensity reached 4.6 MJ/USD in 2014, on the back of underlying structural shifts to lower-intensity services and recovery of GDP to 2008 levels. Still, significant annual variations in energy intensity suggest that the sub-region has yet to implement firm policies on cost-reflective energy prices and energy efficiency.

The sub-region's northern neighbours have more challenging climates but often have lower energy intensity, pointing to further scope for energy efficiency action in Southeast Europe. Energy intensity in Southeast Europe is converging slowly toward the levels in the rest of Europe.

In **Caucasus, Central Asia, Eastern Europe, and the Russian Federation** energy intensity declined between 1990–2014 from 12.5 MJ/USD - the highest in the region – to 7.2 MJ/USD.

As in Southeast Europe, variations suggest that prices and policies have still to mature into durable drivers. Changes in structure lie beneath the reported changes in many countries. In Tajikistan, for example, the declining trend was interrupted in 2011, and energy intensity increased as industries grew following long stagnation after the 1992–97 civil war. Israel's energy intensity was low in 2014 (3.7 MJ/USD) as was Turkey's (3.5 MJ/USD) as both benefited from low-energy-intensity industries and mild climates.

Most countries in the sub-region still have energy intensities above 5MJ/USD. Limited policy action, monitoring and evaluation, and data and compliance, coupled with energy price subsidies, slowed gains after 1998.

## Additional Indicator: Supply Side Efficiency in Electricity Generation

Supply side efficiency (calculated as generated power output / primary energy input) in electricity production in the region improved from 36% in 1990 to 41% in 2014 – despite the improvement more than half the primary fossil energy used to generate electricity is wasted. This improvement was driven primarily by investment in high efficiency combined cycle gas turbines, which improved overall gas-fired generation efficiency from 37% to 49% over the period. Transmission and distribution losses dropped from 8.2% in 1990 to 7.2% in 2014, reaching the lowest levels in the world. Natural gas transmission and distribution losses decreased from 1.2% to 0.6% during the same period.

### 2.2.2. Renewable Energy

**SDG 7 Indicator: Share of Renewable Energy in Total Final Energy Consumption[35]**

The UNECE region was the only UN region that consistently increased its share of renewable energy in the mix over the tracking period 2012-2014, and the rate of growth recently accelerated. It was also the only region to report flat growth in TFC over the period 1990-2014. The share of renewable energy in TFC increased from 6% in 1990 to 11% in 2014, with growth fastest in Southeast Europe (see figure 2.10). The share of modern renewable energy reached 11%, the second highest globally, as traditional biomass consumption is negligible in the region.[36]

Initially, the development of hydroelectric power underpinned a high rate of electricity access in the region. More recently, renewable energy developments have been for the most part in large wind and solar farms, reflecting a central supply focus and falling production costs.

Within the UNECE region, most investments in renewable energy occurred in Western Europe and North America as a result of strong price supports and policies such as Feed-in Tariffs (FiTs), auctions and tax incentives.

Within renewable energy sources, the share of modern solid biofuels consumption was the highest in 2014 at 38%, followed by hydropower at 28%, and modern liquid biofuels at 14%. In 2012-2014, wind and solar power production grew fastest, reaching shares of 9.5% and 4.3% respectively.

### Sub-Regional Renewable Energy Trends[37]

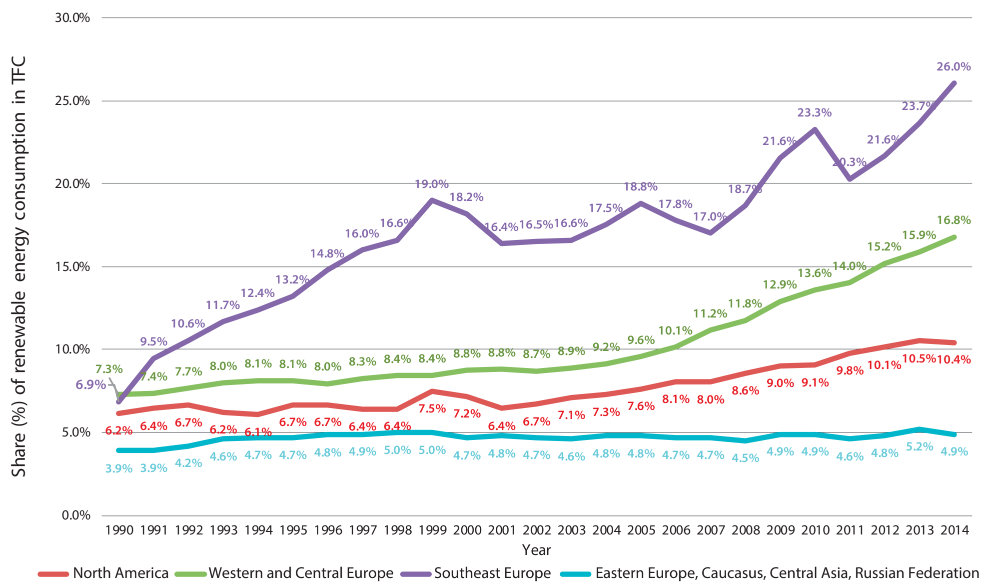
As shown in Figure 2.9, all sub-regions showed an increasing share of renewable energy, albeit from a very low base.

**North America** reported the second lowest share of renewable energy in 2014 in the region at 10%. In 2014, over half of renewable energy came from modern biofuels, and another 26% from hydropower. Between 2012 and 2014, wind and solar power reported the strongest growth, reaching shares of 9.2% and 2.5% respectively.

In **Western and Central Europe**, the share of renewable energy in TFC increased from 7.3% in 1990 to 17% in 2014. Individual country's FiT schemes and the European Union's Renewable Energy Directive 2009/28/EC supported strong growth in installed renewable energy capacity. For those countries that are members of the European Union the 2009/28/EC Directive mandates a binding aggregate target that 20% of energy use be provided from renewable energy sources by 2020. The Directive also sets a target of 10% for renewable energy use in transport by 2020.

The objectives are to be met through measurable national targets and policies set by each country. Countries have set individual targets with some choosing more ambitious 2020 national targets, such as Denmark (30%), France (23%) and Portugal (31%), while others remain below the 20% target of the Directive, such as the United Kingdom (15%), Germany

**FIGURE 2.10:** *Growing Renewable Energy in all UNECE Sub-Regions (Share of renewable energy in TFC, in %).*




*Data Source: IEA and UN Statistics, quoted from World Bank et al. (2017a).*

(18%), and the Netherlands (14%). Overall, the targets range from 10% (Malta) to 49% (Sweden).[38]

According to latest data from EuroStat, in 2015 the 28 member countries of the European Union achieved a 16.7 % share of TFC, up from 8.5 % in 2004.[39] Based on assessments by the European Environment Agency, the European Union is on track to meets its aggregate 2020 target. From the Western and Central Europe sub-region, the Czech Republic (13%), Estonia (25%), Finland (38%), Italy (17%), Lithuania (23%) and Sweden (49%) already have achieved their set targets.[40]

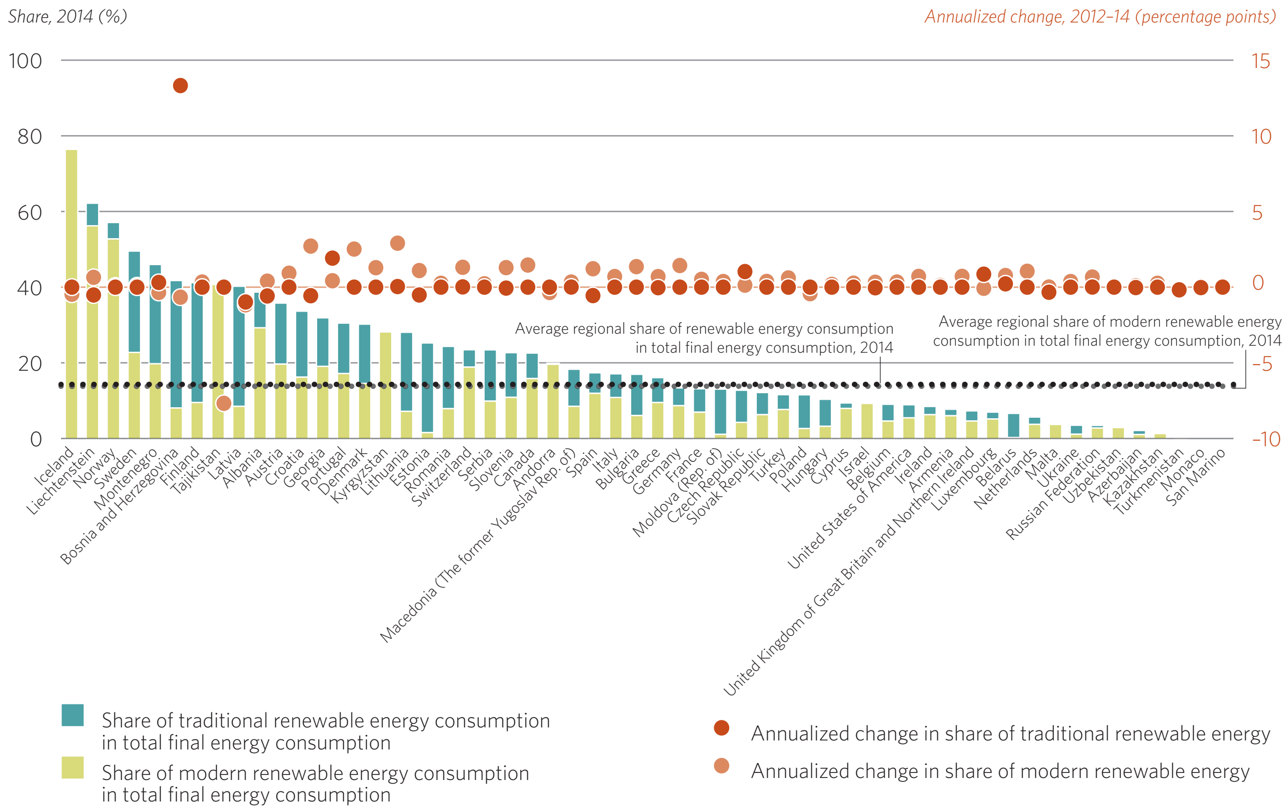
For the whole Western and Central Europe sub-region, over half of renewable energy consumption in 2014 came from modern biofuels and another 23% from hydropower. Since 2010, wind and solar power reported the strongest growth, reaching shares of 11% and 5.6%, respectively, in 2014. Iceland, Norway, and Liechtenstein reported the highest shares of renewable energy use, at 76%, 62% and 57%, respectively. Iceland and Norway have long histories in hydropower and geothermal energy, and Liechtenstein leads globally in solar photovoltaic energy per capita.

In each case the high share of renewable energy is driven by the availability of the resource, commitment of the government and willingness of society as a whole to bear the costs of the transformation. In the case of Norway, it shows that setting ambitious national targets can drive a high share of renewable energy (the 2020 target is 67.5%).

Southeast Europe reached 26% of renewable energy in TFC in 2014, the largest share in the region, with over half in traditional biomass. Montenegro, Bosnia and Herzegovina, and Albania, reported the highest shares of renewable energy in TFC, at 46%, 42% and 39%, respectively. Southeast Europe also has the largest share of hydropower in the region, led by Romania, Croatia and Serbia. In 2012-2014, wind and solar power production showed the strongest growth, reaching 8.0% and 3.3%, respectively, of TFC. Similar to countries in Western and Central Europe, some of the countries are driven by the European Union's Directive 2009/28/EC, including Bulgaria (16%), Croatia (20%), and Romania (24%). All three countries have achieved their set 2020 targets in 2015 already.

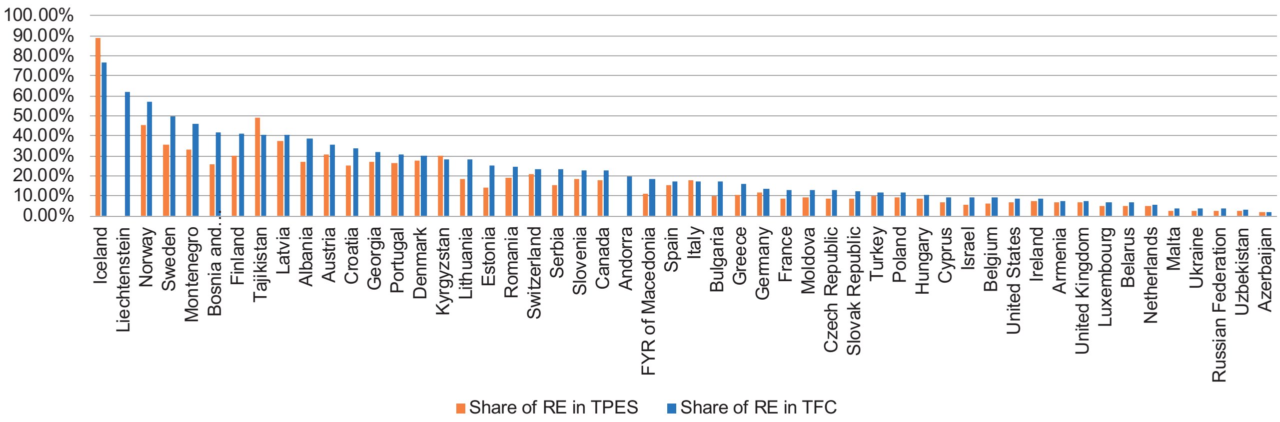
The **Caucasus, Central Asia, Eastern Europe, and Russian Federation** sub-regions presented the smallest share of renewable energy in TFC in the region, at 4.9% in 2014, and investments in the sub-region were focused largely on hydropower. Modern solid biofuels accounted for 20%, having decreased sharply between 1990 and 2014. Hydropower dominated the renewable energy mix with a 62% share in 2014, led by Tajikistan. In 2012-2014, liquid biofuels and wind power recorded the strongest growth, reaching 0.7% and 7.0% shares, respectively. Ukraine reported the fastest growth in wind power in the sub-region, almost doubling the share of wind power in TFC from 16% in 2010 to 29% in 2014.[41]

**FIGURE 2.11:** *Country Proportion of Traditional and Modern Renewable Energy based on TFC and Rates of Change.*




*Data Source: IEA and UN Statistics, quoted from World Bank et al. (2017a).*

**FIGURE 2.12:** *Share of Renewable Energy in TFC and TPES in UNECE Countries (2014).*




*Data Source: IEA World Energy Balances; UN Statistics.*

Figure 2.11 summarises the share of modern and traditional renewable energy for each country, and the rates of change between 2012-2014.[41]

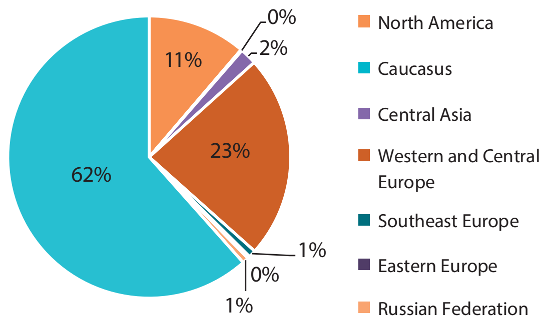
## Additional Indicator: Share of Renewable Energy in Total Primary Energy Supply

A measurement of renewable energy as a share of energy is an indicator of progress in reducing global GHG and local pollution sources, a country's progress in developing and utilising available resources sustainably, and improving sustainability over the entire energy value chain.

Two measurements are possible. A measurement of renewable energy as a share of TFC can be useful, but it ignores the 6-8% transmission losses that are incurred through the transmission and distribution network. A second option is an indicator expressing renewable energy as a share of TPES, but this measurement ignores losses incurred in the combustion of fossil fuels. While both indicators have their advantages, the need to understand primary energy options and implications is important. These measures therefore should be interpreted carefully.

For the UNECE region as a whole, renewable energy from wind, solar, and geothermal accounted for only 1.6% of TPES in 2014.

**FIGURE 2.13:** *Renewable Energy Capacity Additions (2000-2015). Source: IRENA (2016).*




*Data Source: IEA World Energy Balances; World Bank et al. (2017).*

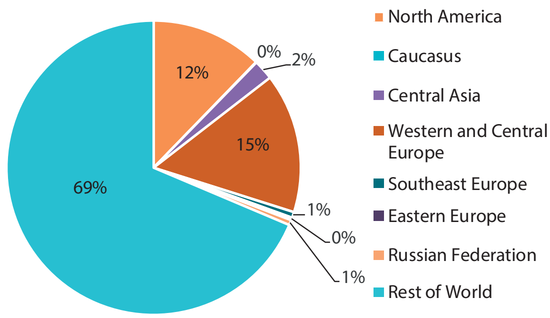
If hydropower, biofuels and waste are included renewable energy accounted for 9% of primary energy supply compared to a global share of 14%[42].

Figure 2.12 shows renewable energy as a share of both TFC and TPES for each country in 2014. Countries with high shares of renewable energy, (e.g., Iceland, Norway, Sweden, and Montenegro) "suffer". There is an obvious transformation efficiency gap for renewable energy. This renewable energy transformation effect is less in Kyrgyzstan and Switzerland because hydroelectric power's "conversion efficiency" is 100%.

## Additional Indicator: Renewable Energy Generating Capacity Additions

Between 2000 and 2015, the UNECE region witnessed growth in renewable energy[43] generating capacity from 434 Gigawatts (GW) to 860 GW. This growth amounted to 38% of all global additions of renewable capacity - consistent with the region's share of global capacity. Non-hydro additions accounted for 86% of total renewable energy generating capacity, or 372 GW, indicating a progressive shift away from hydro to investment in solar photovoltaic (PV), wind and bioenergy. Hydro's share remains high with 57% of total installed renewable energy capacity[44].

**FIGURE 2.14:** *Renewable Energy Capacity Additions (2013-2015).*




*Source: IRENA (2016).*

Over the period 2000-2015, Western and Central Europe led the growth in renewable energy capacity with 23% of capacity additions, followed by North America at 11%. The balance was in Central Asia at 2%, Southeast Europe at 1%, and the Russian Federation at 1% (see figure 2.13). The latter countries represent a small part of the UNECE's total population and GDP base. Ideally, progress would be measured against a scale of economically realisable renewable energy potential capacity in a country or region.

Comparing the first chart with a more recent period of 2013-2015, the UNECE sub-regions which contributed most to renewable energy installed capacity additions were again Western and Central Europe (15%) and North America (12%) (see figure 2.14). The growth in capacity additions in North America is mainly due to the United States which increased its annual additions from 192 GW in 2013 to 219 GW in 2014, making it the country with the most additions in 2015 in the UNECE region.

#### Additional Indicator: Investments in Renewable Energy Capacity

Tracking investments in renewable energy capacity provides further insight into the success of developing renewable energy. On global scale, new investment in renewable energy (excluding large hydro) fell by 23% to USD 241.6 billion, the lowest figure since 2013. In 2015 the figure was USD 258.9 billion, a 5% increase to 2014.[45] At the same time, there were record installations of renewable energy capacity in both years, with 134 GW in 2015, and 138.5 GW in 2016. The investment figures are roughly double the figure for investments in fossil fuel based generation.

The decrease in investments is explained in part by falling costs of renewable energy capacity but also by a marked slowdown in financings, mainly in China, Japan and in some emerging markets. The United States saw a reduction by 10% to USD 46.4 billion, while overall Western and Central Europe enjoyed a slight increase, including the United Kingdom with USD 24 billion and Germany USD 13.2 billion, down 1% and 14% respectively.

The 2017 UNECE Renewable Energy Status Report further provides 2015 figures for 17 countries from the Caucasus, Central Asia, Eastern Europe, the Russian Federation, and Southeast Europe.[46] The investment figures reported are less optimistic: total investments in the 17 countries declined to USD 400 million in 2015, down from USD 700 million in 2014. Data for 2016 point to a further reduction. Countries of this region only represented 0.2% of total global investments in 2015, down from 0.5% in 2014.

Only three countries, Kazakhstan (USD 100 million), the Russian Federation (USD 200 million) and Ukraine (USD 100 million), saw new investment in renewable energy.

A range of international donors and development banks are active in the renewable energy sector in these countries. They provide technical and financial assistance in form of debt financing and grants for renewable energy projects in the region. However, there is a clear gap between the renewable energy potential and the investment provided in these countries, and further assessment of the barriers and how to overcome these is required.

Additional measures are required to allow these countries to benefit from the forecasted global renewable energy share of almost three quarters of the USD 10.2 trillion (Tn) total investment in new power generating technology until 2040.[47]

### 2.2.3. Energy Access

#### SDG 7 Indicator: Share of Population with Physical Access to Electricity

Energy is essential for sustainable development and poverty eradication. According to the UN, in 2015 about 2.8 billion people had no access to modern energy services and over 1.1 billion did not have electricity.[48] Historically, high levels of industrialization have provided a high level of physical electricity access in all countries in the UNECE region. The electrification rate in the UNECE region was 99% in 1990, and almost reached 100% in 2010.

In 2014, all countries reported electrification above 99.9%. In rural areas, virtually universal access at the regional level was achieved in 2010. All countries showed a rate of rural electrification above 99.7% in 2014.

North America and Western and Central Europe had universal access by 1990. Caucasus, Central Asia, Eastern Europe, the Russian Federation, and Southeast Europe collectively achieved 100% access between 2007 and 2010. In 2014, 2,500 people across Kyrgyzstan and Tajikistan did not have access to electricity.

#### Additional Indicator Area: Affordability and Reliability of Electricity Access

Despite 100% physical access to electricity, many countries in the UNECE region are challenged by issues of affordability, quality of access, and service. Many of the infrastructure assets are now old, and substantial renewal and redevelopment is required to improve reliability and quality of supply. For example, it is estimated that more than 60% of the power infrastructure in Kyrgyzstan, Tajikistan and Uzbekistan is older than 60 years[49] (see further information under chapter 2). Power supply in Caucasus and Central Asia suffers where infrastructure maintenance and age reduce supply reliability. In Tajikistan, for example, 70% of the population endure frequent power outages. In 2012, electricity shortages in the winter were estimated at 2,700 GWh, protected to grow to over 6,800 GWh by 2020 in the absence of any offsetting measures.[50]

Across the UNECE region, five areas were reported with inadequate grid access. These were villages in Kraiina and Eastern Bosnia in Bosnia and Herzegovina; 130 largely seasonal residences in rural settlements in Georgia; 20 settlements in the Batken region in Kyrgyzstan, where traditionally power was supplied from outside Kyrgyzstan; 1,500 remote settlements in Uzbekistan; and Tajikistan where the power grid covers 96% of the country, but 10% of the population in remote mountainous regions do not have access. These examples have supply constraints from remoteness, seasonal occupancy, or as a result of conflicts. In each case, efforts are underway to address access.[51]

The required upgrade of aged infrastructure provides both a challenge as well as an opportunity for countries. Planning of new energy infrastructure can integrate aspects of sustainability in the context of the SDGs and in particular SDG 7.

Affordability is also an issue in the UNECE and is not only a problem seen in the eastern countries of the region. The European Union has some of the highest end-consumer electricity prices (29.8 Euro-cent per kWh in the second half of 2016)[52], and German suppliers reportedly cut electricity to 130,000 households in 2015 due to unpaid electricity invoices.[53] In Spain, there were more than 7,000 deaths related to energy poverty in 2014, and in Great Britain more than 15,000 in 2015. These figures can be explained mainly by the elderly who do not heat or cool their houses sufficiently.[54] The World Health Organisation (WHO) estimates that 40% of unnecessary winter mortalities are caused by inadequate living conditions in the European region.[55]

#### Additional Indicator Area: Heat Demand, Affordability of Heating, and Quality of Heat Services

Many of the region's countries circle the arctic, and cold continental climates across most of the region create the highest demand for heating services in the world. The region features older, often poorly insulated buildings with old inefficient central or unitary heating systems. Affordability and service quality of heat services are a particular challenge with the lock-in of older fossil based heat infrastructure and poor insulation remaining an important issue in all countries.

Affordability of heating services is a growing challenge. All countries have at least part of their household population in energy poverty, which is generally defined as more than 10% of household income spent on energy. For example, in the Russian Federation 29% of households spend more than 10% of income on energy, while in four other countries more than 40% of households spend over 10% of their income on energy (Albania 46%, Moldova 52%, Serbia 49%, and Tajikistan 60%).[56]

Security of operation continues to rely on decades-old infrastructure in power systems, district heating networks, and the natural gas network with low efficiency and high losses. Further barriers include a lack of transparency and trust in tariff setting, poor cost recovery and metering, and affordability.

#### SDG 7 Indicator: Share of Population with Access to Clean Cooking

The UNECE region achieved 98% access to clean fuels and technology for cooking in 2014, up from 95% in 2000. With 75.8%, Southeast Europe was the predominant sub-region that did not achieve universal access. Albania had the fastest growth in Southeast Europe and reached 67.1% access, while Bosnia and Herzegovina reported the lowest access, 39.8%, and the slowest growth in 2012–14. Outside of Southeast Europe, only Georgia (55%) in the Caucasus, and Kyrgyzstan (76%) and Tajikistan (72%) in Central Asia, did not achieve access rates above 90%.

In summary, 23.4 million people, 12 million from Southeast Europe, 2 million from Caucasus, 8 million from Central Asia (excluding Turkey), and 1.4 million from Eastern Europe (excluding Israel which has 100% access rates) still relied on traditional fuels for cooking in 2014 in the UNECE region. They mostly lived in remote regions, and relied on locally-gathered firewood. The fuel is typically burnt in a controlled combustion wood stove or a traditional high mass combined space heater and/or cooking oven. Traditional stoves offer users reliable heat from low or no-cost local resources at reasonable efficiencies[57] and are therefore a preferred option in situations where access to commercial energy sources is impractical or expensive.

## 2.3. Beyond SDG 7: Energy for Sustainable Development

As is noted elsewhere in this report energy is the golden thread that weaves throughout the 2030 Agenda. Addressing the net carbon intensity of the energy system is essential for meeting the climate challenge and herewith SDG13. Assuring energy access and affordability connect directly to poverty, hunger, health, education, gender equality, water, economic development and employment, infrastructure, inequality, and sustainable cities.

Attaining the objectives of the 2030 Agenda will require full engagement of industry to transform energy. As a consequence, it is essential to monitor progress on energy for sustainable development in ways that reflect the cross-cutting interconnections among the SDGs.

### 2.3.1. Energy Productivity

Instead of using energy efficiency and energy intensity the concept of energy productivity can be applied. It describes a paradigm shift as it moves from reducing the energy used to optimizing the energy use, e.g. by doing more and using the same or less amount of energy.

Energy productivity expresses the volume of services or products that can be generated per unit of energy. It measures the amount of value added or GDP that can be produced with one unit of energy. This can be done on macro-economic level by dividing GDP by TPES, or on micro-level such as sectors, companies, processes, etc. It is hence the inverse of the concept of energy intensity, an increase in value resembles an improvement in productivity. Nevertheless, it has a series of advantages over using energy intensity as indicator.

The concept of energy productivity is commonly perceived as more positive, since energy intensity is often perceived to carry a negative connotation of using less energy. As most governments are more motivated to improve the country's social wellbeing, economic productivity and environmental impacts rather than "saving energy", improving the country's GDP per unit energy productivity is a priority for a number of countries. Intuitively, people tend to adopt concepts more willingly where an improvement leads to an increase in value rather than a decrease.[58]

The concept of energy productivity is further more aligned with energy efficiency, as both measures divide output by input, which leads to an almost synonymous use when applied on sector or process-level.[59]

There are also mathematical advantages. While countries with initially high energy intensity make large gains in absolute and relative terms over time as GDP generally increases faster than energy consumption. On the other side, countries that did not feature positively in terms of energy intensity improvements actually make larger energy productivity improvements in absolute terms.

Similar to energy intensity, energy productivity is not a perfect concept either because it does not reflect differences between countries such as their economic structure, size, or climate.

There is an urgent need to more broadly apply the concept of energy productivity including in business improvement objectives if the global welfare and environmental improvements sought in the UN's Sustainable Development Goals are to be achieved. Nevertheless, energy efficiency as an indicator does not become obsolete, as it provides an important input to energy productivity by assessing the actual physical improvements to be made to optimize or reduce energy use.

## Additional Indicator: Energy Productivity of GDP to Total Primary Energy Supply

Energy productivity can provide useful information when plotted against energy availability measured in TPES per capita. Normalising energy consumption by the number of citizens makes it possible to compare countries despite differences in population. Per capita energy consumption reflects the wealth of a country, the structure of the economy and the efficiency of energy use. However, countries that are structurally similar can differ in terms of energy use per capita because of differences in size or climate. Monitoring shifts in energy productivity and availability over time can give useful insights on energy consumption based on economic structure and climate zones. Similar countries exhibit similar trajectories of productivity and per-capita consumption over time which indicate how rapidly they might progress towards greater productivity and efficiency.

Between 2001 to 2012 most UNECE member States improved their energy productivity despite variances in energy availability (see figures 2.15a-d). Countries with high per capita consumption are prone to reduce energy demand while improving energy productivity. Many European countries show an intense decline in per capita consumption and improvement in productivity over this period.

Most of the Balkan countries are still developing their energy availability. Some countries like Azerbaijan or Tajikistan have made major shifts in productivity but still have low levels of energy intensity or low energy availability. In contrast, other countries like Kazakhstan or Turkmenistan have massively increased per-capita consumption but achieved moderate improvement in productivity.

**FIGURE 2.15A:** *Productivity Trends 2001-2012 in North America and North-West Europe.*

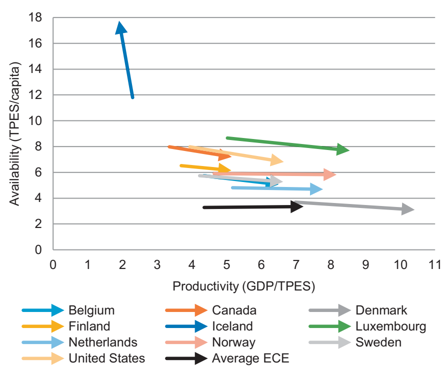



**FIGURE 2.15B:** *Productivity Trends 2001-2012 in Western and Central Europe.*

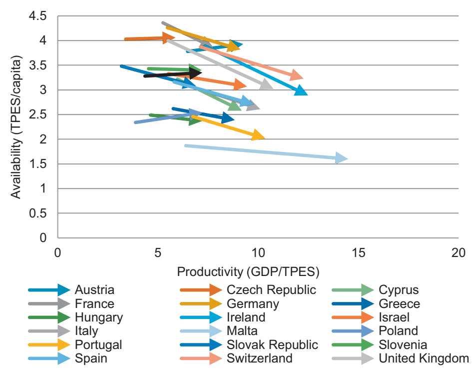


**FIGURE 2.15C:** *Energy Productivity Trends 2001-2012 for Southeast Europe.*

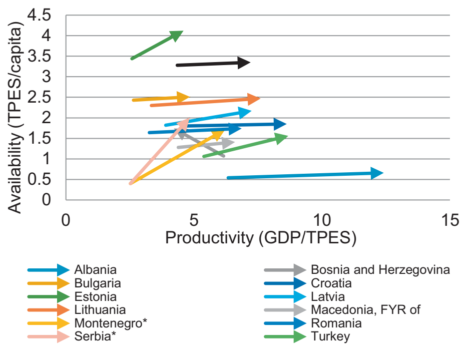
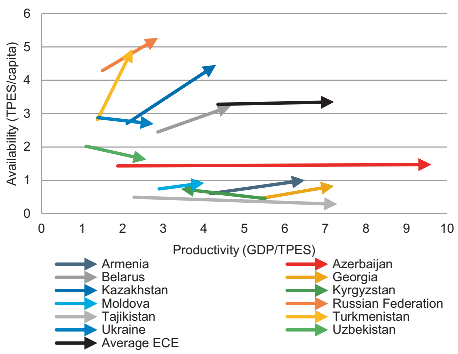



**FIGURE 2.15D:** *Productivity Trends 2001-2012 in Caucasus, Central Asia, Eastern Europe, and the Russian Federation.*

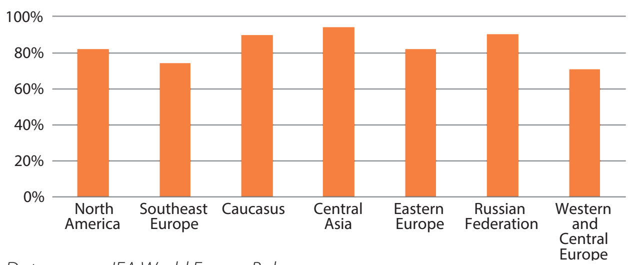



*Note: Due to data gaps, countries not included in calculation: Andorra, Liechtenstein, Monaco, and San Marino. Data for 2001 is given for Serbia and Montenegro as one country.*
*Data source: IEA World Energy Balances.*

## 2.3.2 Fossil Fuels

Given that UNECE region's share of fossil fuels in TPES is 80%, and will likely remain above 50% over the time period, the transition to a clean, affordable and low-carbon energy system will require solutions for the use of fossil fuels. To achieve net zero emissions by the second half of this century, the region's historical dependency on fossil fuels needs to be reduced or there must be a strong focus on carbon capture and storage (CCS).

**FIGURE 2.16:** *Fossil Fuel Shares in TPES of UNECE Sub-Regions (2014).*




*Data source: IEA World Energy Balances.*

To track progress towards this objective, the share of fossil fuels within the energy system must be one indicator to measure progress towards a low-carbon future. Other indicators could include the efficiency of fossil fuel based power generation capacities and methane ($CH_4$) emissions along the energy value chain. Some data are provided below.

**Additional Indicator: Share of Fossil Fuels in Total Primary Energy Supply**

In 2014, 80% of UNECE's TPES came from fossil fuels, compared to the global share of 81%. The balance was made up of 10% nuclear and 9% renewable sources of energy including hydro, biofuels and waste, as well as geothermal, solar and wind. Figure 2.16 gives an overview of the share of fossil fuels in each sub-region.

The figures vary across the UNECE sub-regions from 71% in Western and Central Europe to 94% in Central Asia. For more analysis on the role of fossil fuels in the UNECE region, please see Issue 1 in Chapter 5.3.

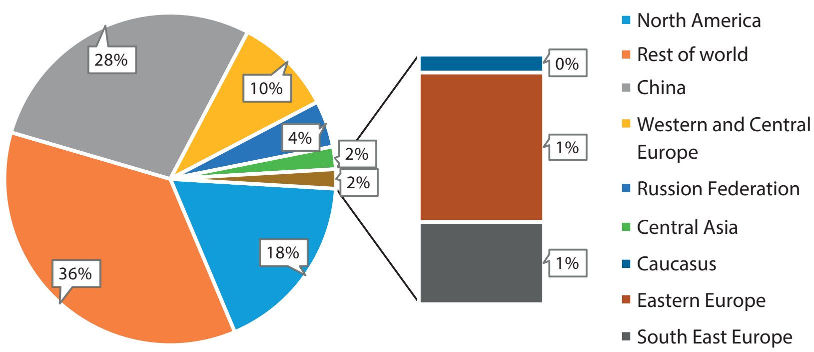
## 2.3.3. Climate Commitments

SDGs 7 and 13 are linked through the Paris Climate Agreement that aims to limit global warming to well below 2°C. Meeting them both requires clear understanding of the climate-related impacts of energy and the development-related opportunities of energy. Meeting the climate change challenge necessarily involves fundamental transformation in how energy is produced, transformed, transmitted, and used.

According to the Intergovernmental Panel on Climate Change's (IPCC) Fifth Assessment report, mitigation scenarios aiming to limit global temperature increases below 2°C over the 21st century include substantial cuts in anthropogenic GHG emissions by mid-century. These cuts will have to be achieved through both large-scale changes in energy systems and potentially land use. The mitigation scenarios are characterized by more rapid improvements in energy efficiency and a tripling to nearly a quadrupling of the share of zero- and low carbon energy supply from renewable energy, nuclear energy and fossil energy with CCS, or bioenergy with CCS (BECCS) by the year 2050.[60]

The IPCC report confirms that energy plays a crucial role in combating climate change. The $CO_2$ emissions from fossil fuel combustion and industrial processes contributed about 78% of the total GHG emission increase from 1970 to 2010.[61] According to the IEA, 80 % of global $CO_2$ emissions come from the energy sector, while it contributes a third to global GHG emissions.[62] The two most relevant GHGs are $CO_2$, mainly from the combustion of fossil fuels, and methane along the energy value chains. Three indicators are suggested to track progress towards a less-carbon intensive energy sector: GHG intensity of TPES, GHG intensity of TFC, and per capita GHG intensity of energy. The UNECE region also is falling short on these relevant indicators.

**FIGURE 2.17:** *Global and UNECE Share of $CO_2$ Emissions from Fossil Fuel Combustions (2014).*




*Data Source: IEA World Energy Balances.*

## Additional Indicator: $CO_2$ Emissions from Fuel Combustion

Over the 1990-2010 period, total $CO_2$ emissions from fossil fuel combustion increased by about 45% globally. In 2010, $CO_2$ contributed 76% of global GHG emissions (one third from the energy sector), $CH_4$ (methane) about 16%, $N_2O$ about 6% and the combined fluorinated gases (F-gases)[63] about 2%.[64]

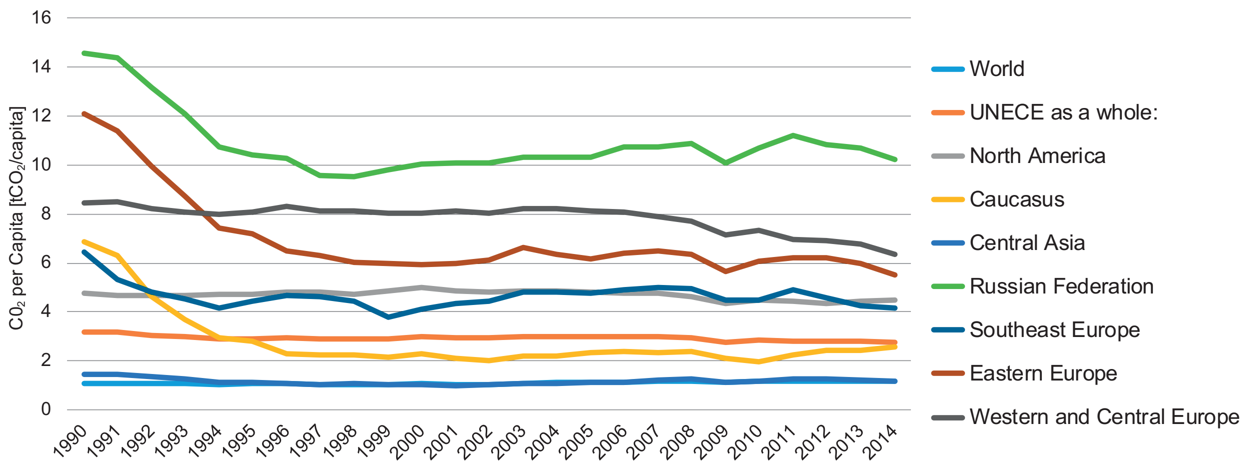
The UNECE region contributed 36% of global $CO_2$ emissions from the combustion of fossil fuels in 2014 (see figure 2.17),[65] which is about 11 $GtCO_2$ out of the total global 32 $GtCO_2$ emitted. While globally there was a small increase of emissions less than 1% compared to 2013, $CO_2$ emissions in the UNECE region saw a reduction in 2014 compared to the previous year. North America has the largest share at 18%, Western and Central Europe at 10%, the Russian Federation 5%, Central Asia 2%, Eastern Europe and Southeast Europe 1% each, compared to China with 28%.

In light of commitments made under the Paris climate agreement, UNECE countries need to address GHG emissions from the energy sector. Country sizes vary considerably, and while emissions must be tackled at an absolute emission level, normalizing emissions by factors such as population, geographical area or economic activity offers useful insights into the scope and capacity for change.

On a per capita basis there is considerable range in the carbon intensity of fossil fuel energy[66] (in $tCO_2$/capita) in UNECE sub-regions. With 9.1 $tCO_2$/capita in 2014, the UNECE average is two times higher than the global average of 4.5 $tCO_2$/capita. Figure 2.17 shows the trend for $CO_2$ emission per capita for the UNECE sub-regions.

Since 1990, most sub-regions have converged towards the world average per capita emissions, especially the former Soviet Union countries, Caucasus, Central Asia, Eastern Europe, and the Russian Federation. Central Asia has tracked the world average closely, while Western Europe and North America showed later progress as their post-millennial policies on energy efficiency, renewable energy and climate took effect. Figure 2.18 shows that UNECE countries have high per capita fuel combustion $CO_2$ emissions to address in order to achieve sustainable energy.

**FIGURE 2.18:** *Total Fossil Fuel Combustion related $CO_2$ per Capita for UNECE Sub-Regions (2014).*




*Data Source: IEA World Energy Balances.*

**FIGURE 2.19:** *Total $CO_2$ Emissions from the Consumption of Energy (2014).*

*Data Source: US EIA Statistics.*

In addition to IEA data, the United States Energy Information Administration (EIA) publishes data for total $CO_2$ emissions from the consumption of energy.[67] Figure 2.19 provides an overview of emissions within UNECE with the darkest shades representing the highest emitters.

## Additional Indicator: Carbon Intensity of Primary Energy and Final Energy Consumption

The carbon intensity of primary energy is calculated by dividing all net $CO_2$ emissions from fuel combustion by TPES ($tCO_2/TJ$). The carbon intensity of final energy consumption is calculated by dividing all net $CO_2$ emissions from fuel combustion by TFC ($tCO_2/TJ$).

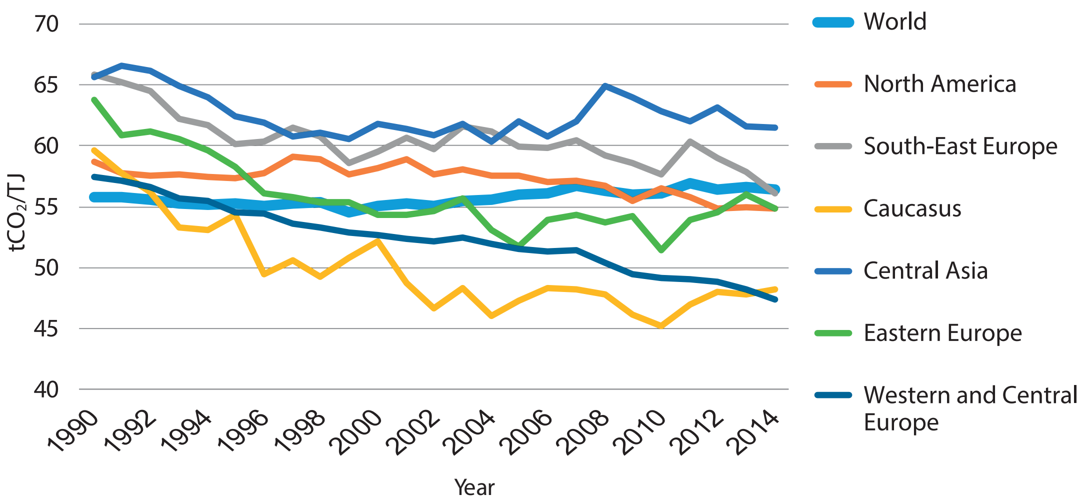
According to IEA data, the global carbon intensity of primary energy in 2014 was 56.6 $tCO_2/TJ$, averaged over all energy sources including fossil fuels, nuclear and renewable energy. Figure 2.20 shows the development of this indicator for the different UNECE sub-regions from 1990 to 2014.

The carbon intensity of primary energy sources differs significantly across the regions. Central Asia and Southeast Europe's trend is upwards until 2012.

Western and Central Europe has witnessed a continued decline of carbon intensity. In 2014 the sub-region reported 47 $tCO_2/TJ$, well below the global carbon intensity of 56 $tCO_2/TJ$.

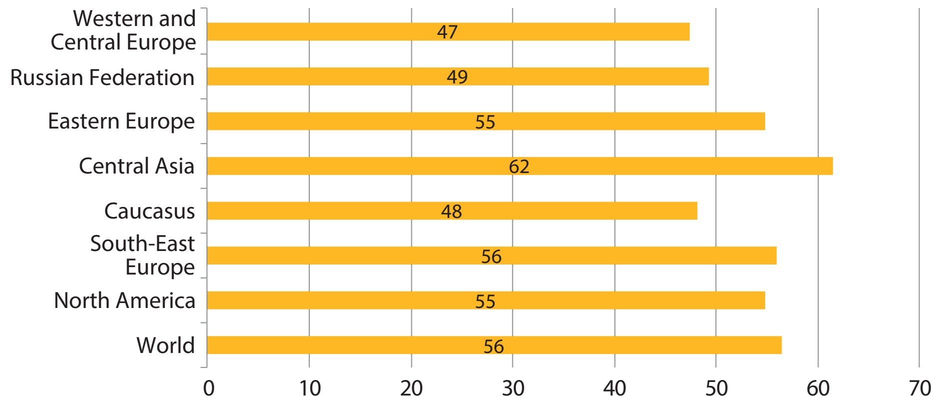
Figure 2.21 gives a detailed overview of the 2014 carbon intensities at sub-regional level. The highest national carbon intensity figures for TPES in the region are Malta, Poland, Estonia and Kazakhstan with 72, 71, 70, and 70 $tCO_2/TJ$, respectively.

**FIGURE 2.20:** *$CO_2$ Emissions from Fossil Fuel Combustion per TPES in UNECE (1990-2014, in $tCO_2/TJ$).*




*Data Source: IEA World Energy Balances.*

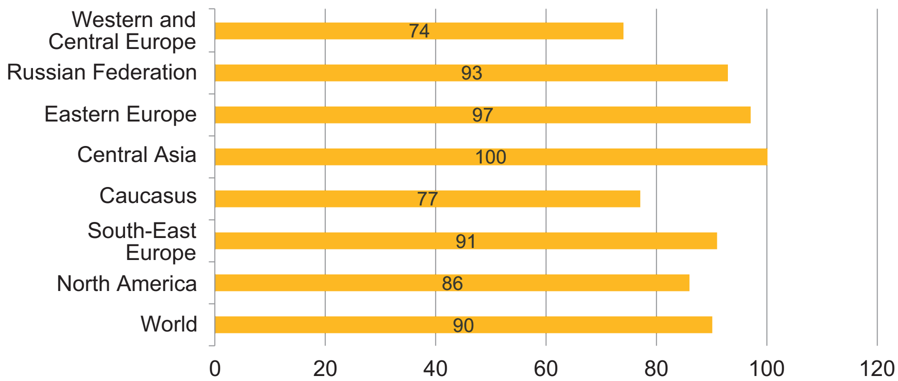
**FIGURE 2.21:** *$CO_2$ Emissions from Fuel Combustion per TPES for UNECE Sub-Regions (2014, in $tCO_2/TJ$).*




*Data Source: IEA World Energy Balances.*

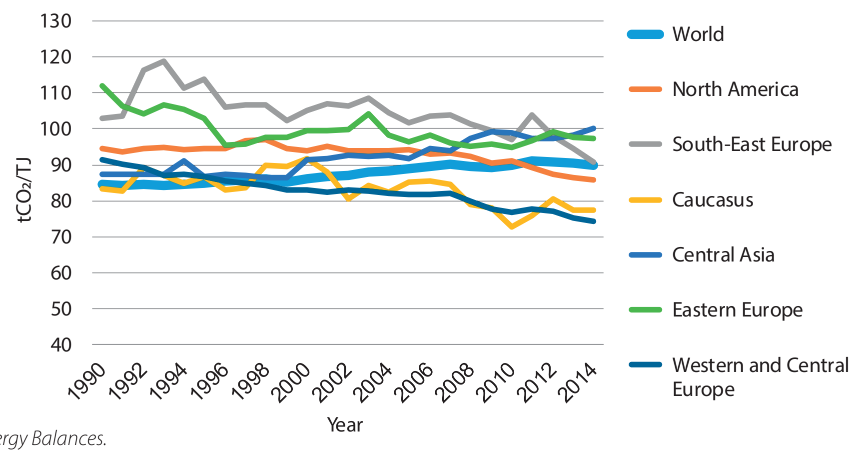
2014 figures for TFC are given in Figure 2.22 and the carbon intensity trends for 1990-2014 are shown in Figure 2.23. Only the sub-regions of Caucasus, North America, and Western and Central Europe are below the global figure of 90 $tCO_2/TJ$. The highest national carbon intensity for final energy are Estonia and Kazakhstan with 150 and 149 $CO_2/TJ$, respectively.

**FIGURE 2.22:** *$CO_2$ Emissions from Fuel Combustion per TFC for UNECE Sub-Regions (2014, in $tCO_2/TJ$).*




*Data Source: IEA World Energy Balances.*

**FIGURE 2.23:** *$CO_2$ Emissions from Fuel Combustion per TFC for UNECE Sub-Regions (1990-2014, in $tCO_2/TJ$).*

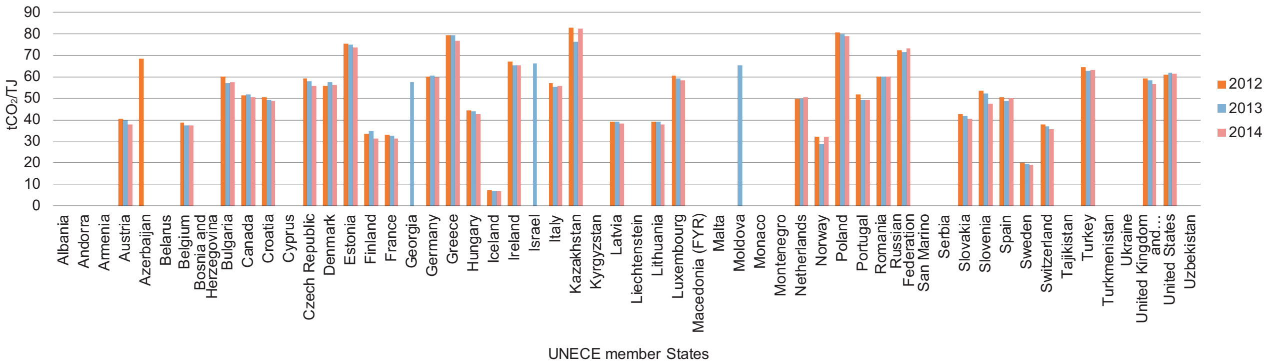



*Data Source: IEA World Energy Balances.*

## Additional Indicator: Greenhouse Gas Intensity of the Energy Sector

In 2010, $CO_2$ emissions from the energy sector were 76% of global GHG emissions. Other GHGs such as $CH_4$, $N_2O$, and the combined F-gases accounted for about 16%, 6% and 2% of global emissions, respectively.[68] In order to calculate the GHG intensity of the energy sector, additional data sources are required.[69] Energy-related emissions[70] are communicated as part of UNFCCC processes through the official national emission inventories. Figure 2.24 shows data for GHG emissions per TPES in $tCO_2/TJ$ for those countries for which data was available from the UNFCCC. As the reporting dates differ significantly, a time span of 2012-2014 is presented, indicating results for countries from different years.

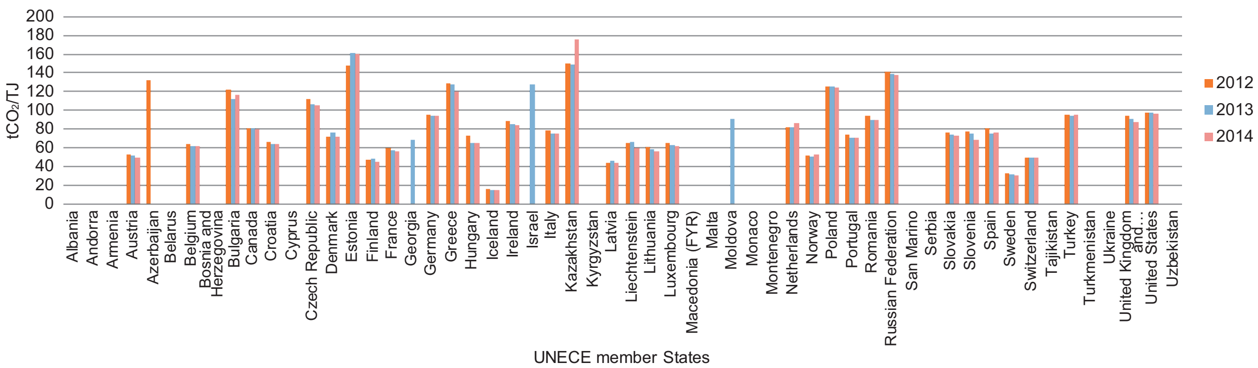
**FIGURE 2.24:** *Energy-Sector Greenhouse Gas Intensity in TPES in UNECE countries (2012-2014, in tCO₂/TJ).*




*Data source: UNFCCC (2017a); IEA World Energy Balances.*

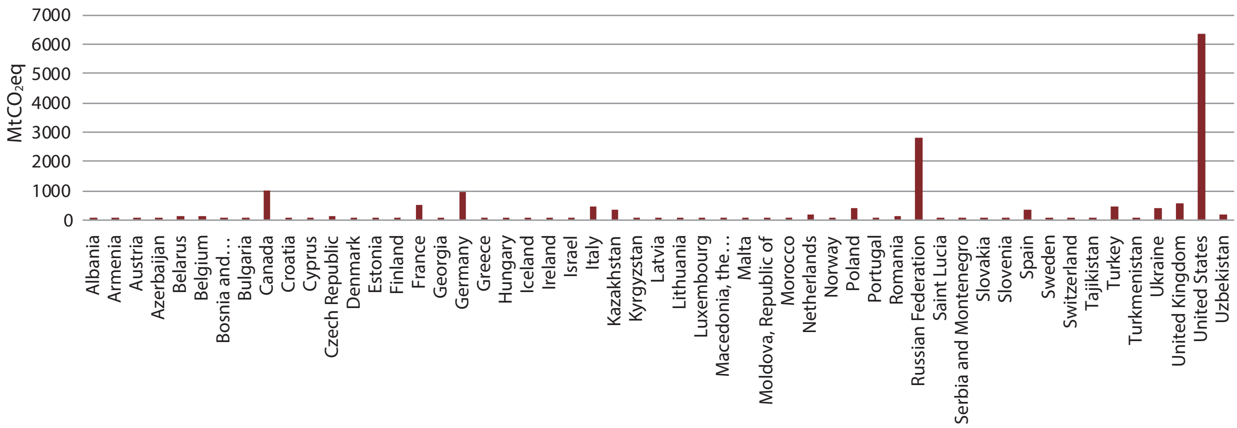
Figure 2.25 shows the GHG emissions per TFC. Countries with a large share of fossil fuels in their energy mix have higher intensities such as in the case of the Russian Federation and Poland, compared to countries with a large-share of low-carbon energy solutions such as nuclear and renewable energies, for example, in the case of France and Norway. Compared to the carbon intensity of TPES, the carbon intensity of TFC reflects conversion efficiencies as well as the GHG emissions and energy content from energy production. For comparison, total GHG emissions by country (not only the energy sector) for 2012 is shown below in figure 2.26. According to this data source, the UNECE region contributed 32% or 17 $GtCO_{2eq}$ of total global GHG emissions in 2012, compared to the global total of 54 $GtCO_{2eq}$.

**FIGURE 2.25:** *Greenhouse Gas Intensity in TFC in UNECE Countries (2012-2014, in tCO₂/TJ).*




*Data source: UNFCCC (2017a); IEA World Energy Balances.*

**FIGURE 2.26:** *Total Greenhouse Gas Emissions of UNECE Countries (2012, in Mt $CO_2$ eq).*




*Data source: European Commission Joint Research Center (2014).*

# III. Sustainable Energy in UNECE: Selected Issues and Country Case Studies

This part of the report explores country experiences that underpin the data reported in Section 2. As outlined in Chapter 1, the aim is to highlight systemic challenges and recognise that all elements in an energy system are connected, similar to the interdependencies of the SDGs: human needs drive demand for services, which in turn drives demand for energy technology, and in turn drives supply investments and resource demand.

## 3.1. Overview to Issues Considered in this Report

The energy system explained in Figure 1.2 in Chapter 1 above forms the basis of a system logic that influences the policy drivers to improve the sustainability of the energy system.

An overview of the issues and case studies is presented in Table 3.1. The following sub-chapters look at the issues, potentials and prospects for each element of the energy system.

## 3.2. Improving Required Energy Services

The need to improve consumer service is a significant challenge. Despite the high levels of access reported by the GTF indicators, for many consumers connection to a utility network bears little relation to the services actually received through the connection.

As outlined in chapter 2, much of the infrastructure in the UNECE region derives from mid-20th century, it is old, less than reliable, and faces important quality of supply challenges. Discrete pockets of remote settlements with limited access to grid power remain.

### 3.2.1. Selected Issues and Country Responses

The level of service quality achieved by households and businesses is a combination of three aspects of consumer end use.

#### Access to energy

At a naïve level, access is indicated by connections to electricity, gas or heat networks. The capacity, consistency and quality/reliability of supply can vary considerably in established networks even with 100% connections for households and businesses.

#### Affordability of energy

In all countries lower socio-economic groups struggle to afford to purchase energy they need. Typically, less well-off households and businesses make trade-offs, compromising quality and quantity of food, clothing or health care to maximize utility from a limited service capability while maintaining basic levels of comfort for health.

**Issue 1:** Heat services – A Critical Service with Substantial Quality and Sustainability Challenges

While consumers need diverse energy resources, heat services stand out in the UNECE region as a critical resource due to the prevalence of extreme cold.

The region's countries circle the arctic, and cold continental climates over most of the region create the highest demand for heat services in the world in almost all UNECE countries except those bordering the Mediterranean and the southern states of the USA (see figure 3.1).

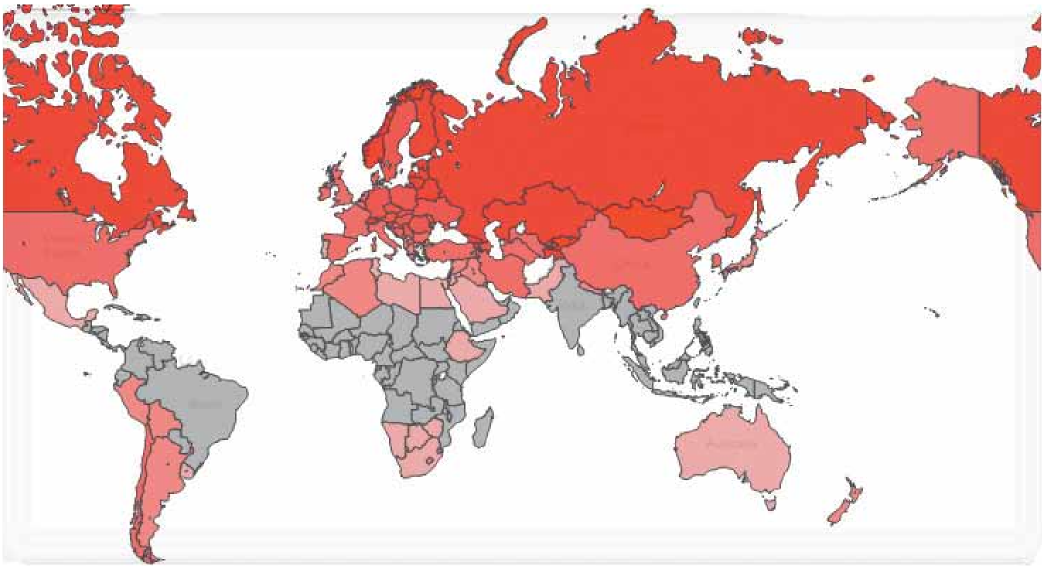
While consumers and policy makers can influence a number of variables, weather and climate are outside of their control. Cold climates oblige more energy use to ensure human health and wellbeing. The extent of heating demand can be described by Heating Degree Days – the cumulative number of degrees over a year that daily average temperatures are below 18°C, a recognized temperature below which buildings need to be heated. UNECE region countries face a higher demand for heat services than any other region.

The historical high dependence on fossil fuels for centralized heat services and lack of investment capital creates a locked-in dependence on fossil fuels. This is often associated with

**TABLE 3.1:** *Issues and Case Studies in this Report.*

| System Element | Selected Issues | Country Responses | Page |
|---|---|---|---|
| **Required Energy Services** | **Issue 1:** Heat services: A Critical Service with Substantial Quality and Sustainability Challenges. | **Case Study 1:** The Vast Heat Service Challenge in UNECE.<br>**Case Study 2:** District Heating.<br>**Case Study 3:** European Union's Policy Actions for Heating. | 31<br>32<br>33 |
| | **Issue 2:** Quality of Supply Challenges Despite Universal Electricity Access. | **Case Study 4:** A Nexus of Inadequate Service, Waste and Vulnerable Consumers. | 33 |
| | **Issue 3:** Energy Affordability Despite Universal Access. | **Case Study 5:** Community–led Sustainable Energy in the U.K. | 34 |
| **End-use Energy Efficiency / Productivity** | **Issue 1:** Pollution and Energy Waste from Low Efficiency Heating Systems and Poor Insulation. | **Case Study 6:** Local and Global Harm from Poor Fossil Fuel Heating and Building Inefficiencies in Poland. | 36 |
| | **Issue 2:** A Lack of Energy Efficiency Building Codes and Slow Retrofitting. | | |
| | **Issue 3:** Improving Appliance and Equipment End-Use Efficiency. | **Case Study 7:** Appliances and Equipment Energy Efficiency: The European Union's Eco-Design Directive 2009/125/EC.<br>**Case Study 8:** Appliance Energy Efficiency Market Transformation Process in Turkey. | 39<br>40 |
| | **Issue 4:** Improving Transport Sustainability and Service Quality. | **Case Study 9:** The Global Fuel Economy Initiative's Activities in Georgia, FYR of Macedonia, and Montenegro. | 41 |
| | **Issue 5:** Improving Industrial Productivity with Energy Efficiency. | **Case Study 10:** Industry-Government Agreements for Industrial Energy Efficiency. Examples from Finland and the Netherlands.<br>**Case Study 11:** ISO50001 Energy Management Systems. | 42<br>43 |
| **Distributed Generation / Distribution** | **Issue 1:** Integration of Variable Renewable Energy: Market Design Challenges. | **Case Study 12:** Integrating Variable Renewables into Grids.<br>**Case Study 13:** Assigning Responsibility for Managing Increasing Variability of Supply. | 50<br>51 |
| | **Issue 2:** Distributed Renewable Energy for Remote Communities. | **Case Study 14:** Wind Turbine Cooperatives in Denmark.<br>**Case Study 15:** Distributed Renewables: Croatia's High Share of Traditional Renewable Energy. | 51<br>52 |
| **Transmission and Generation** | **Issue 1:** A Unsustainable and Continued High Reliance on Fossil Fuels | | |
| | **Issue 2:** Inadequate Progress in Supply Sector Efficiency of Fossil Fuel based Generation. | | |
| | **Issue 3:** Integration of Variable Renewable Energy: Policies to Support Renewable Energy Uptake. | **Case Study 16:** A Shift from Renewable Energy Feed-In Tariffs to Auctions? - An Example of Off-Shore Wind Energy in Germany. | 58 |
| | **Issue 4:** Diverging Concepts of Energy Security: Energy Self-Sufficiency versus Energy Interdependence. | **Case Study 17:** European Energy Security: Improving Import Dependency. | 58 |
| | **Issue 5:** The Difficulty of an Energy Transition Paradigm Shift. | **Case Study 18:** To Renewables via Gas: The United States Fossil Fuel Transition in the United States.<br>**Case Study 19:** Power Sector Reform Experiences in the Russian Federation. | 61<br>61 |
| **Energy Resources Sustainability** | **Issue 1:** Commitments to Reduce Energy Sector Greenhouse Gas Emissions. | **Case Study 20:** The European Union's Nationally Determined Contributions. | 64 |
| | **Issue 2:** Management of Methane Emissions From Fossil Fuel Extractive Industries. | **Case Study 21:** Coal Seam Methane Recovery: Examples from Poland and Ukraine. | 66 |
| | **Issue 3:** The Energy-Water-and Nexus. | **Case Study 22:** Drina River Basin Energy-Water-Land Nexus Solutions Assessment. | 66 |

**FIGURE 3.1:** *Heating Degree Day Distribution.*



*Source: KAPSARC (2016).*

poor efficiencies and a perception of heating security based on indigenous (typically fossil) energy resources. There is enormous scope for improvement in the adequacy of heat services in the region, including both their efficiency and their affordability.

Heating services in buildings and industry represent over 40% of final energy consumption in the UNECE region (see case study 1). By contrast, in Western Europe, the Russian Federation and United States, energy for cooking is less than 4% of total heat services. Generally cooking is undertaken with commercial cooking fuels (gas and electricity). Exceptions occur in remote areas where controlled combustion wood stoves provide heating and cooking services. 13 million people in 17 countries still rely on solid fuels for cooking. Bosnia and Herzegovina and Georgia stand out with 42% and 54% access, respectively, to non-solid fuels for cooking.[72]

### Case Study 1: The Vast Heat Service Challenge in the UNECE Region.

The UNECE average share of final energy consumed for heating services stands at 40%, but there is significant variation around this average. The European Union consumes 23EJ or 56% of its TFC for heating services; the Russian Federation, 18.5EJ or 56% of its TFC%; and the USA, 22EJ or 35% of its TFC on heating services.[73]

Uzbekistan stands out as a country with high space heating energy use. Residential, commercial, and public buildings account for 65% of final consumption of natural gas, and most of the consumption is for space heating. The average specific heat consumption of residential buildings in Uzbekistan is about 290 kWh/m2. This can be compared to 95 kWh/$m^2$ in the Netherlands, which are similarly dependent on natural gas for primary and final energy consumption, relies heavily on individual gas boilers for space heating, and has a slightly colder and longer winter than Uzbekistan.[74]

In the Russian Federation, 70% of the population's heating requirements are met by district and local heating.[75] Although the network is extensive, it is very old and it is estimated that 60% of the network requires major repairs or replacement.[76] The resulting inefficiencies mean frequent service interruptions for some urban populations[77] and 29% of households spend more than 10% of their income on energy.[78]

Quality of life issues dominate many of these systems that were based on abandoned collectivist policies. With new distributed energy efficiency and renewable options available, a substantial rethink of heat and power supply systems is possible.

Four key aspects of heat service access and service quality warrant attention.

**I. Legacy Systems:** Many buildings and energy systems in Eastern Europe, Central Asia, date to post-war reconstruction. Upgrading or replacing infrastructure to improve service quality across the eastern sub-regions of the region is a much larger task than provision of access to the remaining areas with poor access. Both are priorities and require an underlying policy base that ensures investment is allocated efficiently to achieve service and access quality improvements and a simultaneous economic transition to distribute renewable energy. Ensuring affordability and access to quality of service merit further exploration.

**II. Adequacy of Service:** Adequacy of heat service, efficiency and affordability remain challenges in most countries. A high level of energy access, measured as connections to final energy systems, does not measure service quality. Those countries that recognise energy poverty (the inability of households to maintain safe indoor temperatures without undue burden on their income) face complex barriers of built–in inefficiencies, capacity to pay and access to modern efficient technology.

**III. Fossil Dependency:** While the generators and engines in power generation and transport fleets require liquid or gaseous fossil fuels, heat services are still highly dependent on fossil fuels. The institutional and technological infrastructure was designed to use historically available fossil fuels. There is a locked-in dependence on fossil fuels. Primary transformation processes in power generation, and energy provision also face locked-in dependence on fossil fuels with often poor efficiencies. The transition is neither obvious nor easy, however, great potential exists when infrastructure modernisation is undertaken in connection with the development of solid national energy strategies.

**IV. Energy Security:** Most countries of the region focus on energy security based on indigenous (typically fossil) energy resources. While many UNECE countries are major exporters of energy resources to global markets, strong regional and cultural behaviours lock in an on-going reliance on indigenous resources. If growing energy demand is to be met, in the near that will likely be covered by existing fossil resources as renewable energy sources and infrastructure are not yet adequately developed.

An integrated approach to energy efficiency in buildings could pave the way for other sectors. Addressing heating needs and economically optimising investments in both end-use energy efficiency and renewable energy could provide the enabler for other approaches to follow suit. Supportive policy frameworks need a long term perspective: integrating building owners, the building sector and financiers in substantial retrofits. Heat services remain an imperative for health, safety and productivity in the region. Reticulated gas and district heating systems tend to exist in cities. Smaller settlements and rural areas are much more likely to depend on solid fuels for heat services and cooking.

## A chance to re-think the sustainability of heat?

Lower costs for distributed renewable energy and better insulated homes and high costs for updating ageing central district heating systems is enabling a shift from economically unsustainable subsidised heat supply systems. Many district heating systems operate within a municipal mandate that required connection, were built without heat metering, and have struggled under central control economics to update as societal demands evolved. See more information in case study 2.

### Case Study 2: District Heating.

Globally, 15.8 EJ were used in 2010 (2.6 % of global TPES) to produce nearly 14.3 EJ of district heat for sale by Combined Heat and Power (CHP) (44%) and heat-only boilers (56 %) After a long decline in the 1990s, district heat returned to a growing trajectory in the last decade, rising by about 21 % above the year-2000 level (IEA, 2012a). This market is dominated by the Russian Federation with a 42% share in the global heat generation, followed by Ukraine, United States, Germany, Kazakhstan, and Poland. Natural gas dominates in the fuel balance of heat generation (46%), followed by coal (40%), oil (5%), biofuels and waste (5%), geothermal and other renewables (2.4%), and a small contribution from nuclear.

Development of intelligent district heating and cooling networks in combination with (seasonal) heat storage allows for more flexibility and diversity (combination of wind and CHP production in Denmark) and facilitates additional opportunities for low-carbon technology (CHP, waste heat use, heat pumps, and solar heating and cooling).[79] In addition, excess renewable electricity can be converted into heat to replace what otherwise would have been produced by fossil fuels.[80]

Statistically reported average global efficiency of heat generation by heat-only boilers is 83%, while it is possible to improve it to 90–95% depending on fuel used. About 6.9 % of globally generated heat for sale is lost in heating networks. In some Russian and Ukrainian municipal heating systems, such losses amount to 20–25 % as a result of excessive centralization of many district heating systems and of worn and poorly maintained heat supply systems.[81]

The promotion of district heating and cooling system should also account for future technology developments that impact the district heating sector (building heat demand reduction, high-efficiency single-housing boilers, heat-pump technology, cogeneration reciprocating engines, or fuel cells, etc.), which may allow switching to more efficient decentralized systems.[82] District heating and cooling systems could be more energy and economically efficient when heat or cold load density is high through the development of tri-generation, the utilization of waste heat by communities or industrial sites, if heat (cooling) and power loads show similar patterns, and if heat-loss control systems are well-designed and managed.[83]

Distributed renewable energy is now competing directly with fossil fuel options and taking market share in new plant construction. When used in conjunction with modern low-energy construction techniques, distributed renewable energy is also starting to challenge district heating systems, particularly older smaller systems with often marginal operational economics.

The question is if distributed renewable energy options offer a lower life-cycle cost to consumers and governments than ongoing system costs of existing district heating such as replacement costs for the less economic parts of a district heating system

Case study 3 provides information on the European Union's policy actions for heating.[84]

### Case Study 3: European Union Policy Actions for Heating.[85]

Article 14 of the European Union's Energy Efficiency Directive 2012/27/EU issues comprehensive guidance on: identifying and implementing adequate measures for efficient district heating and cooling infrastructure, the development of high-efficiency cogeneration, the use of heating and cooling from waste heat and renewable energy sources, where benefits exceed the costs. Procedures for operators of electricity generation installations, industrial installations and district heating and cooling installations to ensure that they carry out an installation-level cost-benefit analysis on high-efficiency cogeneration and/or the utilization of waste heat and/or connection to a district heating and cooling network when they plan to build or refurbish capacities above 20 MW thermal input or when they plan a new district heating and cooling network.

## Issue 2: Quality of Supply Challenges Remain, Despite Universal Electricity Access

Electrification rates (the ratio of electricity connections to number of households) across the entire UNECE region have been reported at 100% since 2012. Only Armenia, Azerbaijan, Bosnia and Herzegovina, Kazakhstan, FYR of Macedonia, Moldova and Ukraine had electrification access levels below 95% in 1990[86] and these have since achieved 100% electricity access. Countries in the UNECE region meet the objective for electricity access in the sense of connections to networks, but there are still aspects of this objective that warrant policy attention. There are still 'pockets' of remote settlements where access to electricity remains a challenge:[87]

- Small villages in Bosnia and Herzegovina face abnormally high costs to reinstate electricity distribution systems damaged during the 1990s conflict. The Government, supported by the United Nations Development Programme (UNDP), is developing distributed renewable power solution projects for these communities.
- A 2012-2016 Georgia rural electrification programme, supported by the United States Agency for International Development (US AID), as connected 29 off-grid villages.
- The Kyrgyzstan Government and Islamic Development Bank are redeveloping supply to 20 settlements in the Balkan region, including supply from Tajikistan.
- In Uzbekistan 1500 settlements (predominantly in the Republic of Karakalpukstan) have no commercial electricity supply. Solutions underway include residential scale solar systems and government promoted mini hydro.
- In Tajikistan, the electricity grid covers 96% of the country, but remote settlements still have no grid connection. A more significant issue is that 70% of the population face outages from reduced winter hydro inflow.

### Case Study 4: A Nexus of Inadequate Services, Vulnerable Consumers and Climate Change.

Synergies among policies to advance social wellbeing and energy poverty and to address climate change are possible, but not achieved in practice. A number of studies warn that unless strong energy efficiency measures are put in place, climate change policy can increase the risk of energy poverty, mainly due to the funding of carbon reduction programmes through utility bills. Experts have been warning that this way of financing the energy transition is highly regressive, because an increase in energy prices affects the poor more than those who are better off. In addition, the poor face a 'double penalty', since they pay for renewable energy subsidies through their energy bills but cannot benefit from producing renewable energy themselves because of high up-front investment costs. A solution could be to improve the energy efficiency of their homes and appliances, but without financial aid these improvements are usually out of reach of the energy poor.

In its March 2013 resolution on the Energy Roadmap 2050, the European Parliament warned that the de-carbonisation strategy could in some Member States cause 'a massive increase in energy poverty' and therefore the situation of these countries should be taken into account. It asked the Member States to protect households from rising energy bills, and suggested that one of the ways to address energy poverty would be combining energy efficiency measures and renewable energy solutions for heating and cooling.[88]

## Issue 3: Energy Affordability

The UNECE region is particularly challenging in heat services. For example in the Russian Federation 29% of households spend more than 10% of income on energy, in 4 UNECE countries more than 40% of households spend over 10% of their income on energy (Albania 46%, Moldova 52%, Serbia 49%, and Tajikistan 60%).[89]

In reality each of these issues combine together, those that struggle to purchase energy, also struggle to afford and get access to the efficient appliances that will lower their dependence on constrained access to energy, and lower their energy costs.

### A service quality affordability problem.

Six UNECE countries have aggregate energy intensities below the 0.06 EJ/capita (or 1.5mtoe/capita): Bosnia and Herzegovina, Tajikistan, Turkmenistan, Uzbekistan, Kyrgyzstan, Montenegro, and Georgia. While these countries can improve their energy efficiency and expand the current crop of economic renewable energy, their prospects for productivity and development would improve by improving the quality of their energy access. These countries warrant attention from access initiatives.

There is no comprehensive study on energy poverty across the UNECE, but insights across the European Union and other countries show both universality to energy poverty and huge variety in experiences. Any country will have a share of its population struggling to pay energy bills or heat their homes. Examples include:

- The Building Performance Institute Europe estimates 54 million people cannot afford to heat their homes in winter, and 50 and 125 million persons live in energy poverty in the European Union.[90]
- Energy poverty is more prevalent in Central and Eastern Europe, where it rose dramatically with the end of state subsidies for energy and increased poverty in general in the 1990s. More than 40% of people in Bulgaria were not able to keep their homes warm in 2014, and 32.9% were behind with their bills. The impacts can be disproportionate. According to the European Fuel Poverty and Energy Efficiency project, groups most at risk are retired and unemployed people, the working poor, those on welfare, elderly and disabled people and single parents.[91]
- The award winning Cold@home website explores the impact on the lives on individuals struggling with energy poverty in documentary form.[92]
- A study from the United Kingdom showed that while 87% of low-income households were able to pay with their bills, typically they cut back on non-essentials, food and heating. 65% of those who saved on heating were also saving on food, and 59% of those who saved on food were economising on heating[93] (see also case study 5).
- A study on Vienna identified that the ways of handling this problematic situation vary greatly and that people follow different strategies when it comes to inventing solutions for coping with the restrictions that high energy bills impose on the household.[94]

The impact on humans is real has consequences in terms of unnecessary health and welfare costs. The consequences of energy poverty are numerous: an excess number of winter deaths, respiratory problems, increased hospitalisations, greater incidences of mental diseases, as well as negative effects on social life, relationships and education of children.

### Energy efficiency is central to addressing energy poverty

A number of options exist for alleviating energy poverty: social welfare payments, progressive tariffs for energy, policies limiting disconnections, information and consumer protection policies. These address the symptoms of poor service, but some are more socially and economically efficient than others. Some measures may produce progressive outcomes, others may create distortions – subsidising one attribute of welfare at the expense of another. Only improving energy efficiency goes to the heart of the problem addressing the underlying failure of efficient service delivery. A 2010 European Commission paper considers energy efficiency one of the most effective long term measures for lifting people out of energy poverty.

## 3.2.2 Opportunities and Prospects

Increasingly, consumers are finding ways to cooperate and address energy service problems and household sustainability themselves. Many cities have community level household sustainability and home weatherization co-operatives that make measurable improvements to vulnerable households despite limited resources. Community-led action can often tackle challenges more effectively than government alone, developing solutions to meet local needs. Putting communities in control of the energy they use can improve energy security, tackle climate change, help people save money on their energy bills, improve resilience of communities, and deliver social and economic benefits. However, committed action by the central government is still needed to drive improvements in energy service and address energy poverty.[95]

**Case Study 5: Community-led Sustainable Energy Programmes in the United Kingdom.**

The United Kingdom's government's Community Energy Strategy empowers local government to act on identified energy access and poverty challenges and develop local sustainable energy resources by: Generating electricity or heat; Reducing energy use through energy efficiency and behaviour change; Managing energy by balancing supply and demand; Purchasing energy in collective purchasing processes or switching suppliers to reduce costs (21,000 households switched energy suppliers through the Cheaper Energy Together scheme, leading to an average costs saving of £131).

At least 5,000 community energy groups have been active across the United Kingdom since 2008. Community energy projects are currently focused on renewable electricity generation, with the most prevalent technology being solar PV and onshore wind. At least 60MW of community-owned renewable electricity generation capacity is currently in operation. While this remains a small fraction of installed renewable electricity generation capacity, it is located close to communities and there is significant potential for growth. Energy regulators, local authorities, power project developers are required to work with communities. The Government is establishing a dedicated Community Energy Unit to act as the Department's policy lead on community energy and to take forward implementation of the strategy.[96]

**Opportunity: Health and Wellbeing Impacts of Energy Efficiency Measures.**

Prominent health impacts associated with energy efficiency improvements include reduced respiratory disease symptoms and lower rates of excess winter mortality (EWM) in cold climates. Fewer deaths from dehydration are reported in heat extremes.

Aside from potential energy demand reductions, improving energy efficiency in buildings creates conditions that support improved health and wellbeing for occupants. Positive health outcomes are consistently strongest among vulnerable groups, including children, the elderly and those with pre-existing illnesses.

Recent evidence shows that chronic thermal discomfort and fuel poverty have negative mental health impacts; energy efficiency improvements can improve mental wellbeing.

Health improvements at the individual level generate indirect social impacts and relieve pressure on public health budgets. Modelling of a high energy efficiency scenario showed that reduced indoor air pollution could save the European public health budget USD 99 billion per year in 2020.

Overlaying proven metrics and assessment methods from epidemiological disciplines with financial metrics can generate market values for identified health benefits, enabling these outcomes to be built into robust policy assessment frameworks.

When quantified health and well-being impacts are included in assessments of energy efficiency retrofit programmes, the benefit-cost ratio can be as high as 4:1, with health benefits representing up to 75% of overall benefits.

The body of evidence linking improved health and wellbeing to energy efficiency measures has prompted several governments to make addressing fuel poverty a central element of energy policy, often optimising investments by targeting vulnerable groups.[97]

The scale of energy poverty is significant in a number of UNECE countries and warrants closer evaluation. Until the scale and impact on human welfare from the three aspects of energy service are quantified, energy poverty will remain a poorly recognized and diffuse policy challenge.

Upgrading or replacing infrastructure to improve access across the Eastern sub-regions of UNECE is a larger task than provision of access to the remaining areas with poor access. Both are priorities and both require an underlying analytical and policy base that ensures investment is efficiently allocated to achieve service and access quality improvements, releases multiple social benefits and a transition to renewables.

The overall pace of adoption of clean fuels and technology for cooking remains slow. A continuation of current trends would mean that only six additional countries would achieve universal access by 2030[98] (Azerbaijan, Latvia and Ukraine by 2020, and Estonia, Croatia and Moldova by 2030). Albania, Bulgaria, Kazakhstan, Romania and Uzbekistan are expected to reach 100 % access by 2040, and the Kyrgyzstan by 2050. The remaining six countries are not expected to reach universal access before 2050. Again this is an area that deserves evaluation in order to better understand the barriers and options for progress.

Consumer norms are not static. Changes in technology stimulate change in energy culture: new heating devices and new insulating technology shift perceptions and accepted norms about warmth and comfort, leading to new material cultures (thermal curtains, better insulation, new heating systems, LED lighting, better refrigerators) and practices (closing curtains, heating bedrooms, tracking electricity consumption).

## 3.3 End-Use Energy Efficiency

Energy efficiency improvements have a clear impact on consumers: reducing energy costs, boosting business performance and delivering more services for household consumers. Energy efficiency is represented by better cooling and heating systems, more efficient appliances, and advanced vehicles. Investing in energy efficiency is crucial to addressing future energy demand growth and mitigating climate change. It improves productivity and leads to reductions of local pollutants and GHG emissions.

Energy efficiency improvements deliver reductions in per capita energy demand and increased utility to consumers (better light, warmer homes, higher productivity, public budget reductions, and supply side cost reductions). This important aspect is often undervalued in policy making and investment decisions, but delivers a range of micro and macroeconomic outcomes.[99] The multiple benefits of energy efficiency can be worth much greater than the value of avoided energy demand, and represent the added value resulting from increased energy productivity.

A key issue for policy makers is that the full range of outcomes need to be understood when developing investment options and designing climate mitigation policies.[100] For example, the term energy rebound effects describes the phenomenon that improvements in energy efficiency can lead to greater use of energy services provided, hereby offsetting the initial energy saving potential of energy efficiency measures.[101] Rebound effects may reduce the contribution of energy efficiency improvements to climate change mitigation. Such effects could alter the relative priority of different $CO_2$ abatement policies. Efficiency rebounds can reach 60%, with rebound in developing countries likely much higher than in rich countries.[102]

### 3.3.1. Selected Issues and Country Responses

Economic growth and static energy demand in the UNECE region reduced average energy intensity from 8.0 MJ/USD in

1990 to 5.1 MJ/USD in 2014. Energy intensity is however not the same as energy efficiency. Energy efficiency describes the concept of using less energy to provide the same service. Energy intensity describes the ratio between TPES and GDP of a country. Energy efficiency is hence a contributing factor in energy intensity, but the concept contains many other elements, including the structure of the economy (e.g. large energy-consuming industries), the country size (transport sector demand), the climate (heating / cooling demand), and the exchange rate.[103] Changes in activity levels (number of homes, population, GDP etc.) and structure (size of homes, industry activity mix, etc.), and fuel mix changes, confound the clear measurement of energy efficiency and need to be isolated using decomposition techniques. So while energy intensity is used as a prime indicator for energy efficiency, it is only a proxy and is subject to significant extraneous drivers.

Reducing energy intensity has led to significant reductions in energy consumption. UNECE regional energy intensity improvements since 1991 have reduced energy demand in 2014 by 131EJ below what would have been required if energy intensity had been held at 1990 levels. There is much scope to continue this trend.

Improvements in energy intensity are happening, but not fast enough. The average compound annual growth rate (CAGR) of energy intensity in the UNECE region was -1.9 % for the period 1990-2014, while the objective is to attain a -2.6 % rate for the period 2010-2030. Although the UNECE region collectively has reduced energy intensity in industrial, transport and service sectors, the rate of improvement has regressed since 1990 and is uneven as some countries make slower progress than others, despite the attractive economics of energy efficiency.

### Drivers for Improving Energy Efficiency

*Key drivers for energy efficiency improvements include cost-reflective prices and consistent, enduring energy efficiency policies. Both drivers are required to drive enduring energy intensity improvements. They influence end-use efficiency and utility efficiency investments notably in North America. Long running energy efficiency policies like minimum energy performance standards (MEPS), corporate average fleet efficiency standards (CAFE), and building codes work in a context of competition to improve productivity, displace inefficient production and drive energy efficiency innovations such as electric vehicles and advanced ICT systems.*

*Achieving absolute energy efficiency improvements requires prices and policies that redefine the energy system as an interconnected cost-reflective system, rather than a supply dominated system. An 'end-use energy efficiency first' demand side led approach also minimizes demand on upstream systems and fossil fuel transition costs, enhances the contribution of renewables investments, and optimizes socio-economic and environmental outcomes.*

## Issue 1: Pollution and Energy Waste from Low Efficiency Heating Systems and Poor Insulation

With a high need for heating services and a high dependence on fossil fuels, both local and global pollution are a significant issues in some countries where locked in reliance on coal, poor heating system efficiency and poor insulation compound to create abnormal air quality problems (see case study 6 below). The choice is stark – either provide heating for human safety and comfort with dangerous levels of air pollution, or suffer inadequate heating.

Effecting change requires a coordinated effort on insulation, heater efficiency and emission controls and access to alternative non-polluting fuels. Industry and transport offer significant opportunities for improved well-being, economic performance, and air quality. This requires central government action on improved heating appliances, improve insulation in buildings, improved industrial energy efficiency, and cleaner and more efficient transport options. The case study below provides more information on the harm from poor fossil fuel based heating.

### Case Study 6: Local and Global Harm from Poor Fossil Heating and Building Inefficiencies in Poland.

The clean fuels and fuel wood heaters that dominate heating services across most of the UNECE region can provide heat with relatively low levels of pollution. However, where heating services rely on coal, local as well as global emissions are a significant challenge. It is difficult to burn a complex fuel like coal at low particulate emission levels. Some 400 cities in Europe exceed the daily norms for PM10 levels (50mg/m3 24hr concentration), with 6 of the 10 most polluted cities in Poland and the remainder in Bulgaria.

In Poland, 70% of single-family homes are heated with coal, with 60% with manually controlled heaters. Despite monitoring and fines by the European Union for exceeding set standards, the problem persists. There are no standards for coal heaters in Europe. 140,000 new coal heaters are installed every year, adding to a stock of 3 million uncontrolled coal burners. The problem is exacerbated by the 3.6 million homes in Poland (70%) that have little or no insulation and only 1.37 million homes with average or better insulation. Market research indicates that 51% of households would be prepared to take up subsidies and loans for energy efficiency improvements.[104]

## Issue 2: A Lack of Energy Efficiency Building Codes and Slow Retrofitting of Buildings

Between 1990 and 2014, residential energy intensity across the UNECE region increased from 25 to 26 MJ/capita. Residential energy intensity increased from 36 to 37 MJ/capita in North America. In Southeast Europe intensity increased from 15 to

16 MJ/capita, and in Caucasus, Central Asia, Eastern Europe, and the Russian Federation it increased from 19 to 21 MJ/capita. Only in the western and central Europe sub-region did residential energy intensity improve from 25 to 22 MJ/capita.

Energy use in commercial buildings in the services sector is a function of the activities undertaken in the building. In the services sector, between 1990 and 2014, energy intensity across the UNECE region improved from 0.9 to 0.7 MJ/USD. Services energy intensity fell from 1.1 to 0.86 MJ/USD in North America, and Western and Central Europe it declined from 0.7 to 0.59 MJ/USD. In Caucasus, Central Asia, Eastern Europe, and the Russian Federation it improved from 1.1 to 0.9 MJ/USD. In Southeast Europe service energy intensity increased from 0.1 to 0.57 MJ/USD.

Most UNECE countries have building efficiency regulatory programmes (see overview table 3.2). While an overview cannot assess the suitability, compliance or effectiveness of codes, it can highlight the different responses based on diverging climatic conditions, regulatory requirements that exist (such as in the form of building codes), and the role that supporting labelling, performance tests and incentives have in countries where policies have matured. Furthermore, the existence of regulation does not imply any degree of compliance with it, and few countries have effective compliance management.

Supply chains for more energy-efficient buildings and the compliance infrastructure are often underdeveloped. Although energy efficiency standards for buildings were introduced in many countries in the 1990's, compliance enforcement is underdeveloped, or may be effective only in larger apartments or commercial buildings. In many countries, poor management of energy efficiency features at the architectural design phase and inconsistent implementation during construction means regulations may be largely ineffective by themselves.

Capacity development is crucial to develop the abilities for compliance management. Knowledge on how to conduct compliances checks as well as resources to implement it are required at the regulator's level.

**TABLE 3.2:** *Summary of Final Energy Consumption of Buildings, Building Codes and Related Policies in the UNECE Region.*

| Country | Residential Building PJ in 2010 | Residential Regulatory Policies | Commercial Building PJ in 2010 | Commercial Regulatory Policies |
|---|---|---|---|---|
| **Austria** | 289 | Austrian Institute of Construction Engineering OIB guideline 2011. Passive House, ZEB incentives for hi efficiency, renovations. 66kWh/m2/year. | 118 | Austrian Institute of Construction Engineering OIB guideline 2011 |
| **Belgium** | 375 | EPB Flanders 2012, PEB Brussels, PEB Wallonia. Energy certificates, renovation grants 2007, tax incentives 2009. | 211 | EPB Flanders 2012 |
| **Canada** | 1297 | National Building Code of Canada 2010 and state codes. ecoENERGY retrofit (2007) | 1054 | National Building Code of Canada 2010 and state codes. LEED. |
| **Czech Republic** | 277 | Energy Performance Certificate. Building retrofit subsidies. | 131 | |
| **Denmark** | 205 | Building regulations (2010). Energy performance certificates, Passive House. ZEB. Tax incentives. | 90 | Building regulations (2010). Energy performance certificates, |
| **Finland** | 241 | National building Code of Finland 2012. Energy Performance of Building undergoing renovation or alteration. Energy performance certificates, Nearly ZEB. Repair and energy grants. | 82 | National building Code of Finland 2012. Energy Performance of Building undergoing renovation or alteration. Energy audits. |
| **France** | 1844 | Reglementation Thermique (2012) Diverse tax instruments. | 980 | Reglementation Thermique (2012) |
| **Germany** | 2600 | EnEV 2012 Energy performance certificates, Passive Haus. ZEB Extensive programme of KfW grants for energy efficiency. | 1344 | EnEV 2012 Extensive programme of KfW grants for energy efficiency. |
| **Greece** | 194 | KENAK (2010) residential. Energy performance certificates, Passive House ZEB. Energy saving at home 2010. | 82 | KENAK (2010) non residential |
| **Hungary** | 240 | OTEK National code, energy performance certificates, ZEB. Climate friendly homes (2010) | 131 | |
| **Ireland** | 133 | Conservation of Fuel and Energy: Dwellings (2011). Energy ratings, Passive House, CO2 neutral buildings. Better Energy National upgrade, and Warmer Homes scheme. | 71 | Conservation of Fuel and energy: Buildings other than Dwelling (2008). |
| **Italy** | 1314 | Italy National Building code (2011) Energy Performance certificates, Passive House, Funding in 4 regions. | 710 | Decree for energy efficiency in requirements in buildings (2015) |
| **Luxembourg** | 20 | Reglement grand-ducal modifie la performance energetique des batiments (2008). Energy Performance Certificate ZEB. Finance aid | 17 | Energy Performance of Functional Buildings 2010<br>District heating and energy conservation in public buildings. |

| Country | Residential Building PJ in 2010 | Residential Regulatory Policies | Commercial Building PJ in 2010 | Commercial Regulatory Policies |
|---|---|---|---|---|
| **Netherlands** | 482 | Bauwbesluit 2015 Chpt 5. Meer met Minder 2008, incentives. | 406 | Bauwbesluit 2015 Chpt 5. |
| **Norway** | 181 | The Planning and Building Act 2016) Energy Performance Certificate, Enova Fund 2001. | 127 | The Planning and Building Act 2016), Energy Performance Certificate, Enova Fund 2001 |
| **Poland** | 879 | Act of 29 August 2014. The Energy Performance of Buildings Law | 358 | Act of 29 August 2014. The Energy Performance of Buildings Law |
| **Portugal** | 120 | Regulation characteristics of Thermal Performance of Buildings 2010. New and existing residential. Energy efficiency fund. | 86 | Energy certification of buildings 2013 non residential |
| **Russian Federation** | 4666 | Thermal Performance of New Buildings 2003. 6 climate zones. 2.1 - 5.6m2.K/W. | 1550 | |
| **Slovak Republic** | 97 | Act 555-2005, new residential and energy performance certificates. 2008 ZEB and Passive house. Govt insulation programme and energy efficiency finance facility. | 88 | |
| **Spain** | 688 | Codigo Tecnico de la Edification (2009) residential, energy efficiency certificates, passive house. | 424 | Codigo Tecnico de la Edification (2009), non-residential, |
| **Sweden** | 316 | Building Reg's BBR10 (2012). EPBD energy performance certification, ZEB, incentives | 208 | Building Regs 2010. |
| **Switzerland** | 270 | MoPEC – MuKEn Harmonised energy requirements for the Cantons 2009 36-58kWh/m2/year depending on building. | 153 | MoPEC – MuKEn Harmonised energy requirements for the Cantons 2009 36-58kWh/m2/year depending on building. |
| **Turkey** | 940 | Bep-TR (Regulation of energy performance of buildings) 2010. 4 climate zones | 238 | Bep-TR (Regulation of energy performance of buildings) 2010. 4 climate zones |
| **United Kingdom** | 1867 | Building regulations, England & Wales 2010, Scotland 2011, Northern Ireland 2010. Supported by BREEAM, Passive House and ZEB labels. Carbon Emissions Target CERT, Community Energy Savings Prog. (CESP2009, | 626 | Building regulations, England & Wales 2010, Scotland 2011, Northern Ireland 2010. BREEAM Non-domestic. |
| **Ukraine** | | Ukraine Thermal Insulation of Buildings 2006, New residential | | Ukraine Thermal Insulation of Buildings 2006, New residential |
| **USA** | 11232 | IECC (2009) Residential enacted as State codes, supported by ENERGY STAR for new homes, Home Energy Rating schemes and labeling in various states. | 8622 | IECC (2009). Commercial, and ASHRAE 90.1 (2010) enacted as state codes supported by LEED |

*Source: IEA (2012a).*

Building codes tend to apply to new buildings and the existing under-insulated building stock is not addressed. Finland's Decree (4/13) on improving the energy performance of buildings undergoing renovation or alteration is one of the few regulatory codes that address existing buildings by providing minimum standards for improving energy performance of buildings in renovations and alterations. Within federations, national building codes provide a framework, typically with individual states undertaking state codes consistent with the national code, but responding to state level climatic and other drivers.

The UNECE publication "Good practices for energy-efficient housing in the UNECE region" outlines a range of policy and identifies measures to improve occupant comfort and health and reduce energy demands.[105] An UNECE-led initiative on *Framework Guidelines for Energy Efficiency Standards in Buildings* seeks to disseminate transformational, principles-based performance guidance for building energy standards.[106] The effectiveness of regulatory measures is improved by complementary measures. Some UNECE member countries implement non-regulatory measures that fall into three policy classes:

- Controlled consumer information: energy performance certificates, home energy rating schemes, voluntary labelling (e.g., ENERGY STAR ratings for the energy efficiency of new homes),
- Design tools; Passive House and Zero Energy requirements as voluntary codes,

- Fiscal and financial incentives; tax breaks for energy efficient homes, tax deductions for energy efficiency equipment, funds or grants for energy efficiency retrofit programmes,

Other areas that deserve further review include compliance monitoring and evaluation, carbon certification and targets for buildings (like the United Kingdom's Carbon Energy Targets CERT), and benchmarking different financial assistance and grant schemes to identify best practices.

## Issue 3: Improving Appliance and Equipment End-Use Efficiency

With current information systems, an evaluation of appliance and equipment efficiency is not possible as energy consumption and costs are not accounted separately from building costs.

National energy efficiency standards and labelling programmes including Minimum Energy Performance Standard (MEPS) have been in existence since the 1970s and now operate in more than 80 countries around the world, covering more than 50 different types of appliances and equipment in the commercial, industrial and residential sectors. Table 3.3 summarizes the existence of appliance and equipment regulatory programmes in the UNECE region. Case study 7 provides additional information on the European Union's Eco-Design Directive.

The design and coverage of energy efficiency standards and labelling programmes vary according to national circumstances. Based on evidence from a wide cross-section of countries with energy efficiency standards and labelling programmes, the energy efficiency of major appliances have improved three times faster than the underlying rate of technology improvement.

**TABLE 3.3:** *Appliance and Equipment Regulatory Programmes in UNECE Countries.*

| Country | Number of Appliances / Equipment | Appliance Regulatory Policies |
|---|---|---|
| **Canada** | 54 MEPS<br>69 labels | MEPS and labelling aligned with United States' market and international standardization processes. Energuide initiated in 1978 is the oldest energy label. Canada is an ENERGY STAR partner country. |
| **European Union** | 62 MEPS<br>35 Labels | European Union Ecodesign of Energy-related Products Directive 2009/125/EC and Energy Labelling Directive 2010/30/EU operate across all member states with a system of supranational independent institutions in what is a single market for appliances and equipment. The mandatory European Union energy label rates energy efficiency classes ranked from A- G. The directives will lead to energy demand reductions across the European Union of 195 Terawatt hours (TWh) by 2020. The European Union is an ENERGY STAR partner. |
| **Israel** | 7 MEPS<br>9 Labels | |
| **Russian Federation** | 8 MEPS<br>9 Labels | The Federal Law on Energy Efficiency obliges producers to indicate the class of energy efficiency. Decree N1222 On Types and Characteristics of Goods which should contain information about class of energy efficiency and labelling', Government of the Russian Federation, 31.12.2009 defines product classes. |
| **Switzerland** | | Switzerland is an ENERGY STAR partner country. |
| **Turkey** | 25 MEPS<br>24 Labels | European Union Ecodesign of Energy-related Products Directive 2009/125/EC and Energy Labelling Directive 2010/30/EU transposed to Turkish law. |
| **Ukraine** | 3 MEPS<br>6 Labels | |
| **USA** | 47 MEPS<br>40 Labels | The United States' Appliance and Equipment Standards Program targets 30% reduction in energy intensity per square foot of building area by 2030. United States Department of Energy (DoE) and Environmental Protection Agency (EPA) operate ENERGY STAR internationally. |

*Sources: IEA (2015c) and CLASP (2017).*

### Case Study 7: Appliances and Equipment Efficiency: The European Union's Eco-Design Directive 2009/125/EC.

The European Union's Eco-design Directive Ecodesign Directive 2009/125/EC sets MEPS for 23 classes of energy using products. Ecodesign legislation, which sets minimum energy efficiency requirements, applies to many everyday products sold in the European Union, such as dishwashers, fridges and heaters. Some types of product must also display energy labels which show how efficient they are.

Under the Eco-design Directive, four of the most energy intensive industrial products (electric motors, circulator pumps, fans and water pumps) are regulated to minimize energy costs and environmental impacts over their respective life cycles and will lead to energy demand reductions across the EU of 195 TWh by 2020. The policy has been accompanied by significant technology development and has initiated European Union and global standardization processes.[107]

By 2020, use of energy efficiency labels and Ecodesign requirements is projected to lead to energy savings of around 165 Mtoe (million tonnes of oil equivalent) in the European Union, roughly equivalent to the annual primary energy consumption of Italy. In relative terms, this represents a potential energy saving of approximately 9% of the European Union's total energy consumption and a potential 7% reduction in carbon emissions. In 2030, this saving is projected to grow to 15% of the European Union's total energy consumption and 11% of its total carbon emissions.[108 109]

## Minimum Energy Performance Standards and Labelling

One-off improvements of more than 30% have been observed when new energy efficiency standards and labelling programmes are introduced to a market where few energy efficiency schemes existed previously. These substantial efficiency improvements for individual appliances and equipment have translated to national energy savings and reductions in $CO_2$ emissions. The most mature national energy efficiency standards and labelling programmes cover a broad range of products and are estimated to save between 10% and 25% of national or relevant sectoral energy consumption. In all of the energy efficiency standards and labelling programmes reviewed by the IEA's Energy Efficient End-Use Equipment Programme (4E Programme)[110], the national benefits outweighed the additional costs by a ratio of at least 3 to 1. Case study 8 provides more detailed information from Turkey.

Energy efficiency standards and labelling programmes deliver energy and $CO_2$ reductions while also reducing total costs. Appliances and equipment covered by energy efficiency standards and labelling programmes have not only dramatically improved in efficiency over the past 20 years, but are also cheaper to purchase. While energy efficiency standards and labelling programmes may have caused small changes in prices close to the implementation of new energy efficiency measures, they appear to have had little long-term impact on appliance price trends.[111]

### Case Study 8: Appliance Energy Efficiency Market Transformation Process in Turkey. [112]

The most important component and starting point for a successful market transformation is the improvement of regulatory framework in agreement with local manufacturers. In the case of Turkey, Customs Union and the presence of worldwide reputable manufacturers in Turkey became an important driving force for an accelerated market transformation. These facts led Turkey to adopt MEPS more rapidly, and ensured completion of transformation of products on the market within about 1.5 or 2 years and, considering the average service life of appliances, it is expected to achieve full market transformation within the next 10 years. The costs and benefits of transformation depend on many factors such as whether the country has a significant appliance manufacturing industry, size of manufacturing industry, international trade relations, level of awareness of supply chain and consumers.

The MEPS and Labelling regulatory framework, adoption of internationally consistent standards via transposition of European Union Directives, pro-active market surveillance, training and communications projects contribute a market transformation effort. At the halfway point of the project it has provided energy savings of 730 GWh corresponding to a GHG reduction of about 450,000 tons (t) $CO_2$. These figures are expected to reach about 3,700 GWh and 2.4 million tons (Mt) $CO_2$ respectively by the end of the project.

The Market Transformation of Energy Efficient Appliances in Turkey is a good example for other countries where no or little energy efficiency legislation is in place or no market transformation movement has been launched so far.

Governments need to underpin energy efficiency efforts with a level playing field of energy efficiency regulations for industrial equipment. MEPS and labelling policies have widespread global impact and target essential energy intensive equipment such as electric motors. Use of international standardization ensures alignment and access to global appliance markets for local industry. Regulatory action is measurable and deliberate. A regulated 'level playing field' enhances consumers and suppliers confidence to invest in higher efficiency products.

## Issue 4: Improving Transport Sustainability and Service Quality

## Transport energy intensity

Between 1990 and 2014 transport energy intensity, including the sub-sectors road transport, aviation, rail and navigation, across the UNECE region improved from 20.4 to 12.3MJ/USD. Transport energy intensity fell from 31 to 17 MJ/USD in North America and from 14 to 8.1 MJ/USD in Western and Central Europe. In Southeast Europe transport energy intensity fell from 8.8 to 8.0 MJ/USD. In Caucasus, Central Asia, Eastern Europe, and the Russian Federation it improved from 15 to 10 MJ/USD.

The sub-regional comparisons highlight transport productivity can vary across countries. North American energy intensity in 2014 was 17 MJ/USD while Western Europe's was under half this energy intensity at 8.1 MJ/USD. Geographic differences make up much of this, as European cities and countries are closer and more compact with higher population densities and economic structures than their North American counterparts. Southeast Europe and Western Europe have nearly identical transport/GDP energy intensities, but the economic structures and transport systems are vastly different.

## Vehicle fuel economy

Global transportation uses 93% of oil production, the balance of transport energy being electric rail and urban rail or electric bus systems. Apart from cities in Western Europe, most countries in the UNECE region are reliant on conventional fossil fuelled light duty vehicles for passenger transport, and fossil fuelled heavy-duty road vehicles for freight. Even with high levels of access to vehicles, mobility may still be constrained for some citizens. Affordability of efficient vehicles or fuel, limits to transport option and networks, and climatic extremes all limit mobility.

While the average fuel economy of vehicles continues to improve, the rate of progress has slowed in recent years. The average amount of fuel required to travel 100 km improved by 1.1% in 2014 and 2015, down from 1.8% between 2005 and 2008. The change reflects the composition of global car sales, as Light Duty Vehicles (LDV) sold in countries of North America as well as Western and Central Europe use less fuel than those sold in countries of the more Eastern stretches of the UNECE region including Caucasus and Central Asia, and suggests a technological gap in engine technology between the two regions. However due to the popularity of large, heavy and powerful vehicles in the United States, total fuel use per kilometre travelled in these countries remains greater than outside the OECD.[113]

Fuel economy improvements in countries of Caucasus, Central Asia, Eastern Europe and the Russian Federation generally outpaced the countries in North America, as well as Western and Central Europe. This is a major change from the trends observed in previous assessments. There are two major reasons for this: trends occurring within specific markets, and effects attributable to market changes within OECD and non-OECD country groupings. Case study 9 provides more information.

**Case Study 9: The Global Fuel Economy Initiative's (GFEI) Activities in Georgia, FYR of Macedonia and Montenegro.** [114]

GFEI is working with UNECE countries from the Caucasus, Eastern Europe, the European Union, North America, and Southeast Europe to promote improved fuel economy. Three examples for in-country work is provided below:

**FYR of Macedonia**

A summary of the relevant automotive fuel economy-related European Union Directives has been drafted and the Regional Environmental Center for Central and Eastern Europe (REC)'s office in the FYR of Macedonia, the local GFEI implementing partner, is collaborating with the Ministry of Economy, which is responsible for integration into the European Union. The automotive fuel economy baseline data collected and analysed to date with the Faculty of Mechanical Engineering includes data from 2005, 2008 and 2013. The FYR of Macedonia's vehicle stock of registered vehicles has seen modest growth, with just over 350,000 vehicles total stock in 2013. The energy efficiency of the average vehicle improved over the years surveyed, from over 200 g $CO_2$/km in 2005 to below 150 g $CO_2$/km by 2013.

**Montenegro**

A first working group meeting has been held. The roles and responsibilities of the work group members have been allocated to: a) provide a review of national legislation and current policy (including taxation) related to fuel economy issues; b) identify key stakeholders and potential barriers to implement fuel economy policy; c) analyse the relevant European Union Directives that set vehicle emission standards; and d) set up a roadmap for transposition of these European Union Directives to national legislation.

**Georgia**

Georgia has completed a baseline (2008-2012), and a white paper on taxation has been submitted to government. The white paper stresses the need for taxation reform in order to improve the fuel economy of the automotive fleet. Analysis of the Georgian car fleet (both imported new and used vehicles) from 2008, 2010, 2011 and 2012 using the GFEI Fuel Economy Policies Impact Tool (FEPIT) has been carried out and a list of actions was produced that will inform the development of a national car fuel economy improvement plan in Georgia.

## Recent trends

Between 2014 and 2015, OECD countries improved their average fuel economy by 0.5%, compared with 1.8% from 2012 to 2013. This rate decline resulted from the combination of a weakening improvement trend in North America, continued improvements taking place in Europe, and market shares that have not experienced major changes in 2015.

- The United States achieved only a small 0.5% annual improvement in average fuel economy, marking a slowdown in improvement compared with the 2.3% average improvement over the 2012-13 time period. This reflects a tendency towards an increase in the average power of new vehicles and is consistent with the fall in oil and petroleum fuel prices.

- Some countries from Western and Central Europe, Southeast Europe as well as Eastern Europe experienced average annual fuel economy improvements of 2% to 3%, which are much closer to the 3.6% improvement rate needed to meet the 2030 target of the Global Fuel Economy Initiative (GFEI)[115], but still falling short of it. The continued improvement in fuel economy in Europe in 2015 is coherent with the weaker impact of changes in oil prices (due to the high fuel taxation regime applied in all European countries, changes in oil prices result in a lower percentage change in fuel prices).[116]

- In 2015, new LDV registrations in the Russian Federation totalled 3 million. The on-road stock of LDVs is estimated at 34 million in the same year. LDV ownership attained nearly 0.24 LDVs per capita, which is much higher than the average for other countries with comparable levels of personal income. Fuel economy is not regulated in the Russian Federation. However, the Russian Federation levies an annual circulation tax on vehicle owners, which increases progressively with vehicle power. From 2010, large vehicles experienced improving specific fuel consumption, with stagnation between 2012 and 2015. Medium-sized LDVs have seen a continuous decrease in specific fuel consumption since 2005, in line with the total average fuel economy. Newly registered small LDVs saw a deteriorating average fuel economy for most of the years since 2005. However, from 2012 onward this trend reversed, with a minor move towards improvement. Specific fuel consumption by powertrain also demonstrated contradicting trends. While diesels saw improving fuel economy, hybrid vehicles worsened. The trend seen in gasoline LDVs was reflected in total specific fuel consumption due to their high market share.[117]

## Issue 5: Improving Industrial Productivity with Energy Efficiency

Industrial productivity and energy efficiency are closely linked. Energy efficiency measures helped to reduce energy use worldwide. Without the 13% improvement of global energy efficiency between 2000 and 2016, global final energy use would have been 12% higher.[118] The achievements within energy efficiency are closely linked to improvements in industrial productivity.

As global populations and economies grow, the demand for energy intensive materials (metals, plastics, cement, pulp and paper) is expected to increase by between 45% and 60% by 2050, from 2010 levels.[119] Many factors of production are at local resource or waste sink limits. Whereas GHG emissions present a global physical limit to increasing production with current technology and methods. Productivity improvements are needed that simultaneously minimise resource and environmental impacts and address the needs of growing economies.

The concept of the circular economy – as opposite to the linear economy - is important in this regard, as it aims to keep materials and energy in use as long as possible, closing loops, and recover and regenerate materials including waste at the end of their life cycle. For example the economic value for waste to energy conversion was valued at USD 25.32 billion in 2013, and is estimated to be worth USD 40 billion by 2023.[120] Improving the reduction, reuse and recycling of waste and materials further contributes to reduce greenhouse gas emissions (such as methane emissions from landfills) and reduces health and pollution related negative effects.

Between 1990 and 2014, industrial energy intensity across the UNECE region improved from 7.5 to 4.9MJ/USD. Industrial energy intensity fell from 7.8 to 5.6 MJ/USD in North America, and from 4.7 to 3.5MJ/USD in Western and Central Europe. In Southeast Europe industrial energy intensity fell from 5.3 to 4.1 MJ/USD. In Caucasus, Central Asia, Eastern Europe, and the Russian Federation it improved from 10 to 6.7 MJ/USD.

The Institute of Industrial Productivity estimates that energy management can reduce direct energy costs of individual businesses by 10-30%.[121] Most industrial energy efficiency investments pay back in less than 3 years, largely because industry is focused on short-term risk and opportunities. For emerging economies, energy efficiency offers a strategic route to improved industrial productivity, an important driver for increasing wealth and welfare.

Industry energy efficiency contributes about 35% (144.5 EJ or 3452 Mtoe) of the total estimated energy savings from 2012 to 2035 in the IEA's Efficient World Scenario. Additional investments of USD 0.7 trillion is required over this period but results in USD 2.2 trillion in fuel cost savings.[122]

### Case Study 10: Industry-Government Agreements for Industrial Energy Efficiency – Examples from Finland and the Netherlands.

**Voluntary Energy Efficiency Agreements 2017 – 2015, Finland**

The Voluntary Energy Efficiency Agreements for 2017 - 2025 are an important means of furthering energy efficiency in Finland, while reducing $CO_2$ emissions causing climate change. The voluntary agreements are a tool, chosen together by the Government and industrial/municipal associations, to fulfil the EU energy efficiency obligations set for Finland. By ensuring that the agreement scheme is comprehensive and successful, Finland can continue to meet the obligations without resorting to separate new legislation or other new coercive measures.

The Energy Efficiency Agreement period 2017–2025 is a continuance to the Energy Efficiency Agreement period 2008–2016. It serves the implementation of the Energy Efficiency Directive 2012/27/EU. Finland has chosen alternative measures to fulfil the Directive's Article 7 binding energy savings target and extensive energy efficiency agreements have an important role in the implementation. The extension of the Agreements addresses 6 out of 3 sectors from the first phase, including 1) industries (industry, private service sector, energy sector); 2) municipal sector; and 3) oil sector (oil-heating and distribution of liquid fuels).[123]

**Long Term Industry Agreements, Netherlands.**

In the Netherlands over 95% of industrial energy consumption is now covered by the third development phase of Long Term Agreements (LTA). The 1st phase was based on energy efficiency. The 2nd phase; LTA 2, (2001 – 2012) was based on Energy Management Systems (EMS). In 2006 90% of companies complied with EMS (or ISO 14001).The 3rd phase LTA 3 (2009-2020) builds upon LTA 2, targeting an improvement of energy efficiency by 30% between 2005-2020 (20% within plant borders and 10% outside). Energy Efficiency improvement results for LTA-2 companies shows that they achieved twice the energy efficiency improvement of non-LTA companies. From 2001 to 2008, energy efficiency improvements achieved by Long Term Agreement members were 2.4% versus 1% for non-LTA industries.[124]

Recognising the private ownership and competitive markets that most business exist in, a number of governments have developed industry – government voluntary partnerships to realise the potential for energy efficiency in industry. Case study 10 from Canada and the Netherlands highlights the nature and scope for energy efficiency improvement from energy management programmes.

### Energy management is central to progressing energy efficiency in industry

All industrial processes can improve their energy productivity. ISO 50001 (like ISO9001, and ISO14001) establishes a framework for effective energy management processes so that businesses can identify, understand, and invest in energy efficiency projects that develop their businesses and improve productivity (see case study 11). After instituting cost-reflective energy prices, energy management is the most important and universally effective policy option for the industrial sector as in identifies economic opportunities for energy efficiency and renewable energy regardless of processes, and enables capabilities to make these investments. The success of any energy management system further depends on monitoring and verification of outputs and tracking that potential measures are efficiently implemented and followed through.

The UNECE Group of Experts on Energy Efficiency is currently examining ways to implement energy efficiency measures through a variety of activities. [125]

**Case Study 11: ISO 50001:2011 Energy Management Systems.[126]**

The ISO 50001:2011 Energy Management System provides the requirements for a framework for organizations to:

- Establish an energy policy;
- Allocate resources and create teams to implement an energy management system;
- Conduct energy reviews;
- Identify opportunities for improving energy performance;
- Establish baselines and energy performance indicators for tracking progress;
- Set energy performance improvement targets; and
- Implement action plans to achieve those targets.

Central elements of the standard include energy performance in operations, procurement and design, as well as an internal audit process to determine how well the organization is doing in implementing the system and achieving its targets. A continuous improvement process includes management review. An energy policy and energy planning process institute implementation and operation checking and controls. Information systems underpin energy management, using internal audits of the energy management system, energy monitoring, measurement and analysis to identify non-conformities, correction, corrective and preventive action for energy use and productivity.

### Energy management capacity building

To extend the application of energy management systems and decision-making capacity for energy efficiency investments, more organisations focus on the improvement of capabilities of energy managers within organisations as well as external energy auditors and advisors. For example, the United Nations Industrial Development Organisation (UNIDO) supports countries to improve industrial productivity, with energy efficiency being a central theme alongside cleaner production and environmental stewardship. It has developed an energy management system expert training programme that establishes a durable energy management capability in businesses.[127] In line with training professionals in energy management, it is also crucial to provide human capacity development for policy makers, as they drive the development and implementation of relevant policies.

Furthermore, GIZ provides targeted trainings as well as train the trainer seminars for energy management, energy efficient buildings and performance, energy controlling and energy auditing, in a range of countries including the Ukraine and Turkey.[128]

## 3.3.2 Opportunities and Prospects

Market transformation: Renovating the building sector to renovate the buildings

The construction sector tends to be highly decentralized and fragmented: building owners, designers, multiple suppliers and constructors, many dwellings are built by small builders with little access to efficient production techniques or modern building components that enable energy efficiency.

In rural areas there may be a large share of informal construction. Compliance with building codes is generally poor. These complex and uncoordinated markets are inherently more difficult to improve.

Applying regulatory controls and energy efficiency standards for buildings is unlikely to be effective when the capacity to respond is limited. UNECE has developed framework guidelines for energy efficiency in buildings and is undertaking a broad-based education and dissemination programme to address these challenges. [129]

### Opportunity: Developing Supply Chain Capability for Renovation.[130]

Ramping up the innovation and competitiveness of the construction sector throughout the entire value chain increases the depth and rate of energy renovation. Successful programmes of deep energy renovation are feasible at a large scale if they are supported by policy measures, and more collaboration among actors. A set of ingredients must come together:

Aggregation of demand; facilitators and integrators of technical solution packages;

Advisory services that give power to customers; having "à la carte" options designed to fulfil users' needs and ambitious policy targets.

Implementing support measures that encourage innovation and scaling up of deep energy renovation

Establishing a harmonised energy renovation target at the European Union level and making public funding conditional on performance achieved is one of the key recommendations.

Empowering frontrunners such as cities, regions or private initiatives to go beyond the set goals and lead by example accelerates the rate and depth of energy renovation.

Public authorities should also lead by example and plan an integrated energy management approach to increase the energy performance of the building stock they own and occupy.

Building owners are not well informed about or motivated to ask for energy efficiency or comply with building energy efficiency standards. This is a general issue with new residential buildings. Only recently have commercial property owners started to recognise that the lower energy and operating costs and better rentals of energy efficiency buildings translate to increased capital value. As different building owners (such as public, private, investors, commercial, and institutional) have diverging interests in energy efficiency, different approaches are required to develop incentives and build awareness.

While much is made of the importance of energy efficiency building codes, they can achieve little in many countries without a deliberate effort to improve the capacity of the entire building value chain top deliver substantially new outcomes. Programmes like Netherland's EnergieSprong that focus on transforming the building value chain as a system, work with all the decision makers in the system. Many building retrofit programmes undervalue the multiple benefits of energy efficiency initiatives. Health benefits in terms of reduced hospital visits, doctor's visits, prescription costs, and reduced sick days, can exceed the energy cost reduction significantly in some cases by 400%. The challenge is that these benefits have not always been well evaluated or considered, and countries vary in their drives for comfort and wellbeing in buildings.

### Opportunity: Transforming the Building Value Chain: EnergieSprong.[131]

Energiesprong uses the social housing sector in each market as the Launchpad for these solutions, with a view to later scale to the private home-owner market. The independent Energiesprong market development teams aggregate mass demand for high quality retrofits (and new built houses) in a market and, in parallel, create the right financing and regulatory conditions. With this structure in place, solution providers can go into a quick and transformative innovation process to deliver against this new standard.

The Energiesprong refurbishment standard implies a renovation is completed within one week, without residents having to vacate the home. Moreover, it comes with a 30 (or 40!)-year warranty covering both the indoor climate and the energy performance. The refurbishment is financed by combining the energy costs savings from the tenants with the costs the social housing organisation saves on maintenance. Ultimately, residents get a better and more comfortable house without any additional monthly expenses.

In 2013, Energiesprong brokered the "Stroomversnelling" deal between Dutch building contractors and housing associations to refurbish 111,000 homes to Near Zero Energy (NZE). Two years later, the Stroomversnelling network consists of contractors, component suppliers, housing providers, local governments, financiers, transmission system operators (TSOs) and other parties. Its goals are to reduce the price of Near Zero Energy renovations, increase occupants' acceptance of these renovations and increase the momentum and growth pace of the NZE housing market itself. Energiesprong programmes are now underway in France, the UK, Germany and New York State.

*Lessons learned.*

- Fix on a clear objective: 'zero energy' in the case of Energiesprong.
- Ensure interventions deliver the full objective rather than incremental or partial changes
- Ensure energy performance guarantee refurbishments are financially more attractive than existing options.
- Employ a market transformation strategy to 'articulate initial mass-market demand using social housing stock. Use this to motivate:
  - Regulators to lift observed and unforeseen barriers,
  - Financiers to re-evaluate value propositions,
  - Builders to invest in better concepts and industrialized refurbishment or new construction packages.
- Work though programs with scale, avoid stand-alone projects unless they show how to structurally improve market conditions for E= 0 programs
- Mobilize collaborative programs where builders and suppliers share knowledge and work together.

A key multiple benefit is the reduction in public budgets from reductions in health and energy subsidies resulting from energy efficiency. Governments can recognise the public benefit from energy efficiency projects account for energy cost reductions in terms of cost of new supply, or export prices and add this to the private benefits regardless of the level of energy subsidies.

**Opportunity: The Economics of Building Energy Efficiency are more Compelling with a Societal Perspective. An example from Uzbekistan.[132]**

Replacing non-standard and inefficient (also known as 'homemade') gas boilers in detached houses and small commercial buildings with efficient modern gas boilers could reduce gas consumption by about 2.4 billion $m^3$ per year, about 13 % of the total gas consumption in residential, commercial, and public buildings in 2013. Enforcing the current building energy efficiency standards in the construction of new detached houses, which account for 99 % of new residential construction, could cut heat energy demand of these new buildings by 50 percent, compared with those that do not implement the requisite energy efficiency measures. In schools and health care facilities, recent demonstration projects achieved over 40 % reduction in space heating energy use through comprehensive thermal retrofit of buildings. All these energy savings can be attained with domestically available technology, products, and materials. They remain largely untapped primarily due to financial, institutional, and informational barriers. Replacement of the current stock of nonstandard gas boilers with modern gas boilers would require investments of about Uzbekistani Som 3.2 trillion, or about USD 1.2 billion at end of 2015 cost estimate and official exchange rate. The financial simple payback periods for residential and commercial consumers are about 6.6 and 5.2 years, respectively, based on the end of 2015 retail gas price. The simple payback periods are shortened to about 3.4 and 2.7 years, respectively, based on the end of 2015 export gas price.

## The "Avoid – Shift – Improve" approach to transport efficiency

The Global Fuel Economy Initiative has a '100 to 50 by 50' objective of doubling the average fuel economy of new cars by 2030 and all cars by 2050.

While global average fuel economy improved by 1.0% on a yearly basis from 2014-15, this is 0.5% less than average improvement in fuel economy from 2010 to 2015 and around one-third of the improvement rate needed to meet the 2030 GFEI target. Of UNECE sub-regions only Western Europe was close to this range (2-3%). Most countries achieved less than 0.5% improvement. Small LDVs experienced deteriorating specific fuel consumption, while medium LDVs saw improving average fuel economy. Newly registered large LDVs gained weight between 2010 and 2015, but their average fuel economy did not change.

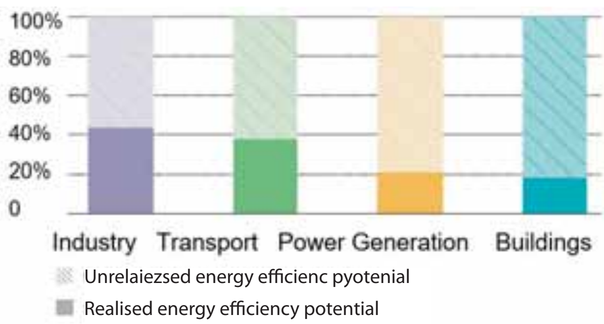
A combination of three strategies can limit transport energy growth to 5% above 1990 levels and reduce transport $CO_2$ emissions by 28%: 1) avoiding the need for travel; 2) slowing travel energy demand growth with better urban planning and demand management and adopting higher fuel economy vehicle and modes; and 3) shifting to lower energy travel modes like public and active transport.

A shift to electricity-based transport could deliver huge improvements in drive train efficiencies and open a way for renewable energy to meet transport energy demand. Most countries are 'takers' rather than 'makers' of vehicles, and while they take what is produced, global fuel economy standards oblige the production of more efficient vehicles. Recent slowing of vehicle fuel economy progress shows how much consumer prices and policy choices can shape transport intensity. Of the end-use sectors, transport is often the most neglected. While residential, commercial, and industry sectors often have reasonably well developed policies, transport ministries are often distanced from the mainstream stationary energy efficiency efforts.

## Developing effective energy efficiency policies

Energy efficiency has a long way to go. No sector has reached even 50% of its efficiency potential. Between 60% and 80% of the global economic potential for energy efficiency is unrealized (see figure 3.2).

**FIGURE 3.2:** *Global Sectoral Energy Efficiency Potential.*




*Note: Potentials based on efficiency scenarios to 2035.*
*Source: IEA (2012b)*

A range of policies have been developed and implemented within the UNECE region. Notably, the 2006 European Union Directive on Energy End-Use Efficiency and Energy Services (Energy Services Directive) requires Member States to submit NEEAPs in 2007, 2011 and 2014. NEEAPs set out estimated energy consumption, planned energy efficiency measures and improvements individual member countries of the European Union expect to achieve. In the first NEEAP, each Member State should have adopted an overall national indicative savings target for end-use sectors of 9% or higher, to be achieved in 2016, and with an intermediate target for 2010.[133]

Also ENOVA (Norwegian National Energy Agency), established 2001, works on energy efficiency improvement, production of energy from renewable energy sources, promoting new technology and enhancing general knowledge about the possibilities for using efficient, environmentally friendly energy solutions. [134]

Table 3.4 summarizes the work to date in reviewing and developing energy efficiency policies and targets in UNECE member States.[135]

**TABLE 3.4:** *Independent Reviews and Energy Efficiency Policies in UNECE Countries.*

| Country | Energy Efficiency Policy Review | National Energy Efficiency Action Plan (NEEAP) or equivalent / Energy efficiency target |
|---|---|---|
| **Albania** | Energy Charter Protocol on Energy Efficiency and Related Environmental Aspects (PEEREA)[137] review 2013[138]<br>Energy Charter review 2008 | NEEAP, 2011 |
| **Andorra** | | |
| **Armenia** | PEEREA review 2005<br>IEA In-depth Review (IDR) 2015 | National Program on Energy Saving and Renewable Energy, 2010 |
| **Austria** | IEA IDR 2014 | NEEAP, 2017 |
| **Azerbaijan** | PEEREA review 2013<br>IEA IDR 2015 | No Strategy. Target 20% energy efficiency improvement by 2020. |
| **Belarus** | PEEREA review 2013<br>IEA IDR 2015 | 37% GDP energy intensity reduction by 2035 from 2010' (by 2020 GDP energy intensity should be reduced by not less than 13%). |
| **Belgium** | IEA IDR 2016 | NEEAP, 2017 |
| **Bosnia and Herzegovina** | PEEREA review 2012<br>Energy Charter regular energy efficiency review 2008 | NEEAP, 2012 |
| **Bulgaria** | PEEREA review 2008 | NEEAP, 2017 |
| **Canada** | IEA IDR 2015 | Energy Efficiency Act 2009 |
| **Croatia** | Energy Charter regular energy efficiency review 2010 | NEEAP, 2014 (2017 under consultation) |
| **Cyprus** | | NEEAP, 2014 |
| **Czech Republic** | IEA IDR 2016 | NEEAP, 2017 |
| **Denmark** | IEA IDR 2011 | NEEAP, 2017 |
| **Estonia** | IEA IDR 2013 | NEEAP, 2017 |
| **European Union** | IEA IDR 2014 | European Commission Action Plan on Energy Efficiency 2006. Note 1. |
| **Finland** | IEA IDR 2013 | NEEAP, 2017 |
| **France** | IEA IDR 2016 | NEEAP, 2017 |
| **Georgia** | PEEREA review 2012<br>IEA IDR 2015 | NEEAP 2017<br>pending government approval |
| **Germany** | IEA IDR 2013 | NEEAP, 2017 |
| **Greece** | IEA IDR 2011 | NEEAP, 2014 |
| **Hungary** | IEA IDR 2011 | NEEAP 2015 |
| **Iceland** | | |
| **Ireland** | IEA IDR 2012 | NEEAP 2017 |
| **Israel** | | |
| **Italy** | Energy Charter regular energy efficiency review 2009 | NEEAP, 2014 |
| **Kazakhstan** | PEEREA review<br>IEA IDR 2015 | Energy efficiency programme 2020.<br>25% energy intensity reduction by 2020 |

| Country | Energy Efficiency Policy Review | National Energy Efficiency Action Plan (NEEAP) or equivalent / Energy efficiency target |
|---|---|---|
| Kyrgyzstan | Energy Charter regular energy efficiency review 2011<br>IEA IDR 2015 | Law on energy conservation and energy efficiency in Buildings 2013. |
| Latvia | PEREEA review 2008 | NEEAP, 2017 |
| Liechtenstein | | |
| Lithuania | | NEEAP, 2014 |
| Luxembourg | IEA IDR 2014 | NEEAP, 2014 |
| Malta | ODYSSEE-MURE 2012<br>Energy Efficiency Watch (EEW) 2013 | NEEAP, 2017 |
| Republic of Moldova | IEA IDR 2015 | NEEAP, 2013. Reduce energy intensity by 10%, building energy by 20%. |
| Monaco | | |
| Montenegro | | NEEAP, 2014 |
| Netherlands | IEA IDR 2014 | NEEAP, 2017 |
| Norway | IEA IDR 2011 | Note 2. |
| Poland | IEA IDR 2016 | NEEAP, 2014 |
| Portugal | IEA IDR 2016 | NEEAP, 2013 |
| Romania | PEREEA review 2006<br>ODYSSEE-MURE 2012 | NEEAP, 2014 |
| Russian Federation | IEA IDR 2014<br>Energy Charter regular energy efficiency review 2007 | Federal Program to reduce energy intensity by 13.5% by 2020 |
| San Marino | | |
| Serbia | | NEEAP, 2013 |
| Slovak Republic | PEEREA review 2009<br>Energy Charter regular energy efficiency review 2006<br>IEA IDR 2012 | NEEAP, 2017 |
| Slovenia | | NEEAP 2014 |
| Spain | IEA IDR 2015 | NEEAP, 2017 |
| Sweden | IEA IDR 2013 | NEEAP, 2017 |
| Switzerland | IEA IDR 2012 | NEEAP, 2008 |
| Tajikistan | PEEREA review 2013<br>IEA IDR 2015 | Law on energy efficiency and energy saving 2013. |
| FYR of Macedonia | Energy Charter regular energy efficiency review 2006<br>PEEREA review 2007 | NEEAP, 2014 |
| Turkey | PEREEA review 2014<br>IEA IDR 2016 | NEEAP (under development) |
| Turkmenistan | IEA IDR 2015 | |
| Ukraine | IEA IDR 2012/13/15<br>Energy Charter regular energy efficiency review 2013 | Strategy to 2030 proposes 30% - 35% energy intensity reduction to 2030 |
| United Kingdom | IEA IDR 2012 | NEEAP 2017 |
| United States | IEA IDR 2014 | National Action Plan for Energy Efficiency (NAPEE) 2006 |
| Uzbekistan | IEA IDR 2015 | Law on Rational use of energy updated 2003. No targets. |

*Source: IEA In Depth Reviews[139]; IEA Policies and Measures Database[140]; IEA (2015a); European Commission (2017e); Nordic Counsil of Ministers Secretariat (2014).*

As table 3.4 indicates, a range of measures have been implemented until today. However, there is still a huge gap to realize the potential of energy productivity.

For example, it is estimated that doubling energy productivity would reduce global expenditures for fossil fuels by more than ÉUR 2 trillion by 2020. It would further contribute to the creation of more htan six million jobs.[141]

Table 3.5 summarizes the multiple benefits of increased productivity for different levels.

**TABLE 3.5:** *Productivity Outcomes from Energy Efficiency Multiple Benefits in Industry.*

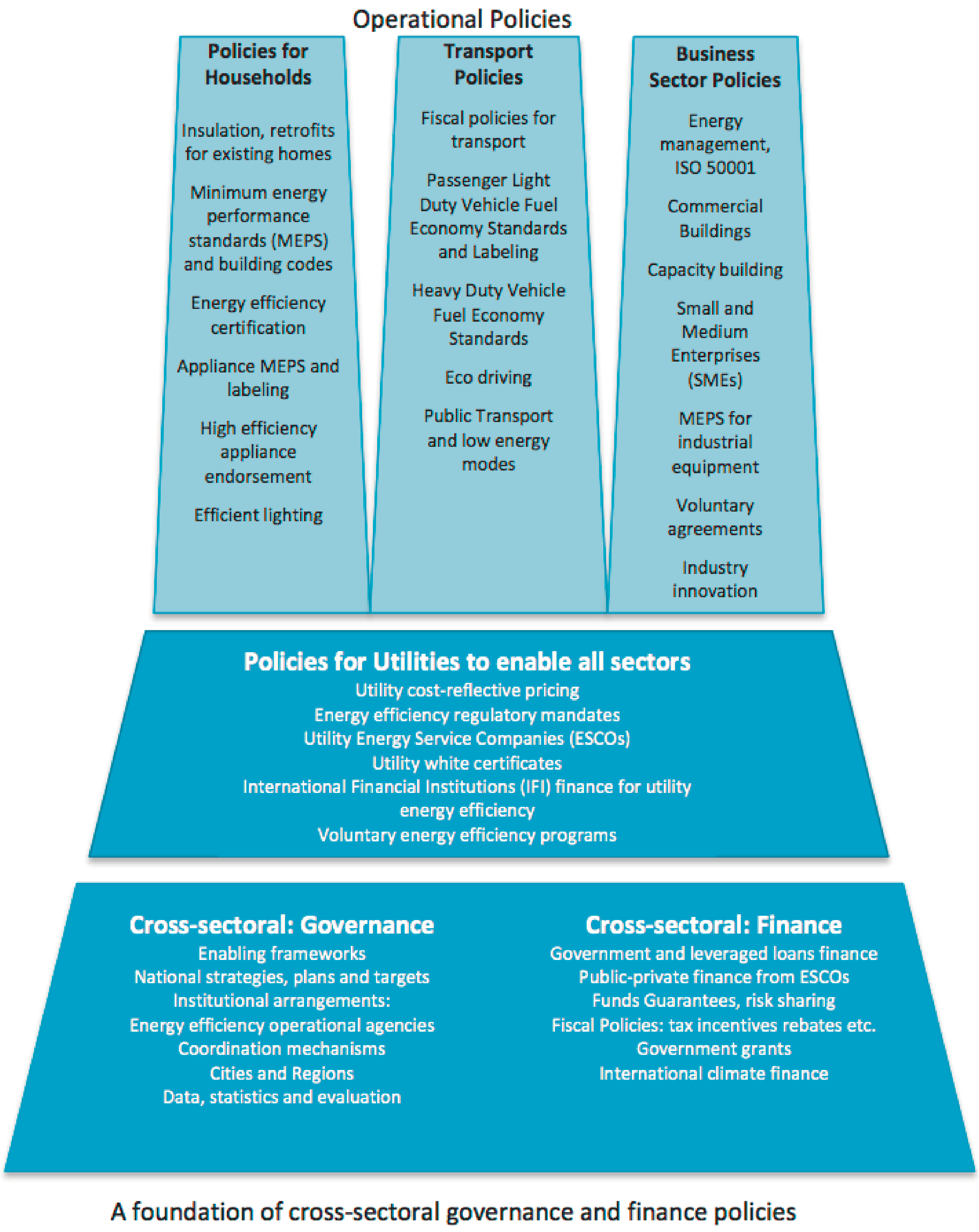
| Energy Efficiency Impact | Economic Outcomes | Social Outcomes | Environmental Outcomes |
|---|---|---|---|
| **The Business** | • Profitability and productivity improvements can be up to 2.5 times of energy cost savings.<br>• Technical energy efficiency improvements new processes and technology<br>• Improved energy security.<br>• Improved competitiveness.<br>• Technology spill over & supply chain improvements.<br>• New business opportunities. | • Safer working conditions.<br>• Improved job satisfaction, better working conditions. | • Reduced local pollution air and water emissions.<br>• Water conservation.<br>• Reduced physical waste. |
| **National Economy and Society** | • Macroeconomic gains.<br>• Increased employment.<br>• Increased tax revenue from higher value services<br>• Economic restructuring to higher value activities<br>• Improved global competitiveness. | • Improved health from lower local pollution. | • Reduced local pollution, air and water emissions.<br>• Water conservation.<br>• Reduced physical waste. |
| **Global Society and Environment** | • New opportunities for trade in green technology and services. | • Less conflict over constrained resources and waste streams.<br>• Higher value labour in energy productivity products and services | • Reduced demand on extraction of finite primary energy and physical resources.<br>• Reduced GHG and other air and water emissions. |

*Sources: Derived from IEA (2014a) and IPCC (2014a).*

To tap into the vast reserve of potential efficiency and renewable energy improvements, governments need to commit to sound governance. Current data from the ground need to be available and verified so as to provide the basis for the development of enabling policy frameworks that are realistic and lead to efficient investment decisions. An enabling framework of governance and financial policies remains the key challenge in most countries. At the same time policies need to be flexible and adaptable in order to allow for continuous improvement as more data feeds back into them.

Figure 3.3 summarizes the scope of energy efficiency policies outlined in a UNECE report which highlights the need for a base of cross-sectoral policies as foundations for energy utility policies, an enabling finance system and operational policies in households, transport and business sectors.

**FIGURE 3.3:** *A Best Practice Framework of Energy Efficiency Policies.*




*Source: UNECE (2015b).*

Best practices in policies can only be effective if they are fully applied in a local context. Policies that have worked well in one setting do not automatically work well in another. The examples that are offered in this report are concrete examples of policies and measures that are best in the settings for which they have been designed. All countries should reflect carefully on their respective development needs, the local conditions that need to be recognized and motivated, and the priorities for tailored energy efficiency policy.

## 3.4. Integrating Distributed Generation

> *Rapid technology advancements and the convergence of multiple disparate trends have already disrupted many industries and businesses, and there are signals that the energy sector may be next in line. A big shift in the way we produce or consume energy could disrupt energy markets as a whole, starting with power markets and snowballing from there.*[142]

Technology has, and will continue, to provide completely new energy technologies for countries to exploit. In order to be able to benefit from these advances, a new set of energy policies and practices are required to enable integration of distributed sustainable energy options.[143] [144] These options are typically renewable energy sources, such as solar PV, wind, biogas, biomass, small hydro and geothermal energy, but can also include gas-fired microturbines. Many features of renewable energy make them difficult to integrate into existing energy infrastructure, either the national transmission grid or local distribution networks.

In many countries, energy efficiency, renewable energy, access and affordability are treated as separate policy streams, often managed in separate agencies and budgets and separate from more mainstream energy policy and planning. New paradigms of demand and asset management, system optimisation and integration are needed are needed which are adaptive and resilient. Countries that recognise this and support the achievement of SDG outcomes can anticipate significant multiple benefits and spill overs delivering broad socio-economic and environmental benefits.

### 3.4.1. Selected Issues and Country Responses

This section focuses on the integration of variable renewable energy which provides challenges for grid integration and current power market design regimes. It further discusses the opportunities provided by distributed renewable energy for remote communities. Case studies are presented for the Ukraine, Denmark and Croatia.

#### Issue 1: Integration of Variable Renewable Energy: The Need for Flexible Supply and Better Market Design

Integrating "variable" or "intermittent" renewable energy (VRE), notably solar and wind, into the energy mix creates challenges for transmission and distribution. Countries are adapting to growing shares of VRE in their energy systems, notably Denmark, Germany, and Spain. Market design and operations are being adapted to enhance integration of VRE and provide the necessary balancing on the grid.

The existing institutional and technological infrastructure in most UNECE countries was designed to use fossil fuels with a base load model. It is not obvious how to upgrade and convert these systems to include renewable energy. One of the challenges is how existing energy systems, which assume fuel storage and on-demand availability, can adjust to accommodate VRE.

**Case Study 12: Integrating Variable Renewables into Grids.** [145]

VRE electricity deployment and integration develops over four stages. Each stage has its own specific characteristics and operational priorities.

Firstly, wind and solar plant output are subject to daily variations in power demand. Annual variable renewable electricity shares are limited to around 3% of annual electricity generation. Secondly, operational practices, such as intelligent forecasting of variable renewable electricity output, are introduced. UNECE countries in this phase include the Netherlands, Sweden, Austria, and Belgium. They have variable renewable energy electricity shares ranging from 3% to almost 15%.

In the third phase variability affects overall system operation, including that of other power plants. In this phase power system flexibility is paramount. The power system must accommodate substantial uncertainty and variability in the supply-demand balance. The two main flexible resources to date are dispatchable power plants and the transmission grid but demand-side options and new energy storage technology are growing in importance. Countries in this phase include Italy, the United Kingdom, Greece, Spain, Portugal, and Germany, with VRE electricity shares ranging from 15% to 25%.

The fourth and final phase sees "highly technical" and "less intuitive" challenges that require resilience in the face of events that could disturb normal operations on very short time scales. Only Denmark and Ireland can be considered to be facing these challenges, with variable renewable electricity share ranging from 25% to 50% in annual generation.

Countries with historically high hydroelectricity shares in their power systems like Norway have been early adopters of policies and market techniques that manage annual hydroelectricity variability.

**Case Study 13: Assigning Responsibility for Managing Increasing Variability of Supply in the Ukraine.[146]**

On 6 April 2017 the Ukrainian parliament submitted Draft Law No. 4493 of 21 April 2016 on Electricity Market (the "Electricity Market Draft Law"). The Draft Electricity Market Law introduces responsibility on generators for managing the hourly imbalances in the day-ahead market where they will sell electricity at "green" tariff rates.

It is planned that the responsibility for solar and wind will be introduced gradually with increases by 10% annually starting in 2021 until 2030 with 10% tolerance for wind and small hydro (the tolerance margin for small hydro will be valid until 2025) as well as 5% tolerance for solar. It also envisages the possibility of signing preliminary power purchase agreements before construction when a producer of electricity from renewables has executed title documents in respective lands, obtained a construction permit or executed a similar document under Ukrainian laws and signed a grid connection agreement.

The producers of electricity from renewables which have commissioned their power plants before the entry into force by the Electricity Market Draft Law are exempt from liability for imbalances until 2030.

Distributed renewable energy can enhance an energy system's resilience and provide improved energy access in countries that do not have sufficient energy resources for their economic development. Although fuel wood and processed biofuels can be stored, most other renewable energy has diurnal or seasonal availability. Therefore VRE need a backup, either supplied from the grid or a local battery or alternative generation system. The scale of the backup power supply depends on the size of demand peaks and their coincidence with the available VRE resources.

Case studies 12 and 13 show that the successful implementation of distributed renewable energy requires enabling energy market policies. Distributed generators should receive energy and capacity price signals that motivate economic investments in distributed renewable energy. The interaction of demand and supply in real time are key drivers for successful distributed renewable energy and are more durable signals for economic investments than typical renewable energy support polices like FiTs or renewable energy subsidies. Indeed, to offer subsidies while investors receive poor price signals for energy used or generated can create perverse outcomes. The World Economic Council report, "The Future of Electricity", highlights that achieving renewable energy requires clearer policies to encourage economic investments.

## Issue 2: Distributed Renewable Energy for Remote Communities

Some of the first investments in renewable energy occurred in remote communities to address social needs and local development agendas with renewable energy because of constraints in traditional energy resources.

Over time, community-developed renewable energy supply expanded and the concept of energy-independent villages evolved, particularly in Western and Central Europe. For example, a series of villages in Germany, most famously the 150-person village "Feldheim", produce sufficient amount of renewable energy to cover its own energy demand, while selling overproduced energy from the 122.6 MW wind, solar and biomass capacities back to the national grid.[147] Essentially, rather than being off-grid, the energy dependence of these villages is enabled through the connection to the national grid as it helps to compensate for the intermittency of VRE.

**Case Study 14: Wind Turbine Cooperatives in Denmark.[148]**

Jointly owned wind turbines in Denmark are organised as partnerships with joint and several liability. In practice, the risk of joint and several liability is minimised in that the partnership is unable to contract debt. This is ensured in their bylaws which maintain that the partnership cannot contract debt and that the turbines must be adequately insured. Partners own a part of the wind turbine corresponding to the number of shares bought. Often one share is calculated as corresponding to the yearly production of 1000 kWh from that particular wind turbine.

Private individuals and cooperatives have played an important role in the development of the Danish wind energy sector. 15 % of the Danish wind turbines today are owned by about 300 cooperatives.

Local acceptance of a wind turbine project is necessary. Public resistance against wind turbines in the landscape has been, and still is, and one of the largest barriers to the development of wind power. Opinion polls show a wide support in the population in favour of wind power in general. However, uncertainties and lack of information in the planning phase of future wind power projects often give raise to local scepticism. The experiences from a number of wind energy projects in Denmark show that public involvement in the planning phase and co-ownership increases the acceptance. Adding to this, two private offshore projects show that cooperative development and ownership is also an option in larger-scale projects.

The Middelgrunden Offshore Wind Farm (40 MW), close to Copenhagen, was developed though cooperation between the municipality, an energy company and, not least, a number of private individuals. Middelgrunden is the world's largest cooperatively owned wind farm with more than 8000 members of the cooperative. The Samsø project off the east coast of Jutland (23 MW) was developed by a cooperative with local people on the island of Samsø and the municipality as members.

**Case Study 15: Distributed Renewables. Croatia's High Shares of Traditional Renewable Energy.[149]**

The use of traditional biomass is still a very significant source of energy in many countries of Southeast Europe, and it is expected to continue to be in the near future.[150] The use of solid biofuel firewood in Croatia exemplifies the ongoing tradition of wood heating in many UNECE countries. Ease of fuel access is a key reason, especially in villages where many people own a small woodlot for reliable access to free fuel. In cities there are also multifamily houses that use firewood for heating, buy fuel wood before winter and store it for winter use. The unit price of fuel wood is much lower than other fuels,

Biomass forms about 55% of total renewable energy consumption in Croatia, from which 91% comes from solid biomass.[151] Solid biomass resources are provided by forest residues, and agricultural by-products mainly from wheat straw and corn stover. The heating potential is estimated to achieve 36 PJ until 2020 (2013 the utilized heating value was 13 PJ). It is further planned to install 140 MW of biomass fired power plants by 2020, and 420 MW by 2030, and to increase the production of pellets and briquettes as fuel for CHP units.[152] Electricity generation by biomass in 2014 stood at 0.9% in 2012, from which about 40% came from solid biomass. Renewable energy heat stood for 10.5% of total heat generated, most (89%) of it provided by solid biomass.[153]

Across the UNECE region there are many settlements where gas or district heating networks are simply not economic, and while electricity is everywhere, heat pumps are still too expensive for some or not practical. In these cases, people tend to use a mix of electricity and wood where economic for heating.

These self-sufficient renewable options are important to address energy poverty. Often houses just heat a living room or one more extra room. The key challenges are to help insulate homes and improve the efficiency of traditional and modern wood burners.

Another example comes from Denmark. With no significant energy resources, by the 1970's the country became dependent on imported oil. Price shocks associated with the 1970's oil embargo highlighted how dependent Denmark was on imported energy. Many of the wind turbines erected in the 1980s and early 1990s were, and still are, owned by local cooperatives. The first established in 1980 near Aarhus in Jutland. Case study 14 provides more details.

In 2015, Denmark produced 42% of electricity from wind, and plans to meet all its energy needs from renewable energy by 2050.

The traditional masonry fuel wood stoves and cookers used throughout the UNECE region generally offer efficient use of a distributed sustainable fuel wood resource. They differ significantly from the poor efficiency and high emissions of cooking stoves of other regions and, for many communities, are a lower cost option than supply of fossil fuelled district heat. See case study 15 for more information on traditional biomass use in Croatia.

The testing of solid fuel heaters is not well coordinated with differing local test procedures and actual performance is subject to operator skill. A limited number of combustion tests point to efficiencies for traditional and modern masonry stoves that are similar to other controlled combustion wood stoves. Efficiencies are generally above 60% and up to 72%.[154]

While widespread uptake of modern renewable energy is central to the necessary energy transition, traditional biofuels still play a key role in many UNECE countries. Policies should ensure traditional biofuels are a practical and enabled element of the energy transition

### 3.4.2 Opportunities and Prospects

Some countries, despite their significant cost-effective fossil fuel reserves, have set ambitious goals for renewable energy. Their ability to pursue these goals hinges on power system and investment capabilities and on their available renewable energy resources. Not all countries are starting their energy transitions with an enabling set of renewable energy potentials.

#### Realising available renewable resources

Underlying climatic and geographical contexts are substantial considerations in a country's primary renewable energy resource potential. In terms of solar energy, The UNECE region is characterised by a low insolation resource in the range of 700 to 1200 kWh / kilowatt peak (kWp)[155] for most countries.[156] The United States has the highest potential, almost reaching 2000 kWh/kWp, followed by Central Asian countries, in particular Tajikistan and Turkey, and afterwards followed by Spain, Italy, and Armenia. Even countries with low insolation levels such as Germany can install solar PV on a large scale. At the end of 2016, the total nominal PV power installed in Germany was 41 GW, distributed over 1.5 million power plants.[157]

Initiatives to track renewable energy source potentials exist, such as the Global Wind Atlas by the International Renewable Energy Agency (IRENA).[158] It indicates that there is ample potential in different sub-regions of the UNECE region, in particular in coastal areas along Western and Central Europe, as well as the North American coast. A similar global map for bioenergy does not yet exist but many national assessments exist, such as the Biofuels Atlas for the United States provided by the National Renewable Energy Laboratory (NREL)[159] and a Bioenergy Simulator by IRENA.[160]

Some countries start from a very low base to pursue significant renewable energy targets. Kazakhstan for example has a 1% renewable electricity share and objectives of 3% by 2020, 10% by 2030, and 50% renewable energy by 2050.[161] As an oil and gas exporting country, a range of support mechanisms and investment incentives need to be put in place in order to utilize the country's renewable energy potential. These offer distributed clean energy solutions in particular for rural areas where 47% of the population live.[162]

Some countries with existing substantial renewable energy capacity face challenges to extend from their traditional centralised renewable energy systems to new renewable and more distributed energy opportunities. The ability to invest in renewable energy and trade renewable energy outputs across borders is therefore important for many countries and can liberate further economic improvements in renewable energy costs for some countries.

## An electricity market evolving to meet the dynamic challenges of distributed power

Electricity markets are already moving their focus towards consumers.[163] There is talk of the "prosumer" who not only consumes electricity but also produces it, for example through roof-top solar panels. The shift is important for network companies who must balance growing distributed VRE capacity while selling lower volumes of electricity. One of the common barriers to change is that the power system has been technically driven and requires a centrally designed planning system to operate effectively because the physics of power systems demand instantaneous response to changes in demand and supply. The reality is however that our ability to measure and understand system dynamics in real time has evolved in the past 30 years. Technical options have evolved away from a central plant investment model towards distributed systems.

A distributed energy transformation, based on demand side energy efficiency and distributed renewable energy, will address the issues of access quality, affordability and system resilience for less cost and lower environmental impact than most supply security options.

New conventional energy supply has been perceived by policy makers as reliable and secure. However there is growing evidence that addressing end-use efficiency is not only cheaper than new supply options, but that it also delivers large multiple social and economic benefits at lower cost than traditional supply options. This is particularly so in countries with inefficient or unaffordable heating services. Here the value of improved comfort and reduced health costs can exceed the value of reducing energy demand and energy efficiency investments. Indeed in the coldest continental climates e.g. Kazakhstan and the Russian Federation, the demand for heat is highest and scope for renewable energy is limited.

A shift in thinking to a system maximising the value to society rather than the current focus on lifecycle cost of renewable energy (and other) supply options is required for improved service provision, energy system economics, and energy resilience.

### Opportunity: A Move from Levelised Cost of Electricity to System Value.[164]

As legacy power systems face disruption from new technology and resources the underlying costs drivers start to shift from simple indicators to more complex metrics. The traditional focus on the levelised cost of electricity (LCOE) is no longer sufficient. Next-generation approaches need to factor in the system value of electricity from wind and solar power.

System value is defined as the overall benefit arising from the addition of a wind or solar power generation to the power system. It is determined by the interplay of positives and negatives. Positive effects can include reduced fuel costs, reduced $CO_2$ and other pollutant emissions costs, reduced need for other generation capacity and possibly grid infrastructure, and reduced losses. On the negative side are increases in some costs, such as higher costs of cycling conventional power plant and for additional grid infrastructure, as well as curtailment of VRE output due to system constraints. System value provides crucial information above and beyond generation costs; in cases where system value is higher than the generation cost, additional VRE capacity will help to reduce the total cost of the power system.

As the share of VRE generation increases, the variability of VRE generation and other adverse effects can lead to a drop in system value. It is important to distinguish the short-term and long-term system value of VRE. In the short term, system value is strongly influenced by existing infrastructure and the current needs of the power system. For example, if new generation is needed to meet growing demand or retirements – as in South Africa – system value will tend to be higher. By contrast, the presence of large amounts of relatively inflexible generation capacity – as is the case in Germany – can lead to a more rapid system value decline in the short term. For long-term energy strategies, the long-term system value is most relevant. This accounts for both fuel savings and capital investments. In order to attract investments in VRE at lowest cost, policy mechanisms are needed that provide sufficient long term revenue guarantees to VRE investors. In turn, such mechanisms need to be designed in a way that accounts for the differences between systems of using different generation technologies. Existing policy practice already provides a number of ways in which the value of VRE can be boosted by facilitating system-friendly deployment strategies.

**Opportunity: Next Generation Wind and Solar – From Cost to Value.**

VRE bring new challenges. A systemic approach is the appropriate answer to system integration, best captured by the notion of transformation of the overall power system. This requires strategic action in three areas:

- System-friendly deployment, which aims to maximise the net benefit of wind and solar power for the entire system.
- Improved operating strategies, such as advanced renewable energy forecasting and enhanced scheduling of power plants.
- Investment in additional flexible resources, comprising demand-side resources, electricity storage, grid infrastructure and flexible generation.

Wind and solar power can facilitate their own integration by means of system-friendly deployment strategies. Six areas are most important:

- System service capabilities. Technological advances have greatly improved the degree to which variable renewable electricity can be forecasted and controlled in real time. With the right framework conditions in place, variable renewable electricity can help to balance supply and demand despite its dependence on the availability of wind and sunlight.
- Location of deployment. With the cost of solar PV and (onshore) wind power falling rapidly, deployment is becoming economical even in lower resource conditions. This gives a wider choice for developing diversity in power plants and allowing electricity to be produced closer to demand.
- Technology mix. The output of wind and solar power is complementary in many regions of the world. It can be complementary to other renewable energy, such as hydropower, deploying a mix of technology coincident to load can bring valuable synergies.
- Local integration with other resources. Distributed deployment of variable renewable electricity can open the opportunity to integrate generation resource directly with other flexibility options to form an integrated package. For example, solar PV systems can be combined with demand-side response or storage resources to achieve a better match with local demand and thus reduce the need for investments in distribution network infrastructure.
- Economic design criteria. The design of wind and solar plants can be optimised to facilitate integration. For example, a detailed modelling study that was carried out as part of this project highlighted that wind turbines with larger blades compared to generator capacity produce electricity in a less variable fashion, which reduces integration challenges.
- Integrated planning, monitoring and revision. The relative costs of VRE and other generation technology, as well as the cost of various flexible resources, are changing dynamically. Consequently, the optimal mix of flexible resources as well as system-friendly deployment strategies will change over time, prompting the need to adjust strategies.

Regardless of current energy market structure, renewable energy, whether centralised or distributed, require durable signals that give investors clearer insight in to the drivers for new capacity, and offer a reliable basis for investment evaluation and return over the life of the investment. This applies whether the investor is an urban householder, a farmer, a business or professional power plant investor. Their motivation to invest is similar - a reliable return on the renewable energy installation.

## 3.5. Improving Supply-Side Sustainability in Generation and Transmission

Naive perceptions of security of supply persist in many countries. Security is perceived to be enhanced by self-sufficiency, often through new domestic supplies of fossil fuels, while energy trade is perceived as unreliable and renewable energy is perceived as variable and challenging to system stability (stability is different to security of supply). The institutional paradigms and policies that served well over the past 50 years are now challenged by a wider range of renewable energy and demand side products and services.

### 3.5.1. Selected Issues and Country Responses

Incumbents in any market have a position of strength based on experience in the market place and a history of shaping and working with the policies and practices in the market. The incumbent generally represents inertia to change due to its business model and the desire to obtain economic rents from sunk capital. The high reliance on fossil fuels and the associated infrastructure in many UNECE countries act as a mass that is very difficult to shift.

A range of issues are considered in this section including the high share of fossil fuels in power generation and the need to improve generating efficiencies. Other issues include the implications and opportunities of energy security driven policy making in the UNECE region, and scaling up of grid-connected renewable energy.

**Issue 1:** A Unsustainable and Continued High Reliance on Fossil Fuels

UNECE countries depend on fossil fuels for 80% of their energy supply. Coal provides 18% of TPES in the region, less than its global share of 29%. Compared to other fossil fuels, coal accounts for disproportionally more $CO_2$ emissions, globally 46%, in addition to the local pollutants it causes. Natural gas represents 31% of TPES in the region compared to a global share of 21%, and emits less $CO_2$ per unit of energy produced compared to coal. Power generators, and transport fleets and heating service all fossil fuels.

The use of fossil fuels has shaped the institutional and technological infrastructure that we use today. It is difficult and expensive to upgrade and convert to renewable energy operation.

There is a locked-in dependence on fossil fuels, often with poor efficiencies. A transition away from this is neither obvious nor easy.

Many fossil fuel based economies, developed as well as emerging economies, rely heavily on energy imports. Germany (64%), Armenia (72%), Belarus (88%), Georgia (70%) and Moldova (90%) are reliant for more than 60% of their TPES on fossil imports.[166]

Overall, fossil fuel shares remain high in countries. For example, in Germany the share of fossil fuels in TPES remains high (80%), despite the Energiewende efforts under way. This is because fossil fuels have advantages. They are comparatively dense energy carriers and are easy to trade, both regionally and globally. Renewable energy does not have these attributes.

However, the fossil fuel infrastructure is aging in most countries and this represents a window of opportunity for change. Those countries that have managed to reduce their fossil-to-TPES ratio to date have had a number of aligned drivers in place for change:

- Economic and fiscal robustness enabling access to and investment in efficient plant to meet demand growth and replace aging plant,
- Competitive energy markets, with cost-reflectivity that rewards investment in improved efficiency,
- Policies to reduce environmental impacts,
- Alternative resources (gas, nuclear, renewables).

For countries with more than 80% fossil fuel share of TPES, one of more of these change drivers has been absent. In most cases countries can alter the first three drivers given time. However, despite the global commitments to advance sustainable development, accessing alternative resources and technology is a real constraint for many countries. While new renewable energy options enable further renewable energy growth, they tend to be distributed and require markets that incentivise consumers to adopt them.

The transition from a fossil to a low carbon energy system is difficult and requires substantial effort across policy, structure, finance and technology.

## Issue 2: Inadequate Progress in Supply Sector Efficiency of Fossil Fuel based Generation

The efficiency of conversion and transformation from primary to final energy is an important aspect of SDG 7. Increasing efficiency reduces costs and greenhouse gas emissions. The ratio of final to primary energy reflects overall energy efficiency in the supply sector. A gradual reduction in this ratio has occurred globally from 72% in 1990 to 68% in 2010. This implies a reduction in conversion and transformation losses.

In the UNECE region the ratio dipped by around 1.4% during the same period but remained higher at 71% than the world's average 68% (2010). In 2015 the ratio was 68%. In 2014, 41% of global electricity generation came from coal-fired power plants and 22% came from gas power plants.[167]

### Efficiency of thermal power plants

Changes in power production fuel mixes are driving the reported average plant efficiencies. The share of coal in the global power generation mix will drop to 36% by 2021, down from 41% in 2014, driven by lower demand from China and the United States, fast growth of renewable energy and a strong focus on energy efficiency.[168]

The share of fossil fuels in the UNECE region's power generation sectors varies from 2% to 100%. 6 countries have less than 3% fossil fuel shares in their power systems (Albania, Norway, Switzerland, Tajikistan all with large hydro resources, Iceland with geothermal, and France with nuclear). Denmark and Germany have achieved fossil fuel shares of 40% and 57% respectively. Eight countries have power systems based on more than 90% fossil fuels, including Kazakhstan 92%, Cyprus 93%, Azerbaijan 94%, Moldova 94%, Malta 97%, Israel 98%, Belarus 99%, and Turkmenistan 100%.[169]

Coal is the dominant fuel (30%) for power production in the UNECE region, followed by gas (25%) and nuclear (21%). Hydro power follows at 15%. Power generation is responsible for 40% of global $CO_2$ emissions, and the power sector in UNECE region contributes a substantial amount of the region's emissions. Coal's higher carbon intensity and the lower efficiency of coal power plants results in comparatively higher emissions. In 2014 coal accounted for 73% of global electric sector carbon dioxide emissions, and gas accounted for 20% of global power plant carbon dioxide emissions.[170]

The average power plant efficiency of electricity generation from of fossil fuels (coal, gas and oil) in the UNECE region improved from 36% in 1990 to 41% in 2014. Gas fired generators improved from 37% in 1990 to 49% in 2014, the highest amongst regions.[171]

Using in-house power plant data systems, GE evaluated the scope for power plant efficiency upgrades and the impact on emissions. Tables 3.7 and 3.8 outline the estimated technical (not economic) potential for efficiency improvements to coal and gas power plants in key UNECE member countries from GE's analysis.

**TABLE 3.6:** *Coal Power Plants: Potentials for Efficiency Improvements and Emission Reductions.*

| Country | Coal generation (GWh) 2015 | Average plant efficiency % | Potential efficiency with upgrades | Potential $CO_2$ reduction Mt | % Change in $CO_2$ |
|---|---|---|---|---|---|
| *World* | 8,920 | 34% | 38% | 924 | 11% |
| USA | 1,356 | 37% | 42% | 296 | 9% |
| Russian Federation | 173 | 25% | 30% | 37 | 16% |
| Germany | 315 | 36% | 41% | 31 | 11% |
| Poland | 134 | 34% | 39% | 16 | 12% |
| Ukraine | 83 | 30% | 36% | 14 | 16% |
| UK | 117 | 38% | 44% | 13 | 13% |
| Kazakhstan | 73 | 30% | 35% | 11 | 14% |
| Czech Republic | 45 | 28% | 33% | 8 | 15% |
| Turkey | 80 | 34% | 38% | 8 | 10% |
| Canada | 64 | 38% | 43% | 6 | 11% |
| Spain | 55 | 36% | 41% | 6 | 12% |

*Source: GE (2017).*

**TABLE 3.7:** *Gas Power Plants: Potentials for Efficiency Improvements and Emission Reductions.*

| Country | Coal generation (GWh) 2015 | Average plant efficiency % | Potential efficiency with upgrades | Potential $CO_2$ reduction Mt | % Change in $CO_2$ |
|---|---|---|---|---|---|
| ***World*** | 5,713 | 39% | 43% | 203 | 8% |
| Russian Federation | 564 | 26% | 30% | 45 | 12% |
| USA | 1,316 | 45% | 48% | 34 | 6% |
| Uzbekistan | 41 | 28% | 33% | 4 | 13% |
| Turkey | 134 | 45% | 48% | 3 | 6% |
| Belarus | 34 | 28% | 32% | 3 | 13% |
| Italy | 130 | 45% | 47% | 3 | 5% |
| Canada | 73 | 41% | 44% | 2 | 8% |
| Turkmenistan | 23 | 25% | 29% | 2 | 14% |

*Source: GE (2017).*

In the UNECE countries that rely on fossil power generation, it would be possible to reduce $CO_2$ emissions by 542Mt through upgrades.

83% of the potential is in coal power plants. Two thirds of coal plant improvements are in turbine and boiler hardware upgrades, with the remaining third in operational data and software improvements.

55% of the gas plant improvement potential is in turbine and boiler hardware upgrades and 45% in data systems.

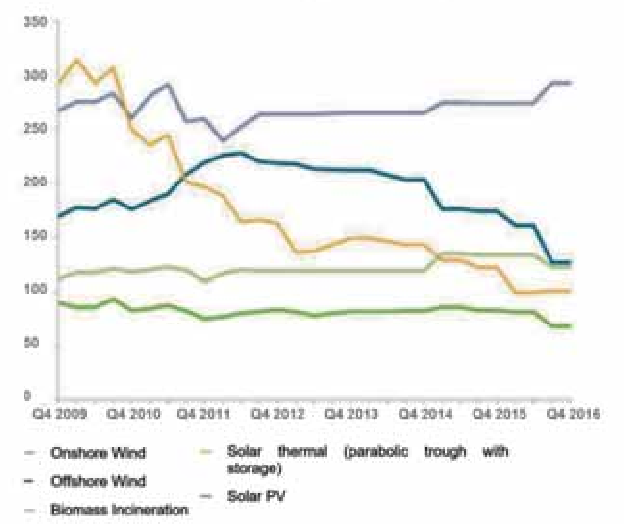
Besides supply side efficiency, losses in electricity transmission and distribution declined from 8.2% in1990 to 7.2% in 2014, the lowest amongst the regions. Natural gas transmission and distribution fell by half from 1.2% to 0.6%.[172]

## Issue 3: Further Development of Policies to Support Renewable Energy Uptake

Despite the declining costs of renewable energy (see figure 3.4) per Megawatt hour (MWh) of renewable energy produced and rapid growth in implementation, challenges exist to maintaining progress and realizing the potential of renewable energy.

Key challenges include the continued lack of supportive, long term sustainable energy policies, the lack of investments and support by domestic banks in many countries with less renewable energy implementation experience, the shortage of specialists and geo-political factors that maintain conventional energy subsidies, constrain trade and maintain the lock-in of older inefficient fossil energy infrastructure.

**FIGURE 3.4:** *Price Trends for Renewable Energy (2009-2016). Levelized Cost of Electricity from selected Renewable Energy Sources (Q3 2009 to H2 2016 in USD/MWh).*




*Source: Bloomberg New Energy Finance (2017).*

Policies that support renewable energy have evolved significantly over the past decades. While initial support mechanisms focused on FiTs guaranteeing a fixed tariff for supplied kWh over a fixed period of time, more effective and efficient support policies have developed over time. In particular the move to renewable energy auctions seeks to address the need for renewable energy to become competitive.

A summary table of the renewable energy policies implemented within the UNECE member States is provided in Annex VI.

Most countries in the UNECE region have established renewable energy policies.

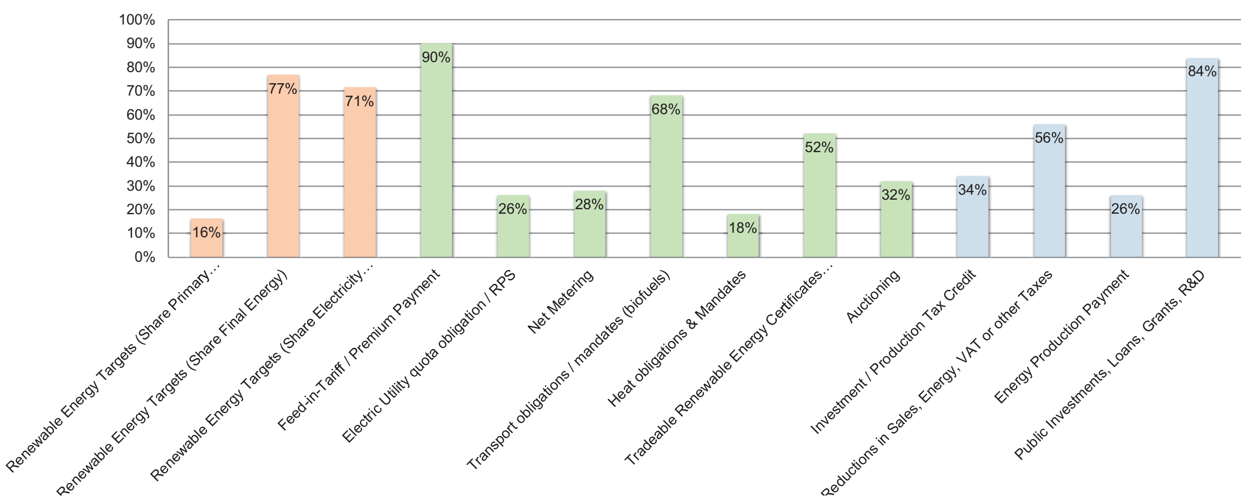
- Bulgaria, where the Energy from Renewable Sources Act (ERSA) and the Energy Act (EA) enables preferential prices for electricity from renewable sources.[173] The regulator set FiTs for electricity produced by new renewable electricity installations and for biomass. Renewable electricity can be sold at freely negotiated prices and/or into the balancing market.
- Ukraine's 2014 National Renewable Energy Action Plan aims to implement a series of renewable energy policies - such as preferential loans for alternative energy production, tax exemptions, accelerated depreciation, import duty waivers - as well as initiatives eliminating fossil fuel energy subsidies for residential users.[174]
- In 2015, the government of Belarus set new FiTs for renewable energy power fed to the country's grid. Tariffs range from 1.1 to 3.3 USD-cents per kWh for the first 10 years to 0.45 USD-cents per kWh after 20 years. In addition, based on a program with performance targets to increase biodiesel production from 2007-2010 by utilizing domestic resources, liquid biofuels consumption increased from zero in 2007 to 0.0010 EJ in 2014.[175]

Figure 3.5 provides the percentage share of policy types implemented across the 56 member States. Three quarters of countries have introduced renewable energy shares in final energy and about two thirds have defined renewable energy targets as share in electricity generation.

Among regulatory policies, the most prominent mechanism remains the FiT or premium payment, despite its economic inefficiency, which 45 countries (re-)introduced for one or more types of renewable energy sources. Transport obligations for biofuels as well as tradeable renewable energy certificates were the second and third most common choices.

Less used are electric utility quota, net metering regulation, or heat obligations. The use of renewable energy auctioning increased. Sixteen countries introduced auction schemes for renewable energy. Notably Spain, which terminated its FiT scheme in favour of an auction scheme for different types of renewable energy. Also Germany is increasingly moving from FiT to auctions as shown in case study 16.

**FIGURE 3.5:** *Type and Share of Renewable Energy Policies introduced in UNECE Countries (2015).*




*Source: UNECE (2017a) for 17 countries, otherwise from REN21 (2017).*

**Case Study 16: A shift from Renewable Energy Feed-In Tariffs to Auctions? An Example of Off-Shore Wind Energy in Germany.**

In a public auction run by the Bundesnetzagentur (German Federal Network Agency for Electricity, Gas, Telecommunications, Post and Railway) in April 2017 both the Danish company Dong Energy and the German company EnBW won rights to build three offshore wind projects in the German North Sea without government subsidies. The world's first subsidy-free offshore wind auction bids have been described as "a highly symbolic first for the industry", in particular when looking back on the large sums of money governments have spent subsidizing offshore wind projects in the hope of creating a clean source of energy that could eventually pay for itself.[176]

While the April 2017 offshore wind auctions were the first of this type, Germany has moved ahead with the implementation of renewable energy auction policies to cover the whole renewable energy sector. In a reform of the German Renewable Energy Act (Erneuerbare Energien Gesetz) in January 2017, FiTs were replaced by an auction system for most renewable technology. Payments to renewables installations are now determined in competitive processes, instead of by the government's FiTs and premiums, with the advantage that costs for renewable power can be limited to the economically necessary level for each installation. Renewable energy auctions may unlock further cost reductions in renewable technology.[177] [178]

## Issue 4: Diverging Concepts of Energy Security: Energy Self-Sufficiency versus Energy Interdependence

The concept of energy security is diverse and different interpretations exist. The IEA defines it as "the uninterrupted physical availability at a price that is affordable, while respecting environmental concerns". Different interpretations exist depending on national and regional circumstances, mainly driven by national resource availability and collaborative contexts. Kazakhstan's Nazarbayev University defines it for the Central Asian and Caspian Countries as security "to ensure secure transportation of oil and gas to the market through multiple pipeline network in geopolitical cooperation among producers and transit countries of the area, to keep a sufficient willingness to invest in the energy sector, and to reduce the risk of export concentration."[179] The European Union which depends on imports for more than half of its consumed energy defines in its Energy Security Strategy the aim "to ensure a stable and abundant supply of energy for European citizens and the economy".[180]

Case study 17 explores the dependence of the European Union on energy imports in more detail. It shows a shift to diversification in energy systems. Energy efficiency and renewable energy are increasing elasticity in energy markets and mitigating supply security risks in Europe.

Global markets for oil, gas and coal have undergone profound change. All three commodities now trade at significantly lower prices than previously, while sustaining medium term volumes and new market entrants. Media focus has shifted from the historical patterns of price volatility to discuss how long suppliers can sustain output and maintain historical patterns of investment in production operation and maintenance at prevailing prices. There had been a shift in market power from the supply side to the demand side in global fuels markets, as technological innovations allow new resources to be extracted and challenge established patterns of demand and pricing.

New domestic supply shifted the United States from a net importer to a net exporter of energy, mainly due to its "shale gas and shale oil revolution", combined with increased output from renewables. The United States EIA estimates that the

**Case Study 17: European Energy Security: Improving Import Dependency.[181]**

18 European Union member States import more than 50% of their energy. Demand for energy is now more than 8% below its 2006 peak due to structural changes in the economy of the EU, the economic crisis and efficiency improvements linked to policies of the past 10 years. Import dependency, reached more than 50% as European production declined after 2006, but stabilised thereafter with increasing renewable energy production and demand reduction. In 2012, oil was at 90% import dependency, gas at 66% import dependency and coal at 42%. Import dependency for uranium is 95% but it is a relatively small quantity.

Oil supply risks are off-set by high market liquidity and regulated 90-day stock holdings.

Gas import pipeline capacity is 8776 GWh/day, LNG terminals 6170 GWh/day. Long term pipeline gas contracts, nearly entirely with the Russian Federation, are estimated to cover 17-30% of market demand. Gas market and gas infrastructure (interconnectors, reverse flows and storage) developments are improving resilience. However the Baltic States, Finland, Slovakia and Bulgaria remain dependent on a single supplier and the Czech Republic and Austria have very concentrated imported gas supplies. A winter supply disruption through Ukraine transit routes would pose challenges for Bulgaria, Romania, Hungary and Greece.

Coal provides 17% of energy in the European Union, used in electricity, CHP and district heating plants, with Germany, Poland, the United Kingdom and Greece being the top four consumers. Coal demand declined by 20% from 1995-2012 in nearly all Member States. Import dependency currently stands at 42% and has been increasing due to the closure of uncompetitive mines in a number of member countries of the European Union.

United States has about 200 trillion cubic feet of proved shale gas resources in 2014.[182] In 'Revolution Now'[183] the United States Department of Energy describes the rapid price declines and uptake of wind, solar photovoltaic, LED lighting and electric vehicles as an *"historic shift to a cleaner, more domestic and more secure energy future is not some far-away goal. We are living it, and it is gaining force"*. In the United States, solar energy accounted for 32% of the nation's new generating capacity in 2014, beating out both wind energy and coal for the second year in a row.[184]

## Oil

From 2011 to 2015, oil prices were sustained on average over USD 100 per barrel (USD/bbl), a sustained price level previously only seen as price peaks. Prices fell during 2015 to 37 USD/bbl, while OPEC held back production. Global production exceeded supply by an average 2 million bbl/day during 2015.[185]

The United States remained the largest consumer at 21%; Europe, 15%; Russia, 3.7%. Main net exporters of oil within the UNECE region are the USA, Norway, and the Russian Federation.

Oil demand decreased 13% in the period 2005-2012 but continues to be 34% of the primary energy source used in the European Union. 64% of final consumption of oil is used in transport where electric vehicles are now looking like a viable alternatives. Oil retains the highest import dependency, 88% (80% if only imports from outside the European Economic Area are taken into consideration), and significant import bill (EUR 302 billion in 2012).

## Natural gas

The European Union relies on natural gas imports for 66% of its gas supply. The European Union's long-term contracts for pipeline gas supply cover 17-30% of the European Union's market demand, are nearly entirely imports from Russia, and are sometimes covered by long term inter-governmental agreements, some of which extend to 2030.

The total capacity of pipelines to the European Union from supplier countries is 397 billion cubic meters per year (bcm/year). New projects under construction include the pipelines of the Southern Gas Corridor, which will allow by 2020 supplies to markets of the European Union of a further 10 bcm per year gas from Azerbaijan. The envisaged infrastructure in Turkey could transport up to 25 bcm per year to the European market allowing further gas volumes from Azerbaijan as well as Northern Iraq.[186]

130 underground gas storage facilities in Europe, including non-European Union countries such as Turkey, comprise a combined capacity exceeding 90 bcm.[187]

Regasification capacity of liquefied natural gas (LNG) terminals in the Europe (excluding small scale LNG) is 200 bcm/year, half the European Union's annual gas imports of 400 bcm in 2015. Further terminals are planned and their total capacity is planned to reach 275 bcm/year in 2022.

The main net exporter of natural gas in the UNECE region are the Russian Federation, the USA, and Norway. While much of the UNECE regions gas is distributed by national and regional pipeline systems, the bulk of global trade is increasingly shaped by LNG system dynamics. Global LNG supply capacity is 300Mt/year but in 2016 only 268 Mt were traded. Buyers in Asia (which makes up 70% of global LNG demand) are shifting from fixed long-term contracts with a priority on security of supply, to more flexible group purchase of short term gas and spot contracts driven by power sector flexibility and deregulation. The United States is likely to be the third largest supplier in 2018, and its flexible terms are likely to be attractive to Asian buyers.[188]

In Europe the 2013/14 winter supply outlook of ENTSOG noted that there were no big variations in Norwegian, Algerian or Libyan supplies, but that there were important decreases in LNG imports (- 32%). The drop in imports of LNG was a result of a divergence of gas prices between Europe and Asia, which led cargos to be redirected to Asia and reducing the arrival of spot cargos in Europe. The drop was replaced by draws on storage (+40%) and increased Russian imports (+7.5%, mostly Nord Stream flows).[189]

LNG export capacity is still growing (US and Australia) and stagnant demand is suppressing gas spot prices. European gas demand not covered by long-term supply contracts has a strong negotiating position.

## Coal

Coal is a low cost, low-grade fuel and a rich chemical feedstock. In 2014, it provided 29% of the world primary energy, but created 46% of global GHG emissions and a disproportionate amount of local air and water pollutants. Disruptive streams of low cost gas (growing LNG supply and lower prices) and renewable energy are eating away at coal's share of demand, but it nevertheless remains locked in to its historical low cost paradigms and infrastructure.[190]

The IEA points to coal being 27% of global energy by 2021. The United States' and European coal demand was 47% of global coal trade in 2000, but this has now dropped to 22%.[191] Coal's role in the developed world's existing power and heat infrastructure is declining. Lack of investments in CCS technology further hinders development of coal-based technology. However, coal remains the mainstay in many emerging economies.

The United States and the European Union are respectively the second and third largest coal-consuming regions in the world, using 25% of global coal production. United States coal supply is almost entirely domestic, and coal consumption dropped 15% in 2015.[192] The European Union meets only about one third of its needs for hard coal with indigenous production.

Demand for solid fuels in the European Union has declined by almost 20% since the mid-1990s. Following the slump in consumption in 2009, demand started recovering and 2012 was the fourth consecutive year of growth in solid fuel consumption. A number of Member States have seen a double-digit growth in consumption between 2011 and 2012, in particular Portugal (+32%), Spain (+20%), France (+13%), Ireland (+12%) and the Netherlands (+10%). The decline in coal and $CO_2$ prices and high gas prices provided coal with a strong competitive advantage to gas in power generation.

The European Union has a diversified portfolio of coal suppliers, with Russian, Colombian and United States imports each accounting for approximately a quarter of hard coal import quantities. Rising production costs of domestic hard coal and depressed prices on global coal markets have made imports an economically attractive option. International prices increasingly serve as leverage to negotiate price contracts with domestic coal producers.

Global coal markets are competitive and have not experienced the spikes or disruptions observed in the crude oil market or regional markets for natural gas. There is no minimum stock requirement in terms of coal inventories and stock changes almost daily.

The current global situation of low coal prices and stagnant global demand is contrasted with significant pressure and change in countries where coal is in a period of intense disruption. Countries carry individual accountability to reduce emissions, so they must improve the economics and efficiency of a vast stock of older coal-fired power plants. New investments in renewable energy challenge the underlying cost structures that have developed the current fleets of power and heat plants.

## **Issue 5:** The Difficulty of an Energy Transition Paradigm Shift

The term 'energy transition' describes a shift over the medium term to a mix of energy efficiency, low carbon options and universal access to quality energy services.

Today an energy transition is under way and change in the global energy system is observable. Renewable generation excluding large hydro accounted for 55.3% of newly added electricity generation in 2016, and produced an estimated 11.3% of total global electricity generation (with a total share in installed capacity of 16.7%). Most of the new generating capacity installed in 2016 came from solar power, followed by wind, coal, gas, large hydro, nuclear and biomass.[193]

The overall increase in the world's nuclear net capacity in 2016 was the highest since 1993, with new reactors coming online in China, the United States, South Korea, India, the Russian Federation and Pakistan. Conversely, Germany, France, and Sweden have announced their intention to withdraw from or reduce nuclear power. In the future capacity additions will be offset at least in part by retirements.

Coal demand fell worldwide but the drop was particularly sharp in the United States, where coal demand was down 11% in 2016 because of price competition with natural gas. In the United States electricity generation from natural gas was higher than from coal.

In the European Union, gas demand rose about 8% and coal demand fell 10%, keeping emissions largely stable last year. Renewable energy also played a role. The United Kingdom saw significant coal-to-gas switching in the power sector, as a result of both cheaper gas and a mandated carbon price floor.[194]

## Energy transition dynamics

While current progress looks promising, there is much more to do before a durable energy transition is confirmed.

Many countries still focus on energy security based on indigenous, typically fossil, energy resources. While 10 UNECE countries are major exporters of energy resources to global markets, strong regional and cultural behaviours persist in an on-going reliance on indigenous resources. Developing a more sustainable energy system requires a shift in the view of security of supply. Economic trade in sustainable resources, increasing demand side focus and innovations in technology and skills will shape sustainable outcomes and produce an adaptive and resilient energy system.

Existing plants, can continue operating despite lower efficiencies because they simply have to cover their cash costs. Their initial investment capital was amortised years ago and they can act as marginal operators.

Although many countries have already expended effort in 'priming' renewable energy with FiTs and have grown renewable energy from a negligible base, they have yet to alter their vastly greater, existing coal systems. A notable example is found in Germany where there has been little change in the efficiency and scale of coal fired capacity.

The challenge is to discern investment pathways that enable an economically efficient transition that is fast enough to meet the 2030 Agenda.

The risk of not participating in the energy transition are high. Countries, may have the financial wherewithal and the technology to deploy high-efficiency, low-emission coal technology but risk stranding investments if competitive gas and renewables displace new coal (see also case study 18).

The transition will neither obvious nor easy but a process of moving power systems to high efficiency gas and renewable energy is do-able both technically and economically. Placing a real price on carbon would reinforce the drivers and accelerate the transition.

**Case Study 18: To Renewables via Gas: The North American Fossil Fuel Transition.**

Currently a third of the United States' electricity is generated in gas-fired power plants. Nuclear plants produce about 20%, hydro 6%, and other renewables 7%. In 2015 solar made up 32% of all new electrical capacity, greater than wind and coal for the second year in a row.[195]

In 2015 United States coal production decreased for the fourth year in a row to 1,165 million (US) tons, a decline of 6.3% from the 2014 levels. United States coal production has dropped 10.3% year-on-year to its lowest levels since 1986. Coal's share of total electricity generation, which was 50% in 2005 and 33% in 2015, is predicted to fall to 21% in 2030 and to 18% in 2040. Coal-fired generators capacity is expected to reduce by one third through 2030, to about 60 GW.[196]

Current LCOE for coal-fired power plants with CCS are 65-139 USD/MWh. Gas-fired plants have a cost of 58 USD/MWh; nuclear 103 USD/MWh; onshore wind 64.5 USD/MWh,[197] solar 85 USD/MWh and hydroelectric 68 USD/MWh. The shale revolution in the United States clearly sharpened the competitive edge between coal and gas in United States power markets, and the progressive reduction in the costs of renewable energy is making them increasingly competitive with both coal and gas even without financial support.

## Restructuring

Markets for energy and utilities that are transparent, competitive and facilitate efficient cost-reflective pricing are a pre-condition for delivering timely, innovative and least cost responses to achieve public policy goals.

The Russian Federation is undertaking one of the most ambitious electricity reform programmes in history making impressive progress by international standards, transforming the sector into a key driver of longer-term economic prosperity (see case study 19). The Russian Federation unbundled and privatised its generation infrastructure USD 30 billion generation assets were unbundled and privatised from 2005), instituted incentive-based economic regulation, and established an investment obligation mechanism targeting new investment.

**Case Study 19: Power Sector Reform Experiences in Russia.** [198]

The wholesale energy market was fully liberalised in 2011 and covers much of European Russia, the Urals and Siberia. Since then most power has been sold and bought on a competitive basis through the central wholesale spot market. Energy prices generally reflected movements in underlying supply-demand fundamentals and short run marginal production costs driven largely by changes in upstream fuel costs. The Federal Antimonopoly Service provides independent objective and consistent supervision with incentive based economic regulation. Open access arrangements are in place for transmission and distribution networks. The Federal Grid Company has a major network development program that will improve regional power flows by 2020, but this is now informed by real detailed regional and grid exit point power flows, enabling solid projections of demand and a better basis for investment decisions.

Competition and innovation. Although Russia's very successful 2008 privatisation brought several new entrants, the government still has considerable scope to diversify ownership and wholesale competition through further divestment as well as virtual power auctions or similar mechanisms to sell rights to the output of publicly owned generators. It can also strengthen market integration and effective competition supervision. Russia's competitive wholesale spot market is one of the most successful components of the reform implemented to date.

Competitive retail markets are in an early phase of development in Russia. Although still concentrated in outmoded retail market structures, Russian policy makers have taken positive steps towards establishing the market rules and regulations needed to develop competitive and innovative retail markets. But much still depends on how effectively these rules and regulations are translated into commercial incentives and practical processes. While progress has been made to rebalance consumer tariffs since 2001, 10% of revenues are still subject to cross-subsidies concentrated in a relatively small part of total load. Residential tariffs still need to increase by 50-70% to address this.

Price reform remains essential for success. The Russian Federation has made considerable progress in rebalancing tariffs, but there is more to do, especially for regulated residential consumers. The presence of dominant 'Guaranteeing Suppliers' with local regulated residential consumers and universal supply obligation franchises remain an inherently unsustainable element. Price increases could be linked to growth in user capacity to pay while direct government welfare payments to regulated users should replace user-funded energy subsidies. At the same time, the government needs to keep pursuing supply-side reforms to help reduce the level of cost-reflective prices.

### 3.5.2 Opportunities and Prospects

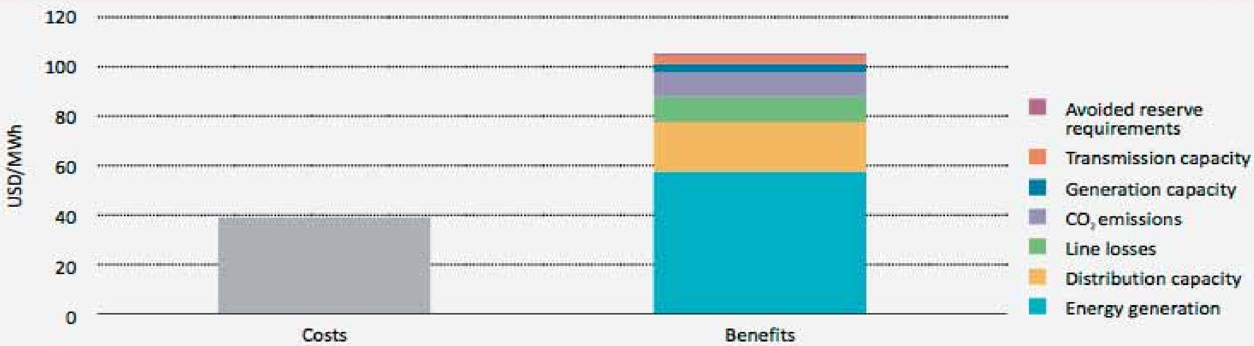
## Integrating consumer energy efficiency with supply side

North American utilities typically work in a regulated market context in which regulators oversee investments and operational performance including the performance of utility demand side management activities. Documents like the Californian Standard Practice Manual set out methods for evaluating the energy efficiency programme costs and both the energy and other benefits that accrue to consumers.

**Opportunity: Utility Benefits from Consumer Energy Efficiency.[199]**

Efficiency Vermont's energy efficiency programmes reduced energy demand by 110 GWh over a 10 year average measure life at a total cost of USD 33 million and at a levelised energy cost of 39 USD/MWh. The energy efficiency measures in turn provided measured benefits 2.4 times greater, over 104 USD/MWh, comprising: avoided generation costs worth 57 USD/MWh, avoided distribution costs of 20 USD/MWh, avoided lines losses of 10 USD/MWh, and avoided $CO_2$ of 9.4 USD/MWh at 20 USD/t$CO_2$. Figure 3.6 summarizes the multiple benefits in a chart.

**FIGURE 3.6:** *Power System Upstream Multiple Benefits.*




Note: Values are expressed as levellised USD/MWh.

Source: Efficiency Vermont (2012), *Annual Report 2010*, Efficiency Vermont, Burlington, www.efficiencyvermont.com/docs/about_efficiency_vermont/annual_reports/2010_Annual_Report.pdf.

## 3.6. Energy Resource Sustainability

Energy resource sustainability addresses a range of issues including the cleaner use of fossil fuel resources (extraction, production, generation, transmission, and consumption) and the increased use of renewable energy. All these have implications to other sectors and resources including water, food, and land use, among others so that nexus issues need to be considered.

As mentioned elsewhere in this report, energy and climate objectives are closely linked, and a summary of the climate commitments of UNECE countries submitted under the Paris Agreement is presented in this section.

### 3.6.1 Selected Issues and Country Responses

**Issue 1:** Commitments to Reduce Energy Sector Greenhouse Gas Emissions

$CO_2$ emissions from energy contributed 76% of total greenhouse gas emissions globally in 2010. In 2012, the UNECE region emitted 31.5% of global GHG emissions.[200] At 32.1 Gt of $CO_2$ emitted, global energy-related $CO_2$ emissions were static for a third straight year in 2016. The global economy grew 3.1% in this same year, signalling a medium term decoupling of emissions growth and economic activity. This decoupling resulted from switches from coal to natural gas, improvements in energy efficiency, structural changes in the global economy, and increasing renewable power generation.[201]

$CO_2$ emissions declined in the United States and China (the world's two-largest energy users and $CO_2$ emitters), offsetting increases in most of the rest of the world, and were stable in Europe. The biggest drop came from the United States, where $CO_2$ emissions fell 3%, or 160 Mt, while the economy grew by 1.6%. The decline was driven by a surge in shale gas supply and renewable power displacing coal. Emissions in the United States last year were at their lowest level since 1992, yet the economy has grown by 80% since then.[202]

Prior to COP21 in 2015, countries submitted their intended nationally determined contributions (INDCs) to define their voluntary contributions to mitigate climate change. These commitments are diverse, as they reflect local conditions and capabilities, and vary in scope, pledged pathway, conditionality, and additionality. Within the outcome document of COP21, the "Paris Agreement", countries agreed to reduce GHG emissions to those consistent with well below 2°C temperature rise. As of 22 August 2017, 165 INDCs[203] covering 192 parties (out of 197), and 155 parties have submitted their Nationally Determined Contributions (NDCs)[204] to the UNFCCC Convention. The NDCs represent 96% of the Parties to the Convention, including the European Union and its member countries as one regional entity.[205]

Within the UNECE region, as of 19 April 2017, all member States have submitted INDCs. Table 3.8 provides a simple overview of each member States' submission of (I)NDCs, the status of ratification, the reduction targets, and an analysis of energy key words.

**TABLE 3.8:** *(Intended) Nationally Determined Contributions ((I)NDCs) of UNECE Countries.*

| UNECE Member State | Date of Ratification | (I)NDC Submission* | Key word mentioned** | | | | Per Capita Emissions in 2015*** | Base-year | Reduction target (by year) |
|---|---|---|---|---|---|---|---|---|---|
| | | | Energy | Renewable energy | Energy efficiency | Energy Access | | | |
| Albania | 9/21/2016 | First NDCs | 1 | 0 | 0 | 0 | 1.53 | BAU | 11.5% (2030) |
| Andorra | 5/24/2017 | First NDCs | 1 | 0 | 0 | 0 | N/A | BAU | 37% (2021-2030) |
| Armenia | 3/23/2017 | First NDCs | 1 | 1 | 1 | 0 | 1.51 | 2010 | 633 million $tCO_{2eq}$ (2030) |
| Azerbaijan | 1/9/2017 | First NDCs | 1 | 1 | 1 | 1 | 3.36 | 1990 | 35% (2030) |
| Belarus | 9/21/2016 | First NDCs | 0 | 0 | 0 | 0 | 6.82 | 1990 | 28% (2021-2030) |
| Bosnia and Herzegovina | 3/16/2017 | First NDCs | 1 | 1 | 1 | 0 | 6.47 | 1990 | 3-23% (2030) |
| Canada | 10/5/2016 | Rev. Sub. 11/05/2017 | 1 | 1 | 1 | 0 | 15.45 | 2005 | 30% (2030) |
| European Union (EU) | **** | First NDCs (EU) | 1 | 0 | 1 | 0 | N/A | 1990 | 40% (2030) |
| Georgia | 5/8/2017 | First NDCs | 1 | 0 | 1 | 1 | 1.8 | 2013 | 15% (2021-2030) |
| Iceland | 9/21/2016 | First NDCs | 1 | 1 | 0 | 0 | 11.76 | 1990 | 40% (2030) |
| Israel | 11/22/2016 | First NDCs | 1 | 1 | 1 | 1 | 5.16 | 2005 | 26% (2016-2030) |
| Kazakhstan | 12/6/2016 | First NDCs | 1 | 1 | 1 | 1 | 15.2 | 1990 | 15-25% (2021-2030) |
| Kyrgyzstan | not yet ratified | INDCs | 1 | 0 | 0 | 0 | 1.19 | BAU | 11.49-13.75% (2020-2030) |
| Liechten-stein | not yet ratified | INDCs | 1 | 0 | 1 | 0 | N/A | 1990 | 40% (2021-2030) |
| Monaco | 10/24/2016 | First NDCs (EU) | 1 | 1 | 1 | 0 | N/A | 1990 | 50% (2021-2030) |
| Montenegro | not yet ratified | INDCs | 1 | 1 | 1 | 0 | 6.69***** | 1990 | 30% (2030) |
| Norway | 6/20/2016 | First NDCs | 1 | 1 | 0 | 0 | 8.27 | 1990 | 40% (2021-2030) |
| Republic of Moldova | 6/20/2017 | First NDCs | 1 | 1 | 1 | 1 | 1.86 | 1990 | 64-67% (2021-2030) |
| Russian Federation | not yet ratified | INDCs | 1 | 1 | 1 | 0 | 12.27 | 1990 | 25-30% (2020-2030) |
| San Marino | not yet ratified | INDCs | 1 | 1 | 1 | 0 | N/A | 2005 | 20% (2030) |
| Serbia | | INDCs | 0 | 0 | 0 | 0 | 6.69***** | 1990 | 9.8% (2021-2030) |
| Switzerland | not yet ratified | INDCs | 1 | 0 | 0 | 0 | 4.83 | 1990 | 50% (2021-2030) |
| Tajikistan | 3/22/2017 | First NDCs | 1 | 1 | 1 | 0 | 0.54 | 1990 | 65-70% (2021-2030) |
| FYR of Macedonia | not yet ratified | INDCs | 1 | 1 | 1 | 1 | 4.71 | BAU | 30% (2030) |
| Turkey | not yet ratified | INDCs | 1 | 1 | 1 | 1 | 4.54 | BAU | 21% (2021-2030) |
| Turkmenistan | 10/20/2016 | First NDCs | 1 | 1 | 1 | 0 | 17.54 | 2000 | 1.7 times less than 2000 level (2030) |
| Ukraine | 9/19/2016 | First NDCs | 1 | 1 | 1 | 0 | 5.1 | 1990 | >40% (2021-2030) |
| United States of America | 9/3/2016 ****** | First NDCs | 1 | 0 | 1 | 0 | 16.07 | 2005 | 26-28% (2020-2025) |
| Uzbekistan | not yet ratified | INDCs | 1 | 1 | 1 | 0 | 3.67 | 2010 | 10% (2020-2030) |

* *First INDC means the NDC is equal to the INDC submitted before COP21, but it has been ratified by the party.*
** *1= key word mentioned in (I)NDC)*
*** *Source: European Commission Joint Research Center (2016): $CO_2$ time series 1990-2015 per capita for world countries. In: Emission Database for Global Atmospheric Research. http://edgar.jrc.ec.europa.eu/overview.php?v=CO2ts_pc1990-2015*
**** *Dates of ratification vary depending on the Member States. As of July 2017 two EU Member States, Czech Republic and The Netherlands, have not yet ratified the Paris Agreement.*
***** *Data only available for Serbia and Montenegro together.*
****** *Withdrawal announced on 1 June 2017.*

From the (I)NDC submission by member States all except two countries (Belarus and Serbia) mention energy within their (I)NDC. Two thirds mention renewable energy, and almost three quarters emphasize energy efficiency. Energy access is only mentioned by a quarter of the (I)NDCs, reflecting the comparatively lower urgency of energy access within the UNECE region. In terms of emission reductions, the EU and its member states have already reduced their emission by 19% on 1990 levels while GDP has grown 44%. Per capita emissions have fallen from 12 $tCO_{2eq}$ in 1990 to 9 $tCO_{2eq}$ in 2012 and are projected to fall to around 6 $tCO_{2eq}$ in 2030 (see also case study 20).[206]

**Case Study 20: The European Union's Nationally Determined Contributions.**

The European Union and its 28 Member States are committed to a binding target of at least 40% absolute domestic reductions in GHG emissions by 2030 compared to 1990 base year. The NDC is to be fulfilled jointly, as set out in the conclusions by the European Council of October 2014. The NDC covers emissions from Energy, Industrial processes and product use, Agriculture, Waste, Land Use, Land-Use Change and Forestry (set out in Decision 529/2013/EU)

The target represents a significant progression beyond its current undertaking of a 20% emission reduction commitment by 2020 compared to 1990 (which includes the use of offsets). It is in line with the European Union objective, in the context of necessary reductions according to the IPCC by developed countries as a group, to reduce its emissions by 80-95% by 2050 compared to 1990. The NDC plans no contribution from international credits.[207]

According to Eurostat, in 2015, greenhouse gas emissions in the European Emission, including emissions from international aviation and indirect CO2 emissions, were down by 22.1 % compared with 1990 levels. The European Union is thus expected to exceed its Europe 2020 target of reducing GHG emissions by 20 % by 2020.[208]

The Paris Agreement is a success that nearly all countries submitted (I)NDCs based on the concept of "common but differentiated responsibilities", as defined by UNFCCC.[209] Since their submission, a range of analysis papers have been published to assess if (I)NDCS are sufficient to limit global warming to 2°C, or even 1.5°C. Results indicate that the combined mitigation actions in country submissions would only limit global warming to between 2.5 and 2.8°C (compared to current policies projections of 3.3 to 3.9°C).[210] The analyses conclude that greater efforts are required by the global community to achieve the stated objectives. This conclusion is particularly true for the UNECE region with high emitting countries and sub-regions, particularly North America and Western and Central Europe, which needs to be reflected in future sustainable energy strategies.

Climate Action Tracker analysed if selected countries can achieve the commitments announced in their (I) NDCs.[211] For example, it is expected that Canada, under its current policies, will miss its 2030 NDC target to reduce GHG emissions by 30% below 2005 levels in 2030 by a wide margin. However, the implementation of a national mandatory carbon-pricing plan that was announced in 2016, would represent a major step towards policies that could change this adverse outlook. With its current policies, the European Union is expected to come close in range of meeting its target of reducing emissions by 40% below 1990 levels by 2030. However, as mentioned above, this will not be sufficient to limiting warming to below 2°C. From the eastern part of the UNECE Region, Kazakhstan is recognized for its plans to transit into a greener future, though currently its implemented policies are not yet sufficient to meet its INDC target to reduce GHG emissions by 15% below 1990 levels by 2030.

## Issue 3: Management of Methane Emissions from Fossil Fuel Extractive Industries

Methane emissions are a serious climate problem as their greenhouse warming potential is 28-84 times greater than the greenhouse warming potential of $CO_2$.[212] Methane also represents a significant safety risk as it easily forms explosive mixtures with air. The corollary of this risk is that if methane can be managed and captured it becomes a high quality fuel resource and safety is improved.

Energy sector non-$CO_2$ emissions are the second largest source of non-$CO_2$ emissions, accounting for approximately 25% of non-$CO_2$ emissions in both 1990 and 2005. Emissions from the energy sector increased 14% between 1990 and 2005 (from about 2,500 to 2,800 $MtCO_{2eq}$), driven by a 21% increase in emissions from natural gas and oil systems, which represented the largest part of emission sources, accounting for 55% of energy-related emissions. The next largest emissions source in this sector were coal mining activities, accounting for 19% of energy related emissions in that year. From 2005 to 2030, energy sector emissions are projected to increase 42% (to about 4,000 $MtCO_{2eq}$). It is estimated that around 8% of total worldwide natural gas production is lost annually to venting, leakage and flaring, resulting in substantial economic and environmental costs. The Russian Federation alone represents 19% of world's oil and gas methane emissions in 2015.[213]

The Global Methane Initiative (GMI) maintains a database of country Coal Bed Methane (CBM) and Coal Mine Methane (CMM) information. The United States Environmental Protection Agency (EPA) currently lists over 200 coal methane management projects.[214] Of this list 143 projects are in UNECE member countries, achieving over 5,401 million ton carbon dioxide equivalent ($MtCO_{2eq}$) reduction in 2014. Where data exists, these are summarised for UNECE countries in table 3.9.

**TABLE 3.9:** *Coal Bed Methane (CBM), Coal Mine Methane (CMM) and Mine Methane Reduction Projects in the UNECE Region.*

| Country | Estimated CBM resource | CMM emissions, in Million cubic meter ($Mm^3$)/year | GHG emissions, in $MtCO_{2eq}$ in 2010 | No. of Projects | Project types and scale |
|---|---|---|---|---|---|
| **Belgium** | | | | 1 | Hydrocarbon permit "Hainaut" covering 443 $km^2$ for exploration of CBM/CMM |
| **Bulgaria** | 195 billion cubic meter ($Bnm^3$) | 101 $Mm^3$ 2010 | | | NA |
| **Canada** | >5 Trillion cubic meter ($Tnm^3$) | 66 $Mm^3$ 2010 | | | NA |
| **Czech Republic** | | | | 21 | 23 megawatt electric (MWe) of CHP.<br>200+ km pipeline network using CMM (~77 million m3/year) and AMM (32 million m3/year) Interconnected system amongst many mines. AMM %$CH_4$=~75; CMM %$CH_4$=50-55. Recovery by OKD DBP started in 1997. |
| **European Union** | | | | | NA |
| **France** | 28 $Bnm^3$ | Gazonor 72 $Mm^3$<br><br>Lons le Saunier 83 $Mm^3$ | | 3 | Gazonor. Abandoned mine methane used as diluting fuel for boilers and in an ash dryer. Operating at least since 2005, also Fuel for coke oven. Operating at least since 2005,<br>Pipeline injection into Gaz de France network. |
| **Georgia** | 11 $Bnm^3$ | 0.25 $Mm^3$ | | | NA |
| **Germany** | 3 $Tnm^3$ | 195 $Mm^3$ | | 37 | 113 MWe CHP projects totalling over 406 $MtCO_{2eq}$ reduction in 2014 |
| **Hungary** | >150 $Bnm^3$ | 1.4 $Mm^3$ | | | NA |
| **Italy** | | 1.4 $Mm^3$ | | | NA |
| **Kazakhstan** | >650 $Bnm^3$ | 995 $Mm^3$ | | 1 | 25 $Mm^3$ $CH_4$ utilised. 1.4 MWe CHP project at Lenina Mine 21.5 $MtCO_{2eq}$ reduction in 2014 |
| **Poland** | 425 $Bnm^3$<br>- 1.4 $Bnm^3$ | 482 $Mm^3$ | | 15 | CHP projects totalling over 105 $MtCO_2e$ reduction in 2014 from over 210 $Mm^3$/year methane gas. |
| **Romania** | | 191 $Mm^3$ | | 2 | 6-10 MW Caras-Severin CHP and 35 MW thermal Lupeni Mine. |
| **Russian Federation** | 48-80 $Tnm^3$ | 3,424 $Mm^3$ | 51 $MtCO_{2eq}$ Coal<br>418 $MtCO_{2eq}$ Oil and Gas | 9 | Over 13 MW CHP projects totalling over 324 $MtCO_{2eq}$ reduction in 2014 |
| **Slovakia** | | | | 2 | Hornonitrianske Mines Bohumin 2 and 3. 2 x 1.2 MW CHP from over 2.4 $Mm^3$/year methane gas. |
| **Spain** | | 46 $Mm^3$ | | | NA |
| **Turkey** | 3 $Tnm^3$ | 135 $Mm^3$ | | | NA |
| **Ukraine** | 1.7 $Tnm^3$ | 1,325 $Mm^3$ | 31 $MtCO_{2eq}$ | 22 | Diverse flaring, thermal and extraction processes incl. 83 MW generation totalling over 1734 $MtCO_{2eq}$ reduction in 2014 |
| **Uzbekistan** | | | 107 $MtCO_{2eq}$ Oil and Gas | | NA |
| **UK** | 2.45 $Tnm^3$ | 191 $Mm^3$ | | 46 | Over 115 MW CHP projects totalling over 543 $MtCO_{2eq}$ reduction in 2014 |
| **USA** | 495 $Bnm^3$ | 5,318 $Mm^3$ 2013 | 78 $MtCO_{2eq}$ Coal.<br>313 $MtCO_{2eq}$ Oil and Gas. | 35 | NA |

*Sources: United States EPA (2016); GMI (2017); United States EPA (2017).*

It should be noted that data sets on methane in both the Coal and Oil & Gas sectors are incomplete and different analyses offer different values for CBM and CMM.

Technologies for detecting and quantifying methane emissions, as well as standard national/regional methods for reporting them are available.[215] However, their implementation is not always harmonised and in some cases it may be too complicated to make comparisons of the data.[216]

With changing commitments following COP21, all data sets and projections need to be reviewed and updated in light of the current policies. However two conclusions can be drawn: (1) the scale of Coal Bed Methane in UNECE is vast, exceeding 12Tnm$^3$, and (2) CMB and CMM offers, if properly managed, an access to abundant valuable resources and provide an opportunity for easily obtainable emission reductions. Case study 21 provides insight on Coal Seam Methane Recovery in Poland and Ukraine

### Case Study 21: Coal Seam Methane Recovery: Examples from Poland and Ukraine.

Poland[217]: 24% of mine methane is currently being captured by methane management systems in Poland. Nevertheless, 110 million m$^3$ of methane was still vented to the atmosphere in 2014. Methane utilization has dropped slightly from 68% in 2013 to 66% in 2014.

With 930 Mm$^3$/year methane bearing capacity, and 338 Mm$^3$/year methane drainage, a potential 680 million m$^3$ VAM (including 110Mm$^3$ that is ready to manage Since 2010 there has been support for electricity produced from high efficiency cogeneration Primary Energy Saving> 10%).

Ukraine[218]: In 2015, 35Mt of coal was mined in Ukraine (less than half the 2014 antebellum levels) with 562Mm$^3$ per year of coal mine methane, of which 404Mm$^3$ are extracted with ventilation and 28% or 158Mm$^3$ by outgassing. In 2015 methane capture was undertaken in 2 mines.

## Issue 3: The Energy - Water - Land Nexus

Energy has significant connections to agriculture, water, and climate. The process of extracting and processing natural energy resources, the subsequent generation of power, and transmission and distribution via grids and pipelines has a significant impact on a variety of other economic and environmental processes and activities. These connections offer an opportunity for synergies to increase sustainability, but they could negatively affect competing sectors. Water captured for a hydropower dam may not be available for irrigation downstream and could impact river ecosystems. Warm water discharge from thermal power plants impacts fisheries and wildlife. The production of biofuels may lead to land competition for food production, binds water resources and leads to mono-cultures. On the other hand, agriculture is an energy-intense sector, with 4% of global electricity and 50mtoe of energy currently being used in irrigation pumping and desalination.[219] Over the next 25 years, the amount of energy used in the water sector will more than double, mostly because of desalination projects that will account for 20% of water-related electricity demand by 2040. Large-scale water transfer projects and increasing demand for wastewater treatment also contribute to the water sector's rising energy needs.

The connections and synergies between sectors are described as a nexus. A nexus offers opportunities to minimize resource input and waste, emission, and energy leakage by narrowing material and energy loops.[220] The energy-water-agriculture nexus is highly relevant for the energy sector. Trans-boundary water basins represent a particular governance challenge – there are over 270 trans-boundary river basins in the world, covering approximately 60% of the globe's freshwater flow and roughly 40% of the population.[221] Additionally, there are an estimated 600 aquifers that are shared by two or more nations.[222] How a river or aquifer is managed or used in one location can drastically affect other locations further up or downstream. Case study 22 on the Drina Basin, covering six UNECE countries, including Bosnia and Herzegovina, Montenegro, and Serbia, provides an analysis on the energy-food-water nexus and its challenges and opportunities for more sustainable resource management.

### Case Study 22: Drina River Basin Energy-Water-Food Nexus Solutions Assessment.[223]

The Drina River, located in the Western Balkans and shared by Bosnia and Herzegovina, Montenegro and Serbia, is the main tributary of the Sava River, and groundwater represents the main source of water supply for communities in the basin. Surface water resources also support significant power generation (both hydropower and thermal power) that is key for the energy security of the three countries and also produces revenues from exports.

A participatory assessment of the intersectoral links, trade-offs and benefits in the water-food-energy-ecosystems nexus involving the energy, agriculture, water and environmental authorities of the three countries and other key stakeholders was carried out under the Convention on the Protection and Use of Transboundary Watercourses and International Lakes. The interactions of energy with other sectors, relevant for resource management, were jointly identified. Selected examples for each group of interlinkages are given below to illustrate possible solutions related to policy or technical measures, also determined in the process.

**Water-Energy** *(selected)*

- *Interlinkages*: Water needed for hydro- and thermal-power production, altered river flow due to uncoordinated hydropower operations, pumped storage playing a key role in integrating RE in the grid.
- *Solutions*: Harmonize legislation related to water resources use for energy generation (i.e. regulate the practice of hydropeaking, pumped storage, implementation of feed-in tariffs for the promotion of non-hydro renewables, legislation on concessions in order to overcome investments barriers) and to permitting of hydropower projects and utilities; Utilize the potential of non-hydro RE to reduce dependence on coal and on water resources from the basin.

**Food/Land-Energy**

- *Interlinkages*: Potential new land use for non-hydro RE (solar and wind); Potential for biofuels in the region.
- *Solutions*: Implement/continue implementing land consolidation policies (making larger clusters, swapping, farm cooperatives), restoring unutilised land; Develop practice in SE or sustainability impact assessment in land use planning.

**Ecosystems-Energy**

- *Interlinkages*: Potential for installation of small scale renewables in the agricultural and eco-touristic sectors; Potential for biomass production associated to the wood industry.
- *Solutions*: Promote the use of renewable energies in eco-tourism (for instance, solar on rooftop of buildings), especially in remote areas.

**Energy-Food/Land**

- *Interlinkages*: Ecosystems compromised by expansion of small hydropower (also in protected areas).
- *Solutions*: Transboundary collaboration on gathering and sharing information on the status of biodiversity, development and enforcement of common regulations (including those related to the siting of small hydropower facilities), and the establishment of transboundary protected areas (notably the Tara-Drina).

The assessment demonstrates various potential benefits from cooperation, to countries and utilities from potential increases in electricity production (e.g. by optimising water release regimes), but also at the regional level through increased energy trade and integration, and energy security.

A related modelling exercise shows that cooperative operation of hydropower dams could deliver more than 600 GWh of electricity over the 2017-2030 period. Setting aside 30% of the dam capacity for flood control would have a cost, through a change in the energy mix, of about 4% of the operational cost of the whole electricity system in the three countries. Pressure on hydropower generation could be reduced by increasing energy efficiency – by as much as 4.1 TWh in the combined Drina Basin – and would also deliver significant reductions in GHG emissions (from 38 Mt in 2017 to about 28 Mt in 2030) representing about 21% of the combined emissions of the three countries in 2015.

### 3.6.2 Opportunities and Prospects

#### Increasing international cooperation to increase ambitions to reduce greenhouse gas emissions

If countries do not act faster in the period to 2030 they will be obliged to make much greater reduction efforts in the period after 2025 to hold the temperature rise below 2°C above pre-industrial levels.[224]

Currently policies for sustainable energy tend to work in a disaggregated way. Separate energy efficiency, renewable energy and climate policies are led by different operational agencies. There is a need to integrate GHG mitigation potentials with the potentials for energy efficiency and renewable energy to develop a clearer understanding of the trade-offs and economically optimal investment paths available to countries in the UNECE region.

#### Exploring technology options to decarbonize fossil fuel based power generation

If the world is to constrain $CO_2$ emissions to levels consistent with a less than 2°C rise in global temperatures, then Carbon Capture and Storage (CCS) will need to contribute about one-sixth of needed $CO_2$ emission reductions in 2050, and 14 per cent of the cumulative emissions reductions between 2015 and 2050 compared to a business-as-usual approach. It is the only technology option other than energy efficiency and shifting the primary energy mix to lower carbon fuels that can deliver net emissions reductions at the required scale. The IPCC's AR5 Synthesis Report estimated that without CCS the cost of climate mitigation would increase by 138%.

Global $CO_2$ storage levels of at least one billion tonnes per year by 2030 need to be in place, and more thereafter. Delivering such an outcome will require collective commitment by governments and industry alike to fund CCS demonstration projects and development efforts in power and industrial applications at levels commensurate with the required abatement outcomes. Ensuring the availability of CCS will require regulatory and legislative support at all levels of government and international cooperation at project level so the necessary financing can be unlocked.

In order to facilitate this transition, UNECE developed Recommendations on CCS and on carbon capture, utilisation and storage (CCUS), which were submitted to UNFCCC before the COP20 in Lima and were well received.

**Opportunity: How carbon capture and storage in cleaner electricity production and through enhanced oil recovery could be used in reducing greenhouse gas emissions.[225]**

The UNECE Group of Experts on Cleaner Electricity Production from Fossil Fuels Coal Mine Methane (CMM) prepared recommendations for how CCS and CCS for Enhanced Oil Recovery (EOR) should be treated in a Post-Kyoto Protocol Agreement. After the approval of the recommendations by the UNECE Committee on Sustainable Energy, they were transmitted to the UNFCCC in 2014. The recommendations covert the following items:

- Policies on CCS/CCUS should have parity with other no carbon/low carbon technology regarding their climate mitigation potential, commensurate with the state of technological and infrastructure development.
- Governments should consider a broad array of fiscal instruments to encourage CCS/CCUS until carbon is properly and adequately priced. Capturing and storing $CO_2$ from all industrial sectors will be essential to reach climate goals. CCS/CCUS deployment will accelerate if governments work together to financially sponsor demonstration projects.
- Developed countries should be encouraged to invest in CCS/CCUS in developing countries.
- CCS developments need to be monitored and tracked globally so best practice guidance on CCS can be developed and disseminated.

## Improved methane management in coal, oil and gas sector

According to the EPA, coal mining accounted for 8% of total global anthropogenic methane emissions in 2010, and these emissions are projected to increase by 33% to 784 million metric tons of carbon dioxide equivalent (Mt $CO_{2eq}$) by 2030. The global abatement potential is projected to be 50 to 468 $tCO_{2eq}$, or 6 to 60% of baseline emissions, in 2030. The cost-effective abatement potential (USD 0 break-even price) is 77.7 $tCO_{2eq}$, or 10% of baseline.

The technological maximum potential (USD 100 + break-even price) is 467.6 $tCO_{2eq}$, or 60% of baseline.

The technological maximum for emissions reduction potential in oil and gas is 1,219 million metric tons of carbon dioxide equivalent ($MtCO_{2eq}$), approximately 58% of projected emissions in 2030. Because of the energy value of the methane captured, EPA estimates that 747 $MtCO_{2eq}$, or 40% of the baseline emissions, can be cost-effectively reduced. Over 26% of total abatement potential is achieved by adopting abatement measures in the oil and gas production segments.[226]

Significant programmes to reduce the flaring of associated gas from oil extraction founded the global natural gas industry during the 1970s. Recovered coal seam methane can be used as a fuel and extraction methods for methane for coal, oil and gas extraction processes are mature; options to recover methane from coal seams include:

- Coal Bed Methane processes extract methane from un-mined coal seams. The coal seams may still be mined in the future but this is largely dependent upon geological factors, such as coal depth and quality;
- Coal Mine Methane processes extract methane during mining activities as the coal is in the process of being extracted and thus emitting significant quantities of the gas;
- Abandoned Mine Methane processes recover methane from mines that have been closed as significant amounts of methane may remain trapped in the mine or may continue to be emitted from openings.

There is significant scope to transform fugitive methane emissions into useful energy resources while mitigating methane GHG. Many countries have coal seam methane management regimes in place. The United States Environmental Protection's (US EPA) modelling outlines global marginal abatement cost curves for methane management but there is no up to date comprehensive evaluation of the potential for methane management programs and their capabilities yet.

The extensive switching of power production from coal to gas and solar in the United States highlights the role that methane resources could play in the energy transition. The increasing utilization of gas has raised the issue of fugitive emissions of methane from both conventional and shale gas production.

Taking into account revised estimates for fugitive methane emissions, recent lifecycle assessments indicate that specific GHG emissions are reduced by one half (on a per-kWh basis) when shifting from the current world-average coal fired power plant to a modern natural gas combined-cycle (NGCC) power plant.[227] This reduction is the result of the lower carbon content of natural gas (15.3 grams of carbon per megajoule (gC/MJ) compared to, e.g., 26.2 gC/MJ for sub-bituminous coal) and the higher efficiency of combined-cycle power plants.[228]

The priority for methane management is to monitor and record emissions accurately using the best monitoring and measurement technology and to assess the best solutions to minimize leaks and emissions. More efficient and effective methane management will offer direct economic benefits which include: decreasing negative health impacts, increasing workers' safety and reducing global warming. However, more work is needed to demonstrate how methane options can advance the energy transition.

Recent progress in fracking technique, and methane management, Degasification and Ventilation Air Methane

(VAM), alter the economics of gas and unconventional oil extraction, and the scope for methane application to power generation suggest the potentials of methane management need to be revisited.[229]

In this context the UNECE Secretariat in consultation with the secretariats of the International Gas Union, the World Coal Association and the World Petroleum Council and other industry experts, has prepared and executed a survey on techniques and measures currently undertaken to measure, report, and verify (MRV) methane emissions in extractive industries. The data obtained from the survey shows that very few entities operating in the extractive industries do not monitor their gas emissions. Similarly, only few do not report the results, as such reporting is oftentimes mandated by law. However, the underlying reason for monitoring are diverse. While the primary purpose was "environment" and "law" for the oil and the gas industries, stakeholder forum the coal industry singled out "safety" as the main reason. More than half of all industries distinguish between methane and other hydrocarbon gases during the monitoring. In terms of continuity of measurements, results vary for sectors. 50% of coal mines measure continuously, as the gas in the mine is released into the working environment. For oil and gas (mid- and downstream), about a third of the companies measure continuously. Only the coal sector has a standardized approach on the control of $CH_4$ emissions. Responses to question #17 (image 10) indicate that methods for $CH_4$ emissions monitoring typically ARE mandated by law for global coal industry and are NOT for the other industrial sectors covered by the survey. Monitoring measures are not standardized across entities and sectors.[230] With a vast resource of coal bed methane and scope to increase The United Nations Economic Commission for Europe (UNECE) Committee on Sustainable Energy recommended that work be done to agree on common philosophies, standards, and technology for monitoring, recording, and reporting methane emissions at each stage of production, processing, storage, transmission, distribution, and use of fossil fuels, whether coal, oil, or natural gas, recognizing at the same time that case by case adaptation to specific situations might be necessary. Additionally, it was agreed there is a need to mitigate methane emissions, including identifying appropriate mechanisms for mobilizing needed resources, and to fund a detailed study on a common basis across the entire UNECE region. In response, the Committee requested that work be undertaken to assess baseline, benchmarking and scale of current methane emissions in the extractive industries, with the aim of giving clear guidance to practitioners and policy-makers.

### Opportunity: Best Practice Guidance for Effective Methane Drainage and Use in Coal Mines.[231]

The UNECE Group of Experts on Coal Mine Methane (CMM) has released the second edition of the Best Practice Guidance for Effective Methane Drainage and Use in Coal Mines. Since the first edition was published in 2010, the industry practice and regulations have evolved, and the second edition captures the most critical developments. The second edition also includes additional case studies that illustrate the application of the best practices in coalmines worldwide. The principles-based second edition of Best Practice Guidance does not replace national or international laws and regulations. Rather, it complements them through a holistic approach to safer and more effective methane management practices.

## Realizing synergies in the Energy-Water-Land Nexus

Understanding the social, economic and environmental diversity and potentials is at the heart of solutions for eco-systems with energy-water–land use nexus challenges. Often the solution lies in better understanding the diversity of needs in the region around the eco-system and the breadth of benefits that can be drawn from the ecosystem. Communities can then find ways to enable that diversity of outcomes from better management of the nexus relationships and dependencies in the eco-system.

To identify opportunities for increase resource sustainability while limiting negative impacts on connected sectors, a range of tools and approaches have been developed in the past. Tools like strategic environmental assessment (SEA) enable new insights into inter-sectoral synergies to address the trade-offs and externalities in resource utilisation and trans-boundary issues. Besides facilitating potential inter-sectoral conflicts (e.g. likely impacts resulting from hydropower development on water resources or agriculture soil in downstream sections), SEA also provides an opportunity for a wide range of stakeholders (environmental and health authorities, businesses, public) to provide their feedback on proposed development in a given sector or area. Thus, efficient application of SEA can streamline development and implementation of specific projects by addressing issues that are difficult to grasp at the project level (especially large-scale and cumulative effects); and by providing an early warning on problems to be solved when designing the projects and carrying out relevant permitting procedure including EIA. This in turn expands the scope of economic sustainable energy potentials and maximises system resilience by opening up multiple options for resources, rather than singular reliance on traditional resources and technology. Countries and regional communities can extract more value from a wider and more sustainable range of resource options, increase economic trade in resources, to improve system sustainability and resilience.

Several tools and approaches have been developed to assess intersectoral links and dynamics including energy at different scales and for different purposes, and could be considered for detailing a scoping level assessment of the kind applied in the river basins referred to in Box "Good Practices and Policies for Inter-Sectoral Synergies to Develop Renewable Energy: Opportunities in hydropower more sustainable". These include: (1) dialogues; (2) mapping; (3) scenarios; (4) extended systems analysis; and (5) institutional analysis.[232] Several more detailed nexus analysis tools and efforts focus on accounting for the inputs and outputs of resources when delivering services, indicating where and how resources are linked, as well as how those linkages will compound direct and indirect demands. Each have an explicit focus on water, energy and land-use activities and how those are linked, and the most appropriate one can be selected depending on the purpose of the analysis.[233]

An example of an integrated resource assessment tool is the INOGATE RESMAP Geospatial mapping for sustainable energy investment project, presented in below box. While this tool currently covers only Georgia. Armenia, Azerbaijan, Moldova, it highlights the scope for a richer understanding of options to fully deliver GHG reductions and SDG objectives and the scope of energy, industrial processes and product use, agriculture, waste, land use, land-use change and forestry options that need to be understood and managed to deliver SDG objectives in full.

## Opportunity: Geospatial Mapping for Sustainable Energy.[234]

The INOGATE RESMAP online geospatial mapping platform demonstrates the value at stake from wind and solar investment to stakeholders in Georgia, Armenia, Azerbaijan and Moldova. It enables assessment of the theoretical, ecological and economically viable wind and solar energy resource maps, using highly granular data (at least 10km square resolution). Infrastructure and constraint maps on a web-based 'GeoExplorer' map enable labelling, zoom, measurement functions, scroll down boxes and relevant information tools. This enables stakeholders (investors, policy makers, equipment suppliers) the location, amount (MW and GWh/year) and Net Present Value of the economically viable wind and solar resource available in their country, at different combinations of capital cost, investment discount rate and power purchase tariff, thereby determining the value at stake. Mapping existing reference projects, wind and solar resource will assist dialogue between policy makers, investors and other stakeholders and a better optimisation of resources constraints and objectives.

A series of policies and technology already exist that can help reduce water and energy demand, and ease potential chokepoints in the water-energy nexus. These include integrating energy and water policymaking, co-locating energy and water infrastructure, utilising the energy embedded in wastewater, using alternative sources of water for energy and improving the efficiency of both sectors.

The box below presents suggested solutions for policy and technology options and cooperation opportunities based on the results of transboundary river basin energy-water-land nexus analysis from the Balkans (the Sava and its tributary the Drina), the Caucasus (the Alazani/Ganykh) and Central Asia (the Syr Darya).

## Opportunity: Good Practices and Policies for Inter-Sectoral Synergies to Develop Renewable Energy: Opportunities in making hydropower more sustainable.[235]

Renewable energy can play a strong role in helping to achieve better management of resources within the water-energy-food-ecosystems nexus. The nexus approach itself presents an opportunity to strengthen the actions aimed at achieving the SDGs.

So far, four nexus assessments have been completed in the Alazani/Ganikh (Azerbaijan, Georgia), Sava (Bosnia and Herzegovina, Croatia, Montenegro, Serbia, and Slovenia), Syr Darya (Kazakhstan, Kyrgyzstan, Tajikistan, Uzbekistan7), and Drina Basins (Bosnia and Herzegovina, Montenegro and Serbia).

The assessments provide the input to develop policy recommendations, including measures that could facilitate renewable energy deployment, which is more sustainable and accounts for the nexus trade-offs between the energy, water and food sectors and the ecosystems. The nexus assessments demonstrate that depending on the context, diverse solutions to externalities from hydropower development and making renewable energy more sustainable can be identified, ranging from technical measures to information and governance. Some selected examples about such solutions are given below (with a focus on energy sector measures):

The Sava and Drina River Basins - Develop hydropower sustainably and integrate other renewable energies; coordinate operation of hydropower plants (for flood control, for energy system benefits, ensuring environmental flow); and development of new capacities ideally with a basin-wide strategy, taking into account the trade-offs with other water uses and the environment;

The Alazani/Ganykh River Basin - Facilitate access to modern energy sources and energy trade; minimize impacts from new hydropower development; apply catchment management to control erosion to limit impacts on infrastructure;

The Syr Darya River Basin - Promote restoring the regional grid and vitalizing energy market; improve efficiency in energy generation, transmission and use; improve efficiency in water use (especially in agriculture).

The basin cases show that through regional and transboundary cooperation in both the energy sector and in water management – across sectors – negative intersectoral and environmental impacts can be reduced and synergic beneficial actions have more impact.

# IV. Conclusions and Recommendations

## Identifying sub-regional challenges in the UNECE region

Attainment of the objectives of SDG 7 is falling short in the UNECE region. Many good examples exist, but overall countries need to accelerate efforts in order to achieve all three pillars of SDG 7: energy access, energy efficiency and renewable energy.

While many of the energy challenges in the region are similar to those elsewhere in the world, the region has specific climatic, economic, environmental and political circumstances and the implications are found in inefficient use of energy, power cuts, increasing energy costs, and unsustainable and unaffordable heating in winter.

Moving beyond the UNECE regional level, sub-regional analysis provides useful insights behind the aggregated UNECE results. Although the region as a whole has tremendous untapped potential for all forms of renewable energy, so far renewable energy sources contribute only 11% of TFC. While this share and the underlying progress rate is insufficient to achieve the global target of 18% renewable energy share in 2030, Southeast Europe has achieved the 2030 target already (26%). This is mirrored by sub-regions at the lower end of the spectrum, including the Russian Federation (3.5%), Eastern Europe (5.2%), and Caucasus, and Central Asia (7.4%).

Looking deeper into the sub-regions with low renewable energy shares, in 2015, 17 UNECE member States from these sub-regions only received USD 400 million investments. This represents only about 0.2% of the global total investment in renewable energy technologies, a decrease from 0.5% in 2014. An absence of new investments is noticeable in the Caucasus, Central Asia, and Southeast Europe.

Regarding energy efficiency results, the UNECE CAGR energy intensity of -2.0% for 2012-2014 differs significantly on sub-regional level. North America improved its energy intensity from 5.9 to 5.8 MJ/USD, at a rate of -0.5% per year (CAGR). Southeast Europe's energy intensity declined from 5.0 to 4.6 MJ/USD, at a -4.5% CAGR. The sub-region Caucasus, Central Asia, Eastern Europe and the Russian Federation shows the highest energy intensity rate with 7.2 MJ/USD (−3.8% CAGR). Compared with the required CAGR of -2.6% to achieve the 2030 target, different progress rates on sub-regional level need to be considered when planning how to address the gaps towards the 2030 Agenda.

Although the region has achieved universal household electrification in terms of physical access, ageing infrastructure, a lack of supply diversity and increasing tariffs lead to poor power quality and, for some, energy poverty. This situation is particularly acute during the cold winter months of the Northern hemisphere, and disproportionately affects poor and rural populations. As a result, some consumers have reverted to local sources of solid fuels for cooking and heating, and others to electricity with off-grid diesel generators.

At present, some countries export large quantities of fossil fuels as part of their economic model and feature some of the world's highest levels of energy intensity. The number of countries and the number of people whose national incomes and livelihood depend on fossil energy is important and will remain so over the outlook period. Many countries struggle to provide reliable and affordable energy for their own citizens. Numerous market barriers, often linked to subsidised energy prices, impede the introduction of new, efficient energy technology. Lack of access to basic energy services and frequent disruption of power supply are of particular concern in the Caucasus and Central Asia.

Many of the same countries have high carbon footprints due to a legacy of high energy intensity and high energy inefficiency in industry and buildings. Energy losses from old infrastructure and dilapidated networks are significant. Carbon intensity has remained flat.

## Conclusions

Collaborating on the 2017 GTF and its regional interpretation with internationally respected partners and the other four Regional Commissions has been an extraordinary opportunity for UNECE to gain insights into regional concerns and reflect on progress of SDG 7 implementation in more detail. This report seeks to raise awareness about a number of issues, notably the extraordinary potential that the UNECE region offers with regards to energy efficiency and renewable energy development and deployment. It will be very useful for subsequent activities of UNECE and its partners, serving as a baseline.

From mere tracking progress on SDG 7, this report is has turned into a step towards tracking progress beyond SDG 7. It has become evident that the current approach would benefit from refinements. Relevant indicators should reflect a holistic approach and address the challenges that countries face as systems become more complex and needs more urgent. Taking demand for energy services as the basis of such an approach, a broader set of indicators naturally emerges.

Work is just beginning. UNECE is committed to driving sustainable energy systems further and would like to work with regional partners to shed further light on successful and replicable case studies and business models that can lift barriers and will inspire others to follow.

The report would benefit from more extensive consultation with countries. This requires more time and resources to exchange views with experts in countries, most often in national languages or with interpretation. Rather than embarking quickly on another GTF process, benefit might derive from a further analysis of all existing findings and data and their interpretation and a careful consultation process with countries to develop a set of needs in the context of quality of life.

## Recommendations

There is no common view in the UNECE region of what sustainable energy is or how to attain it. Apart from the global challenges of the Agenda 2030 and addressing climate change, countries in the UNECE have divergent economic development, resource availability and energy mixes embedded in today's national energy strategies. Each country sets its national energy strategy based on its unique perspectives on sustainable development, environmental protection, poverty alleviation, climate change mitigation, quality of life, and the like. As a consequence, multiple national approaches and outcomes can be found. Tracking progress towards sustainable energy forms an important basis for the further development of strategies and policies. Based on this report, the following recommendations to improve progress tracking initiatives emerge:

- Current indicators derive from the existing data gathering and reporting infrastructure that have emerged from the energy system of the past. In order to inform policies to accelerate the transition to an energy system that can support sustainable development, it will be necessary to develop appropriate indicators adapted to the system of the future, adapt data gathering systems, and build the required capacities to collect, analyse, track and report new data and indicators. At a minimum, new indicators should embrace the nexus areas with water, food, and climate, track investments in clean energy and enlarge the chosen energy indicators to include other forms of energy. For energy, it is critical to think in terms of a wholly interconnected, complex system, in which supply, demand, conversion, transport/transmission interact freely and flexibly. This perspective applies within regions, subregions but also between regions and economic sectors.

- Indicators to track energy for sustainable development beyond those for SDG 7 show that increased efforts are required throughout the energy system. Attaining the objectives of the 2030 Agenda will require full engagement of the private sector to transform energy. As a consequence, it is essential to monitor progress on energy for sustainable development in ways that reflect the cross-cutting interconnections among the SDGs and that involve the private sector in more integrated ways.

- While the costs of renewable energy may be falling, the cost of integrating intermittent sources of energy into the grid is not. The challenge goes beyond financing investments and involves approaching a sustainable energy mix from a different angle and applying broad thinking to a net zero-carbon energy system. Every technology has an important role to play in the future energy system over the medium term, not only energy efficiency and renewable energy, but also advanced fossil technology and carbon capture, use and storage. Choices must be economically and socially rational for each country and be made in the broader context of an economy as a whole. The integration should consider quality of life and not just access to energy.

- Growing awareness and interest in renewable energy resources has highlighted a need to normalize the way in which renewable energy potential is classified, reported and managed. A shared framework to evaluate energy resources could also provide a foundation for investors, regulators and governments to implement renewable energy projects.

- Work needs to continue to reinforce investment appetite in key countries in the region in renewable energy. A number of platforms and tools exist to bring the financial sector in contact with technology providers and policy makers. There is equally great potential in the transformation of large industrial complexes. In the UNECE region, there are a number of such complexes, where mining, power generation, metallurgy, manufacturing and shipping facilities are integrated into dense, interrelated businesses. Value might derive from developing replicable and transformation business models, seeking the expertise on a variety of innovative technology and policy aspects. This way, energy efficiency and renewable energy aspects can be integrated into the clean-up of existing fossil structures and thus can contribute to the development of large innovation-led, socially and environmentally responsible projects.

- As noted elsewhere in this report, the UNECE membership is highly diverse. Dividing the UNECE countries in seven sub-regions proves useful to identify sub-regional challenges and progress made so far, while considering national contexts with neighbouring countries.

Additional sub-regional reports analysing progress and experiences more deeply and in a targeted manner could supplement global and regional GTF reports and provide an implementable action agenda to countries.

## Limitations and outlook

Key limitations of this report include the availability of comparable, verified and current data from all countries within the timeframe of the report, not only for the agreed SDG 7 indicators, but also as a basis to broaden the set of indicators to track energy for sustainable development.

The data gathering and reporting infrastructure that exists today has emerged and evolved over many years, and changes and improvements to this system require extensive consultation, adaptation, and capacity development support, which are ongoing, but will take more time to realize in practice. Tracking important pillars such as the carbon intensity of energy, per capita carbon emissions, are difficult across the region due to missing data or differences in reporting approaches.

This report has suggested a number of new paradigms for indicators for the future, whether related to quality of service or holistic systems analysis. There is merit in considering what indicators would point to a future in which energy for sustainable development is assured. Once a concise set of indicators has been identified, it will be necessary to establish data gathering infrastructure to ensure that data are available to populate a new set of indicators credibly.

The energy industry has succeeded in raising quality of life around the world, most notably in the advanced economies, but access and affordability remain challenges. New approaches from a services perspective will allow those without access to energy to leapfrog existing technology and systems and benefit from innovation and falling technology costs. Changing the energy industry to a service configuration involves changing a utility's (or service provider's) business model to one of maximizing the margins between the revenues received for services provided (for example, indoor comfort or mobility) and the costs of providing the services (through, for example, efficiency investments). Realizing the potential will require careful reconsideration of and readiness to revisit the existing regulatory, policy, technical, and organizational infrastructure of energy.

# Acronyms and Abbreviations

| | |
|---|---|
| **AR5** | IPCC Fifth Assessment Report |
| **BECCS** | Bioenergy Carbon, Capture and Storage |
| **CAGR** | Compound annual growth rate |
| **CBM** | Coal Bed Methane |
| **CCS** | Carbon, Capture and Storage |
| **CEO** | Chief Executive Officer |
| **$CH_4$** | Methane |
| **CHP** | Combined Heat and Power |
| **CIS** | Commonwealth of Independent States |
| **CMM** | Coal Mine Methane |
| **$CO_2$** | Carbon Dioxide |
| **$CO_{2eq}$** | Carbon Dioxide equivalent |
| **CSE** | UNECE Committee on Sustainable Energy |
| **DOE** | United States Department of Energy |
| **ECA** | Economic Commission for Africa |
| **ECLAC** | Economic Commission for Latin America and the Caribbean |
| **EIA** | United States Energy Information Administration |
| **ESCAP** | Economic and Social Commission for Asia and the Pacific |
| **ESCWA** | Economic and Social Commission for West Asia |
| **EU** | European Union |
| **EUR** | Euro |
| **FiT** | Feed-in Tariff |
| **GFEI** | Global Fuel Economy Initiative |
| **GHG** | Greenhouse gas |
| **GDP** | Gross Domestic Product |
| **GMI** | Global Methane Initiative |
| **GTF** | Global Tracking Framework |
| **HFC** | Hydrofluorocarbons |
| **ICP** | Investor Confidence Programme |
| **ICT** | Information and communications technology |
| **IEA** | International Energy Agency |
| **INDC** | Intended Nationally Determined Contribution |
| **IDR** | In-depth Review |
| **IPCC** | Intergovernmental Panel on Climate Change |

| | |
|---|---|
| **IRENA** | International Renewable Energy Agency |
| **LCOE** | Levelised cost of electricity |
| **LDV** | Light Duty Vehicle |
| **LNG** | Liquefied Natural Gas |
| **MEPS** | Minimum Energy Performance Standard |
| **$N_2O$** | Nitrous Oxide |
| **NDC** | Nationally Determined Contribution |
| **NEEAP** | National Energy Efficiency Action Plans |
| **NGCC** | Natural gas combined-cycle |
| **NREL** | National Renewable Energy Laboratory |
| **NZE** | Near Zero Energy |
| **PEEREA** | Protocol on Energy Efficiency and Related Environmental Aspects |
| **PFC** | Perfluorocarbons |
| **PPP** | Power purchasing parity |
| **PV** | Photovoltaics |
| **RC** | Regional Commission |
| **REN21** | Renewable Energy Policy Network for the 21st Century |
| **SDG** | Sustainable Development Goal |
| **SEforALL** | Sustainable Energy for All |
| **SEA** | Strategic environmental assessment |
| **F6** | Sulfurhexafluoride |
| **TFC** | Total final energy consumption |
| **TPES** | Total primary energy supply |
| **TSO** | Transmission System Operator |
| **UN** | United Nations |
| **UNDP** | United Nations Development Programme |
| **UNECE** | United Nations Economic Commission for Europe |
| **UNEP** | United Nations Environment Programme |
| **UNFC** | United Nations Framework Classification |
| **UNFCCC** | United Nations Framework Convention on Climate Change |
| **UNIDO** | United Nations Industrial Development Organisation |
| **USD** | United States Dollar |
| **US AID** | United States Agency for International Development Aid |
| **US EPA** | United States Environmental Protection Agency |
| **VAM** | Ventilation Air Methane |
| **VRE** | Variable Renewable Energy |
| **WB** | World Bank |
| **WHO** | World Health Organisation |

# Units of Measurement

| | |
|---|---|
| **°C** | Degree Celsius |
| **bbl** | Barrel |
| **bcm** | Billion cubic metres |
| **Bn** | Billion |
| **$Bnm^3$** | Billion cubic meters |
| **EJ** | Exajoules (One exajoule equals one quintillion (1018) joules) |
| **gC** | Grams of carbon |
| **Gt** | Gita tons |
| **GW** | Gigawatt |
| **GWh** | Gigawatt-hour (equals 1 million kilowatt-hours) |
| **kWh** | Kilowatt-hour |
| **kWp** | Kilowatt-peak |
| **$m^3$** | Cubic meters |
| **MJ** | Megajoules (One megajoule equals one million (106) joules) |
| **$Mm^3$** | Million cubic meters |
| **Mt** | Million tons |
| **$MtCO_{2eq}$** | Million tons carbon dioxide equivalent |
| **mtoe** | Million tons oil equivalent |
| **MW** | Megawatt |
| **MWe** | Megawatt electric |
| **MWh** | Megawatt hour |
| **PJ** | Petajoules (One petajoule equals one quadrillion (1015) joules) |
| **t** | Tons |
| **TJ** | Terajoules (One terajoule equals one trillion (1012) joules) |
| **Tn** | Trillion |
| **$Tnm^3$** | Trillion cubic meters |
| **TWh** | Terawatt hour (equals 1 billion kilowatt-hours) |

# Glossary

**Compound Annual Growth Rate (CAGR), in %**

CAGR of primary/final energy intensity between two years. Represents the average annual growth rate during the period. Negative values represent improvements in energy intensity (less energy is used to produce one unit of economic output), while positive numbers indicate declining energy intensity (more energy is used to produce one unit of economic output).

**Energy Intensity, in MJ/2011 PPP USD**

Primary energy intensity is used as a proxy indicator for energy efficiency. It is calculated as the ratio of TPES to GDP measured at PPP in constant 2011 USD (MJ/2011 PPP USD): Energy intensity is an indication of how much energy is used to produce one unit of economic output. Lower ratio indicates that less energy is used to produce one unit of output (GTF 2017 definition).

**Gross Domestic Product (GDP), in 2011 PPP USD**

GDP (in 2011 PPP USD) is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. GDP is measured at purchasing power parity at constant 2011 USD (GTF 2017 definition).

**Kilowatt Peak (kWp)**

Kilowatt peak stands for peak power. This value specifies the output power achieved by a solar module under full solar radiation (under set Standard Test Conditions). Solar radiation of 1,000 watts per square meter is used to define standard conditions. Peak power is also referred to as "nominal power" by most manufacturers. Since it is based on measurements under optimum conditions, the peak power is not the same as the power under actual radiation conditions. In practice, this will be approximately 15-20% lower due to the considerable heating of the solar cells. Source: SMA Solar Technology AG (2011).

**Levelized Cost of Electricity (LCOE), in USD-Cents/kWh**

Levelized cost of electricity (LCOE) represents the kilowatt-hour cost of building and operating a power generation plant over an assumed financial life and duty cycle (Solar Mango definition).

**Own Production, as ratio +/-1**

Dividing the total primary energy supply of a country by its energy production gives an indication on the level of self-sufficiency (or dependency) of a country (IEA Energy Atlas definition).

**Total Energy Production**

Production is the production of primary energy, i.e. hard coal, lignite, peat, crude oil, NGL, natural gas, combustible renewable energy and waste, nuclear, hydro, geothermal, and solar and the heat from heat pumps that is extracted from the ambient environment. Production is calculated after removal of impurities (e.g. sulphur from natural gas) (IEA definition).

**Total Final Energy Consumption (TFC), in Mtoe**

Sum of energy consumption by the different end-use sectors, excluding non-energy uses of fuels. TFC is broken down into energy demand in the following sectors: industry, transport, residential, services, agriculture, and others. It excludes international marine and aviation bunkers, except at world level where it is included in the transport sector (IEA definition)

**Total Primary Energy Supply (TPES), in Mtoe**

TPES is made up of: Production + Imports - Exports - International marine bunkers - International aviation bunkers +/- Stock changes (IEA definition).

**Renewable Energy**

Total Renewable Energy includes modern and traditional energy. Traditional energy stands for solid biomass when consumed in the residential sector in non-Organisation for Economic Cooperation and Development (OECD) countries. It includes the following categories in International Energy Agency (IEA) statistics: primary solid biomass, charcoal and non-specified primary biomass and waste. Modern Energy includes all types of technology including solar, wind, biomass, geothermal, hydro, liquid biofuels, biogas, marine, and renewable wastes (GTF 2017 definition).

# Annexes

## Annex I. Overview: Socio-Economic Data for UNECE member States

**TABLE A.1:** *UNECE Country Populations, Population Density, and GDP per Capita in 2015.*

| Countries | Population (million) | Population Density (people per sq. km of land area) | GDP/Capita, PPP (current USD) |
|---|---|---|---|
| **North America** | | | |
| **Canada** | 35 | 3.9 | 43,248 |
| **United States** | 321 | 35 | 56,115 |
| **Southeast Europe** | | | |
| **Albania** | 2.9 | 105 | 3,945 |
| **Bosnia and Herzegovina** | 3.8 | 74 | 4,249 |
| **Bulgaria** | 7.2 | 66 | 6,993 |
| **Croatia** | 4.2 | 75 | 11,535 |
| **Montenegro** | 0.62 | 46 | 6,406 |
| **Romania** | 19.8 | 86 | 8,972 |
| **Serbia** | 7.0 | 81 | 5,235 |
| **FYR of Macedonia** | 2.1 | 82 | 4,852 |
| **Caucasus** | | | |
| **Armenia** | 3.0 | 105 | 3,489 |
| **Azerbaijan** | 9.6 | 116 | 5,496 |
| **Georgia** | 3.7 | 64 | 3,795 |
| **Central Asia** | | | |
| **Kazakhstan** | 17.5 | 6.5 | 10,509 |
| **Kyrgyzstan** | 5.9 | 31 | 1,103 |
| **Tajikistan** | 8.5 | 61 | 926 |
| **Turkey*** | 78 | 102 | 9,125 |
| **Turkmenistan** | 5.4 | 11 | 6,672 |
| **Uzbekistan** | 31 | 73 | 2,132 |
| **Eastern Europe** | | | |
| **Belarus** | 9.5 | 47 | 5,740 |
| **Israel*** | 8.4 | 387 | 35,728 |
| **Moldova** | 3.6 | 124 | 1,848 |
| **Ukraine** | 45.2 | 78 | 2,115 |
| **Russian Federation** | 144 | 8.8 | 9,092 |

| Countries | Population (million) | Population Density (people per sq. km of land area) | GDP/Capita, PPP (current USD) |
|---|---|---|---|
| **Western and Central Europe** | | | |
| **Andorra** | 0.07 | 150 | N/A |
| **Austria** | 8.6 | 105 | 43,774 |
| **Belgium** | 11.3 | 371 | 40,324 |
| **Cyprus** | 1.16 | 126 | 23,242 |
| **Czech Republic** | 10.5 | 136 | 17,548 |
| **Denmark** | 5.7 | 134 | 51,989 |
| **Estonia** | 1.3 | 31 | 17,118 |
| **Finland** | 5.5 | 18 | 42,311 |
| **France** | 66.8 | 122 | 36,205 |
| **Germany** | 81.4 | 234 | 41,313 |
| **Greece** | 10.8 | 84 | 18,002 |
| **Hungary** | 9.8 | 108 | 12,363 |
| **Iceland** | 0.33 | 3.3 | 50,173 |
| **Ireland** | 4.6 | 67 | 61,133 |
| **Italy** | 60.8 | 206 | 29,957 |
| **Latvia** | 1.9 | 32 | 13,648 |
| **Liechtenstein** | 0.037 | 234 | 74,950 |
| **Lithuania** | 2.91 | 46 | 14,147 |
| **Luxembourg** | 0.57 | 219 | 101,449 |
| **Malta** | 0.43 | 1349 | 22,596 |
| **Monaco** | 0.037 | 18,865 | N/A |
| **Netherlands** | 16.9 | 503 | 44,299 |
| **Norway** | 5.2 | 14 | 74,400 |
| **Poland** | 38 | 124 | 12,554 |
| **Portugal** | 10.3 | 113 | 19,222 |
| **San Marino** | 0.03 | 530 | n/a |
| **Slovak Republic** | 5.4 | 113 | 16,088 |
| **Slovenia** | 2.1 | 102 | 20,726 |
| **Spain** | 46.4 | 92 | 25,831 |
| **Sweden** | 9.8 | 24 | 50,579 |
| **Switzerland** | 8.3 | 209 | 80,945 |
| **United Kingdom** | 65 | 269 | 43,875 |
| **UNECE Total** | **1,318** | | |

*Note: In order to integrate Israel and Turkey in sub-country cluster analysis, Israel was assigned to Eastern European cluster, and Turkey to the Central Asian cluster. This clustering and assignment do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations concerning the legal status of any country, territory, city or area, or of its authorities, or concerning the delimitation of its frontiers or boundaries. In particular, the boundaries shown on the maps do not imply official endorsement or acceptance by the United Nations.*

*Source: World Bank (2017c).*

# Annex II. UNECE member States' TPES, TPES / Capita and Own Production in 2014

**TABLE A.2:** *UNECE National TPES, TPES per Capita, and Own Production in 2014.*

| Member State | TPES PJ in 2014 | TPES in MJ/Capita 2014 | Own Production Index* |
|---|---|---|---|
| **North America** | **104,505** | **7.04** | **0.99** |
| Canada | 11,718 | 7.87 | 1.68 |
| United States | 92,787 | 6.94 | 0.91 |
| **Southeast Europe** | **3,543** | **1.76** | **0.73** |
| Albania | 97 | 0.80 | 0.86 |
| Bosnia and Herzegovina | 327 | 2.05 | 0.77 |
| Bulgaria | 749 | 2.48 | 0.63 |
| Croatia | 336 | 1.90 | 0.54 |
| Montenegro | 400 | 1.54 | 0.72 |
| Romania | 1,326 | 1.59 | 0.83 |
| Serbia | 555 | 1.86 | 0.71 |
| FYR of Macedonia | 109 | 1.26 | 0.48 |
| **Caucasus** | **907** | **1.27** | **2.81** |
| Armenia | 123 | 0.98 | 0.29 |
| Azerbaijan | 599 | 1.50 | 4.10 |
| Georgia | 183 | 0.98 | 0.31 |
| **Central Asia** | **11,523** | **1.91** | **1.21** |
| Kazakhstan | 3,209 | 4.43 | 2.17 |
| Kyrgyzstan | 158 | 0.65 | 0.50 |
| Tajikistan | 117 | 0.34 | 0.64 |
| Turkey* | 5,088 | 1.59 | 0.26 |
| Turkmenistan | 1,119 | 5.04 | 2.92 |
| Uzbekistan | 1,828 | 1.42 | 1.23 |
| **Eastern Europe** | **6,675** | **2.39** | **0.55** |
| Belarus | 1,161 | 2.93 | 0.13 |
| Israel* | 950 | 2.76 | 0.33 |
| Republic of Moldova | 138 | 0.93 | 0.10 |
| Ukraine | 4,424 | 2.33 | 0.73 |
| **Russian Federation** | **29,763** | **4.94** | **1.84** |
| **Western and Central Europe** | **65,607** | **3.19** | **0.60** |
| Andorra | N/A | N/A | N/A |

| Member State | TPES PJ in 2014 | TPES in MJ/Capita 2014 | Own Production Index* |
|---|---|---|---|
| Austria | 1,346 | 3.77 | 0.37 |
| Belgium | 2,209 | 4.73 | 0.38 |
| Cyprus | 82601 | 2.29 | 0.06 |
| Czech Republic | 1,725 | 3.91 | 0.71 |
| Denmark | 678 | 2.87 | 0.99 |
| Estonia | 252 | 4.57 | 0.97 |
| Finland | 1,420 | 6.21 | 0.54 |
| France | 10,158 | 3.67 | 0.57 |
| Germany | 12,814 | 3.78 | 0.39 |
| Greece | 968 | 2.12 | 0.38 |
| Hungary | 956 | 2.31 | 0.44 |
| Iceland | 245 | 17.8 | 0.89 |
| Ireland | 534 | 2.76 | 0.16 |
| Italy | 6,145 | 2.41 | 0.25 |
| Latvia | 181 | 2.185 | 0.55 |
| Liechtenstein | N/A | N/A | N/A |
| Lithuania | 293 | 2.39 | 0.25 |
| Luxembourg | 159 | 6.82 | 0.04 |
| Malta | 32 | 1.80 | 0.02 |
| Monaco | N/A | N/A | N/A |
| Netherlands | 3,054 | 4.33 | 0.80 |
| Norway | 1,203 | 5.59 | 6.83 |
| Poland | 3,936 | 2.44 | 0.72 |
| Portugal | 885 | 2.03 | 0.28 |
| San Marino | N/A | N/A | N/A |
| Slovak Republic | 667 | 2.94 | 0.41 |
| Slovenia | 279 | 3.24 | 0.56 |
| Spain | 4,796 | 2.46 | 0.31 |
| Sweden | 2,016 | 4.96 | 0.72 |
| Switzerland | 1,049 | 3.06 | 0.53 |
| United Kingdom | 7,511 | 2.78 | 0.60 |
| **UNECE Total** | **222,525** | **4.46** | **0.99** |
| **World** | **573,555** | **1.89** | **1** |

*Note: The "own production index" is the same as IEA's "self-sufficiency index". Dividing the TPES of a country by its own energy production gives an indication of a country's energy balance. TPES is the sum of production and imports less exports and stock change. A value above 1 indicates a net exporter, below 1 means a net importer.*

*Source: IEA World Energy Balances.*

# Annex III. Energy for Sustainable Development Indicators and GTF Methodology

## History and Methodology: SDG 7 (SEforALL) indicators used for the Global GTF Report

The methodology applied for the Global GTF Report can be found at http://gtf.esmap.org/methodology

## Beyond SDG 7 Indicators: Information needs and challenges for Sustainable Development

The energy systems structure used in this report is intended to complement the GTF SE4ALL reporting framework and extend from it to offer a structured set of insights into the challenges and opportunities to improving the sustainability, societal wellbeing, economic and environmental implications of energy systems in UNECE member countries. The content provided in this report goes beyond the SDG 7 indicators in order to provide perspectives beyond aggregate framework indicators. The ability to do this depends on the quality and competence of underlying data systems.

### Methodological issues

In many countries a number of agencies collect energy, activity and related social and environmental data.

Regional and global assessment like this report rely on the data gathering and management processes operated by a number of key agencies that have developed leading capabilities and relationships that enable consistency in data definitions, quality management, data warehousing and publication. The 'data specialisations' are recognized, and also characterized by cooperation and data validation across the data managing agencies: World Bank and OECD economic activity data; UN population and human activity data; WHO health and wellbeing data; IEA energy data. While individual countries, and agencies specializing on one or another aspect of global activities also publish data, their perspectives and data validation processes tend to occur within a limited perspective of the global data managers.

### Data differences

Differences in data derive from three main areas:

- Data frameworks and definitional differences.
- Data sources with different perspectives.
- Accounting misalignments.

Consistent data standards IEA Stats, UN data definitions etc.: Where differences in data occur this is always an opportunity to explore the cause and nature of underlying differences in data systems.

### Missing data

The data gathering and reporting infrastructure that exists today has emerged and evolved over many years. This report has suggested a number of new paradigms for indicators for the future, whether related to quality of service or holistic systems analysis. There would be merit in considering what indicators would point to a future in which energy for sustainable development is assured. Once a concise set of indicators has been identified, it will be necessary to establish data gathering infrastructure to ensure that data are available to populate a new set of indicators credibly.

# Annex IV. Draft List of Indicators to Track Energy for Sustainable Development

**TABLE A.3:** *: Draft List of Indicators and Areas for Possible Indicators to Measure Energy for Sustainable Development to Achieve th 2030 Agenda.*

| Pillars | Suggested Indicators (or areas for indicator formulation) |
|---|---|
| **Energy** | |
| **Energy Access** | • **7.1.1 Proportion of Population with Primary Reliance on Clean Cooking Fuels and Technology***<br>• **7.1.2 Proportion of Population with Access to Electricity***<br>• **Affordability, expressed as share of household income spent on energy****<br>Suggested areas to formulate additional indicators:<br>• **Reliability and quality of electricity access****<br>  ◦ Number of hours of access to electricity per day (outage rates)<br>  ◦ Technical quality (frequency, voltage)<br>  ◦ Number of turnoffs by type of consumer<br>  ◦ Number of households with access to main grid<br>  ◦ Time required to fix disruptions<br>  ◦ Number of households with generators<br>  ◦ Loss of GDP through interrupted supply (VOLL)<br>  ◦ Transmission losses<br>• **Energy Poverty, encompassing access to and quality of heating and cooling**** |
| **Renewable Energy** | • **7.2.1 Renewable Energy Share in Total Final Energy Consumption (TFC)***<br>• **Share of modern / traditional renewable energy in TFC****<br>• **Share of renewable energy in Total Primary Energy Supply (TPES)****<br>• **Additions of renewable energy installed capacity****<br>• **Investments in renewable energy****<br>• Share of renewable energy in bus-bar energy (e.g. post combustion but pre transmission & distribution losses)<br>• Installed reliable renewable energy capacity per capita<br>• Renewable energy by type of output (electricity, liquids, heat)<br>• Ratio of renewable energy (capacity, production/consumption) to total electricity (capacity, production/consumption)<br>• Share of renewable energy expressed in terms of Total Primary Energy Requirements (i.e., taking into account the actual non-renewable primary energy required to provide the same final RE).<br>• Number of people with access to RE<br>• Terms of access of renewable producers to networks<br>• Share of renewable energy in installed reliable capacity (versus generation)<br>• Cost of producing 1kWh from solar PV / wind /other renewable energy (under consideration of distribution Losses with a view towards improving the network)<br>• Installed energy storage (batteries (including EV's), pumped storage, phase change materials, other technologies) |

| Pillars | Suggested Indicators (or areas for indicator formulation) |
|---|---|
| **Energy** | |
| **Energy Efficiency** | ● **7.3.1 Energy Intensity Measured in Terms of TPES to GDP (MJ/USD)***<br>● **Energy Productivity Measured in Terms of GDP to TPES (USD/MJ)****<br>● **Supply side efficiency in electricity generation****<br>● Ratio of TFC to GDP (MJ/USD)<br>● Compound annual growth rate, or CAGR of TFC as well as of TPES<br>● Transmission losses<br>● Ratio of TPES to TFC net of imports and exports<br>● For SDG indicator 7.a.1: Replace "USD invested in energy efficiency" with "USD invested divided by energy saved over the life of the investment"<br>● Price elasticities of energy demand and supply<br>● Spend by governments on energy efficiency (through grants, concessionary finance etc.).<br>**Sector-specific Indicators (industry, transport, buildings) required disaggregated data**<br>● Energy use in buildings (kWh per $m^2$ of used space)<br>● Efficiency measured as the amount of energy needed to provide demanded energy services<br>**Sector-specific Physical Energy Intensity Indicators**<br>● Specific energy consumption defined as the amount of energy to produce a tonne of steel |
| **Other Energy Sources** | ● **Share of fossil fuel in TPES****<br>● **Efficiency of fossil fuels in generation****<br>● Methane emissions along the value chain<br>● Share of nuclear in TPES<br>● Cost comparison of unsubsidized renewable energy with unsubsidized fossil<br>● Bringing it all together, Fuel Mix in TPES; Fuel mix in Electric Generating Capacity; TFC by end-use |

**NEXUS**

| | |
|---|---|
| **Climate** | ● **$CO_2$ emissions from fossil fuel combustion (total and per capita) per TPES and per TFC****<br>● **GHG emissions of energy sector**** |
| **Water** | ● Clean water treatment (sanitation, desalination volumes and efficiency, . . .)<br>● Water resource depletion (aquifer), intermittent energy supply<br>● Fracking and water use, chemical pollutions<br>● Water cooling systems in the energy world (evaporation losses, thermal losses through cooling)<br>● Transfer of water (system to system, transboundary), hydro, agriculture<br>● Impacts of large hydro development<br>● International water resource management<br>● Thermal pollution in rivers / impact of water cooling systems in energy generation |
| **Land** | ● Land intensity of renewable energy (wind, solar, biomass)<br>● Deforestation caused by use of traditional biomass<br>**Suggested areas to formulate additional indicators:**<br>● Land management in cities<br>● International land management |
| **Food** | ● Food waste for biofuels / compost<br>● Fertilizer production<br>● Energy embodied in food exports / imports |

| Pillars | Suggested Indicators (or areas for indicator formulation) |
|---|---|
| **Energy** | |
| Environment | • Energy use per passenger miles<br>**Suggested areas to formulate additional indicators:**<br>• Air quality / health / exposure; Health impacts of household air pollution<br>• Waste as resource: Recycling; waste to energy |
| Socio-Economic | • Energy poverty / affordability: household money spent on energy<br>**Suggested areas to formulate additional indicators:**<br>• Quality of building codes (does it cover humidity, indoor air quality)<br>• Embodied energy in materials and structures (cement, steel, use)<br>• Economic value added of energy exports (benefits in the receiving country)<br>• Corruption index associated for PPP energy<br>• Number of hours spent by households gathering fuelwood |

* *SDG7 indicator / indicator used in global 2017 GTF.*

** *Recommended indicator to be used to track Energy for Sustainable Development within the 2030 Agenda for Sustainable Development.*

*All remaining: Suggestions made (1) in the context of a workshop "Tracking Progress on Energy for Sustainable Development: Data and Indicators", held in Astana on 14 June 2017, as part of the Eighth Forum on Energy for Sustainable Development; (2) by expert reviser, partly based on E. Worrell et al. (1997): Energy intensity in the iron and steel industry: a comparison of physical and economic indicators. In: Energy Policy, Vol. 25, 1997; (3) as part of the preparatory work to develop a Policy Brief "Indicators and Data for Energy for Sustainable Development" as input paper for the High-Level Political Forum 2018.*

**TABLE A.4:** *Potential Indicators within Different Elements of the Energy System.*

| System Element | Insights | Potential Indicators |
|---|---|---|
| **Consumer service quality** | There is a need to move beyond simple notions of 'access' and 'energy poverty' to real metrics for end use service quality, entitlement and access in households and businesses, while accommodating diversity in resources, expectations and needs. Importantly how these contribute to SDG outcome goals. | Systematic tracking of:<br>1. Achieved end-use service quality against basic welfare norms.<br>2. Affordability of end use service quality (the cost of the service attained rather than the unit price of energy) |
| **End-use efficiency** | There is a need to move beyond naïve energy intensity to real energy efficiency indicators, with a concatenated structure of indicators that also highlight structure and activity within households and businesses. | Systematic tracking of:<br>1. Changes in household size, occupancy, and efficiency of key end use applications in households.<br>2. Changes in economic structure, end use efficiency and value added in industry and commerce.<br>3. Changes in modal and vehicle structure, activity and end use efficiency in transport. |
| **Distributed cost-reflective utilities** | There is a need to identify how utilities can better incentivise consumer demand responsiveness and end-use efficiency as T&D utilities shift from being energy distributors to become capacity managers of diverse central and distributed energy producers. | Systematic tracking of:<br>1. Changes in the actual performance of central supply systems, distributed and end-use renewable energy, within competent life cycle analytical frameworks. |
| **Supply system innovation and sustainability** | There is a need to understand how supply side policies and practices can evolve a more sustainable and economically efficient supply system. | Systematic tracking of:<br>1. Changes in supply system value and performance within competent life cycle analytical frameworks. |
| **Resource sustainability** | There is a need to understand how diversifying the resource mix, economic trade, and managing environmental nexus impacts can enable a more resilient and sustainable energy system. | Systematic tracking of:<br>1. Metrics for separate and integrated resource (energy water, land, and air) system resilience.<br>2. Changes in resource (energy water, land, and air) system value and performance within competent life cycle analytical frameworks.<br>3. Metrics for nexus dynamics. |

# Annex V. Overview: Status of Renewable Energy Policies in UNECE member States.

**TABLE A.5:** *Overview to Renewable Energy Support Measures in UNECE Countries.*

| | Renewable Energy Targets (national and sub-national) | | | Regulatory Policies (national and sub-national level) | | | | | | | Fiscal Incentives and Public Financing (national and sub-national level) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Renewable Energy Share in Primary Energy | Renewable Energy Share in Final Energy | Renewable Energy share in Electricity Generation | FiT / Premium Payment | Electric Utility quota | Net Metering | Transport obligations (biofuels) | Heat obligations | Tradable RE Certificates | Auctioning | Investment / Production tax credit | Tax Reductions | Energy Production Payment | Public loangs, investments, R&D |
| **Southeast Europe** | | | | | | | | | | | | | | |
| **Albania** | 18% (2020) | 38% (2020) | N/A | 1 | 1 | | 1 | | 1 | | 1 | 1 | 1 | |
| **Bosnia and Herzegovina** | 20% (2016) | 40% (2020) | N/A | 1 | | | 1 | | | 1 | | | | |
| **Bulgaria** | N/A | 16% (2020) | 20.6% (2020) | 1 | | | 1 | | | | | | | 1 |
| **Croatia** | N/A | 20% (2020) | 39% (2020) | 1 | | | 1 | | | | | | | 1 |
| **FYR of Macedonia** | N/A | 28% (2020) | 24.7% (2020) | 1 | | | | | | | | | | 1 |
| **Montenegro** | N/A | 33% (2020) | 51.4% (2020) | 1 | | | | | | | | | | |
| **Romania** | N/A | 24% (2020) | 43% (2020) | | 1 | | 1 | | 1 | | | | | 1 |
| **Serbia** | N/A | 27% (2020) | 37% (2020) | 1 | | | | | | | | | | 1 |
| **SUM** | 2 | 8 | 6 | 7 | 2 | 0 | 5 | 0 | 2 | 1 | 1 | 1 | 1 | 5 |
| **%** | 25% | 100% | 75% | 88% | 25% | 0% | 63% | 0% | 25% | 13% | 13% | 13% | 13% | 63% |
| **Caucasus** | | | | | | | | | | | | | | |
| **Armenia** | 21% (2020); 26% (2025) | N/A | 40% (2020) | 1 | | 1 | | | | | | | 1 | 1 |
| **Azerbaijan** | N/A | 9.7% (2020) | 20% (2020) | | | | | | | | | | 1 | 1 |
| **Georgia** | N/A | N/A | N/A | 1 | | 1 | | | | 1 | | | 1 | 1 |
| **SUM** | 1 | 2 | 2 | 2 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 3 | 3 |
| **%** | 33% | 67% | 67% | 67% | 0% | 67% | 0% | 0% | 0% | 33% | 0% | 0% | 100% | 100% |
| **Central Asia and Turkey** | | | | | | | | | | | | | | |
| **Kazakhstan** | N/A | N/A | 3% (2020); 50% (2030) | 1 | | | | | | 1 | | | | 1 |
| **Kyrgyzstan** | N/A | N/A | N/A | 1 | | | | | 1 | | 1 | 1 | 1 | 1 |
| **Tajikistan** | N/A | N/A | 10% (N/A) | | | | | | 1 | | 1 | | 1 | 1 |
| **Turkey** | N/A | N/A | 30% (2023) | 1 | | | 1 | | | 1 | | | | 1 |

| | Renewable Energy Targets (national and sub-national) | | | Regulatory Policies (national and sub-national level) | | | | | | | Fiscal Incentives and Public Financing (national and sub-national level) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Renewable Energy Share in Primary Energy | Renewable Energy Share in Final Energy | Renewable Energy share in Electricity Generation | FiT / Premium Payment | Electric Utility quota | Net Metering | Transport obligations (biofuels) | Heat obligations | Tradable RE Certificates | Auctioning | Investment / Production tax credit | Tax Reductions | Energy Production Payment | Public loangs, investments, R&D |
| **Turkmenistan** | N/A | N/A | N/A | | | | | | | | | | | |
| **Uzbekistan** | N/A | 16% (2030); 19% (2050) | N/A | | | | | | | | | | | |
| **SUM** | 0 | 1 | 3 | 3 | 0 | 0 | 1 | 0 | 2 | 2 | 2 | 1 | 2 | 4 |
| | 0% | 17% | 50% | 50% | 0% | 0% | 17% | 0% | 33% | 33% | 33% | 17% | 33% | 67% |
| **Eastern Europe** | | | | | | | | | | | | | | |
| **Belarus** | N/A | 28% (2015); 32% (2050) | N/A | 1 | 1 | | 1 | | 1 | | | | 1 | |
| **Israel** | N/A | 13% (2025); 17% (2030) | 10% (2020); 17% (2030) | 1 | | | 1 | 1 | 1 | 1 | | 1 | | 1 |
| **Moldova** | 20% (2020) | 17% (2020) | 10% (2020) | 1 | | | | | | | | 1 | | 1 |
| **Ukraine** | 18% (2030) | 11% (2020) | 11% (2020); 20% (2030) | 1 | | 1 | | | | | | 1 | 1 | 1 |
| **SUM** | 2 | 4 | 3 | 4 | 1 | 1 | 2 | 1 | 2 | 1 | 0 | 3 | 2 | 3 |
| | 50% | 100% | 75% | 100% | 25% | 25% | 50% | 25% | 50% | 25% | 0% | 75% | 50% | 75% |
| **Western and Central Europe** | | | | | | | | | | | | | | |
| **Andorra** | N/A | N/A | N/A | 1 | | | | | | | | | 1 | |
| **Austria** | N/A | 45% (2020) | 70.6% (2020) | 1 | | | 1 | | 1 | | 1 | | | 1 |
| **Belgium** | 9.7% (2020) | 20% (2020) | 20.9% (2020) | | 1 | 1 | 1 | | 1 | 1 | 1 | 1 | | 1 |
| **Cyprus** | N/A | 13% (2020) | 16% (2020) | 1 | | 1 | 1 | | | | | | | 1 |
| **Czech Republic** | N/A | 13.5% (2020) | 14.3% (2020) | 1 | | | 1 | | 1 | 1 | 1 | 1 | | 1 |
| **Denmark** | N/A | 35% (2020); 100% (2050) | 50% (2020); 100% (2050) | 1 | | 1 | 1 | | 1 | 1 | 1 | 1 | | 1 |
| **Estonia** | N/A | 25% (2020) | 17.6% (2020) | 1 | | | 1 | | | | | | 1 | 1 |
| **Finland** | N/A | 38% (2020); 40% (2025) | 33% (2020) | 1 | | | 1 | | 1 | | | 1 | 1 | 1 |

| | Renewable Energy Targets (national and sub-national) | | | Regulatory Policies (national and sub-national level) | | | | | | | Fiscal Incentives and Public Financing (national and sub-national level) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Renewable Energy Share in Primary Energy | Renewable Energy Share in Final Energy | Renewable Energy share in Electricity Generation | FiT / Premium Payment | Electric Utility quota | Net Metering | Transport obligations (biofuels) | Heat obligations | Tradable RE Certificates | Auctioning | Investment / Production tax credit | Tax Reductions | Energy Production Payment | Public loangs, investments, R&D |
| France | N/A | 23% (2020); 32% (2030) | 27% (2020); 40% (2030) | 1 | | | 1 | 1 | 1 | 1 | 1 | 1 | | 1 |
| Germany | N/A | 18% (2020); 30% (2030); 45% (2040); 60% (2050) | 40-45% (2020); 55-60% (2030); 45% (2035); 80% (2050) | 1 | | | 1 | 1 | 1 | 1 | 1 | 1 | | 1 |
| Greece | N/A | 20% (2020) | 40% (2020) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 1 |
| Hungary | N/A | 14.65% (2020) | 10.9% (2020) | 1 | | | 1 | | | 1 | | 1 | | 1 |
| Iceland | N/A | 64% (2020) | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Ireland | N/A | 16% (2020) | 42.5% (2020) | 1 | | | 1 | 1 | 1 | | | | | |
| Italy | N/A | 17% (2020) | 34% (2020) | 1 | | 1 | 1 | 1 | | | 1 | 1 | | 1 |
| Latvia | N/A | 40% (2020) | 60% (2020) | 1 | | 1 | 1 | | | | | 1 | | |
| Liechtenstein | N/A | N/A | N/A | 1 | | | | | | | | | | |
| Lithuania | 20% (2025) | 23% (2020) | 21% (2020) | 1 | 1 | | 1 | | | | | 1 | | 1 |
| Luxembourg | N/A | 11% (2020) | 11.8% (2020) | 1 | | | 1 | | | | | | | 1 |
| Malta | N/A | 10% (2020) | 3.8% (2020) | 1 | | 1 | | | | | | 1 | | 1 |
| Monaco | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Netherlands | N/A | 16% (2020) | 37% (2020) | 1 | | 1 | 1 | | 1 | | 1 | 1 | | 1 |
| Norway | N/A | 67.5% (2020) | N/A | | 1 | | 1 | | 1 | | | 1 | | 1 |
| Poland | 12% (2020) | 15.5% (2020) | 19.3% (2020) | 1 | 1 | | 1 | | 1 | 1 | | 1 | | 1 |
| Portugal | N/A | 31% (2020); 40% (2030) | 60% (2020) | 1 | 1 | | 1 | | 1 | | | 1 | | 1 |
| San Marino | N/A | N/A | N/A | 1 | | | | | | | | | | |
| Slovak Republic | N/A | 14% (2020) | 24% (2020) | 1 | | | 1 | | 1 | | | 1 | | 1 |

| | Renewable Energy Targets (national and sub-national) | | | Regulatory Policies (national and sub-national level) | | | | | | | Fiscal Incentives and Public Financing (national and sub-national level) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Renewable Energy Share in Primary Energy | Renewable Energy Share in Final Energy | Renewable Energy share in Electricity Generation | FiT / Premium Payment | Electric Utility quota | Net Metering | Transport obligations (biofuels) | Heat obligations | Tradable RE Certificates | Auctioning | Investment / Production tax credit | Tax Reductions | Energy Production Payment | Public loangs, investments, R&D |
| **Slovenia** | N/A | 15% (2020) | 39.3% (2020) | 1 | | 1 | | | 1 | 1 | 1 | 1 | | 1 |
| **Spain** | N/A | 20.8% (2020) | 38.1% (2020) | | | | 1 | 1 | 1 | 1 | 1 | | 1 | 1 |
| **Sweden** | N/A | 50% (2020) | 62.9% (2020) | 1 | 1 | | 1 | | 1 | | 1 | 1 | | 1 |
| **Switzerland** | 24% (2020) | 24% (2020) | N/A | 1 | | | | 1 | 1 | | | 1 | | 1 |
| **United Kingdom and Northern Ireland** | N/A | 15% (2020) | N/A (Scotland: 100%) | 1 | 1 | | 1 | | 1 | | | 1 | 1 | 1 |
| **SUM** | 4 | 28 | 24 | 27 | 8 | 9 | 24 | 7 | 19 | 10 | 12 | 21 | 5 | 25 |
| **%** | 13% | 88% | 75% | 90% | 27% | 30% | 80% | 23% | 63% | 33% | 40% | 70% | 17% | 83% |
| **North America** | | | | | | | | | | | | | | |
| **Canada** | N/A | N/A | N/A (4 provincial targets) | 1 | 1 | 1 | 1 | | | 1 | 1 | 1 | | 1 |
| **United States of America** | N/A | N/A | N/A (29 state or municipal targets) | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | 1 | | 1 |
| **SUM** | 0 | 0 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 2 | 2 | 0 | 2 |
| **%** | 0% | 0% | 100% | 100% | 100% | 100% | 100% | 50% | 50% | 50% | 100% | 100% | 0% | 100% |
| **Total UNECE** | **9** | **43** | **40** | **45** | **13** | **14** | **34** | **9** | **26** | **16** | **17** | **28** | **13** | **42** |
| **%** | **16%** | **77%** | **71%** | **90%** | **26%** | **28%** | **68%** | **18%** | **52%** | **32%** | **34%** | **56%** | **26%** | **84%** |

# References


Ackermann T., Andersson G., Soder L. (2001): Distributed Generation: A Definition. In: *Electric Power System Research,* Vol. 57 (2001), pp. 195-204.

Anderson W., White V., Finney A. (2010): 'You just have to get by': Coping with low incomes and cold homes. University of Bristol. https://core.ac.uk/download/pdf/29025974.pdf.

Bashmakov (2009): Resource of energy efficiency in Russia: scale, costs, and benefits. Energy Efficiency 2, 369–386. www.mdpi.com/jour- nal/sustainability. in section 7.6.2 Climate Change 2014: Mitigation of Climate Change. Intergovernmental Panel on Climate Change. http://www.ipcc.ch/report/ar5/wg3/

BlackRock (2017): *BlackRock. Black Rock Investment Stewardship engages on Climate Risk.* https://www.blackrock.com/corporate/en-us/literature/market-commentary/how-blackrock-investment-stewardship-engages-on-climate-risk-march2017.pdf

Blok, K., Hofheinz, P., Kerkhoven, J. (2015): *The 2050 Energy Productivity and Economic Prosperity Index. How Efficiency Will Drive Growth, Create Jobs and Spread Wellbeing Throughout Society.* https://www.ecofys.com/files/files/the-2015-energy-productivity-and-economic-prosperity-index.pdf

Bloomberg New Energy Finance (2017): *New Energy Outlook 2017*. https://about.bnef.com/new-energy-outlook/

Bondarak J. (2016): *Poland Coal Sector Update*. Presented at the Global Methane Initiative Coal Subcommittee Meeting 24 October 2016. https://www.unece.org/fileadmin/DAM/energy/se/pp/coal/cmm/11cmm_gmi.cs_oct2016/4_GMI_Poland_coal.pdf

BPIE and i24c - Buildings Performance Institute Europe; Industrial Innovation for Competitiveness (2016): *Scaling up Deep Energy Renovation, Unleashing the Potential through Innovation and industrialization. Building Performance Institute of Europe and Industrial Innovation for Competitiveness.* http://bpie.eu/publication/scaling-up-deep-energy-renovation/

Brunner K., Spitzerb M., Christanell A. (2012): *Experiencing fuel poverty. Coping strategies of low-income households in Vienna/Austria*. http://www.sciencedirect.com/science/article/pii/S0301421511009748

BSW-Solar (2015): *Statistische Zahlen der deutschen Solarstrombranche (Photovoltaik).* German Solar Industry Association (BSW-Solar).

CLASP - Collaborative Labeling and Appliance Standards Program (2017): *Standards and Labeling Database.* http://clasp.ngo/Tools/Tools/SLSearch

Clean Energy Wire (2016): *EEG reform 2016 – switching to auctions for renewables.* https://www.cleanenergywire.org/factsheets/eeg-reform-2016-switching-auctions-renewables

Climate Action Tracker (2017a): *Effect of current pledges and policies on global temperature*. http://climateactiontracker.org/global.html

Climate Action Tracker (2017b): *Tracking (I)NDCs*. http://climateactiontracker.org/indcs.html

Cold@Home Today (2017): *Homepage*. http://www.coldathome.today/

Cosic, B. (2013): *Status of Bioenergy in Croatia*. Presented at the Workshop –International cooperation in the Field of Bioenergy October 22-23, 2013. http://iet.jrc.ec.europa.eu/remea/sites/remea/files/files/documents/events/cosic.pdf

DENA - Deutsche Energie-Agentur (2010): Identifying Energy Efficiency potential in Russian Local and District Heating Networks. In UNDP (2014): *Sustainable Energy and Human Development in Europe and the CIS*. http://uabio.org/img/files/news/pdf/undp2014-sustainable-energy-cis.pdf

Deutscher Bundestag (2017): Energiearmut im Winter in Deutschland. http://dip21.bundestag.de/dip21/btd/18/113/1811351.pdf

DkVind (2017). *Danmarks Vindmollering (Danish Wind Turbine Owner's Association)*. http://dkvind.dk/html/eng/cooperatives.html#sthash.ze1WdtmC.dpuf

Domac, J.; Risovic, S., Šegon, V., Pentek, T., Šafran, B., Papa, I. (2015): *Can biomass triger an energy-wise transition in Croatia and rest of Southeastern Europe?*. http://www.sumari.hr/sumlist/pdf/201505610.pdf

EBRD – European Bank for Reconstruction and Development (2016)*: How to become a green city*. http://www.ebrd.com/news/2016/how-to-become-a-green-city.html

EBRD (2017a): *Renewable Energy in Kazakhstan. EBRD Green Energy Transition*. www.ebrd.com/documents/ict/renewable-energy-in-kazakhstan.pdf

EBRD (2017b): *Green Economy Financing Facilities*. https://ebrdgeff.com/.

Economidou, M., N. Labanca, L. Castellazzi, T. Serrenho, P. Bertoldi, P. Zancanella, D. Paci, S. Panev, and I. Gabrielaitiene (2016). *Assessment of the First National Energy Efficiency Action Plans under the Energy Efficiency Directive. Synthesis Report*. European Commission, Joint Research Center (JRC) Science for Policy Report. Ispra, Italy. http://publications.jrc.ec.europa.eu/repository/bitstream/JRC102284/jrc102284_jrc%20synthesis%20report_online%20template.pdf

EDF - Environmental Defense Fund (2016): *Investor Confidence Programme. Project Development Specification*. http://www.eeperformance.org/uploads/8/6/5/0/8650231/projectdevelopmentspecificationv1.0.pdf

Energy Community (2017): *About us*. https://www.energy-community.org/.

Energy Efficiency Agreements Finland (2017): *Energy efficiency agreements 2017-2025*. http://www.energiatehokkuussopimukset2017-2025.fi/en/

Energysprong (2017): *Homepage. http://energiesprong.nl/transitionzero/*

ENOVA (2017): *Homepage*. http://www.enr-network.org/enova.html

European Commission (2012): Article 14 of the Energy Efficiency Directive: Promotion of the efficiency of heating and cooling. In: *European Union Energy Efficiency Directive*. 2012/27/EUhttps://ec.europa.eu/energy/sites/ener/files/documents/Art%2014_1Hungary%20Reporten.pdf

European Commission (2014). *In-depth study of European Energy Security.* http://ec.europa.eu/energy/sites/ener/files/documents/20140528_energy_security_study.pdf

European Commission and Latvia (2015): *Intended Nationally Determined Contribution of the EU and its Member States*. http://www4.unfccc.int/submissions/INDC/Published%20Documents/Latvia/1/LV-03-06-EU%20INDC.pdf

European Commission Joint Research Center (2014): *GHG ($CO_2$, CH4, N2O, F-gases) emission time series 1990-2012 per region/country*. http://edgar.jrc.ec.europa.eu/overview.php?v=GHGts1990-2012&s ort=asc3

European Commission Joint Research Center (2016): *$CO_2$ time series 1990-2015 per capita for world countries*. In: Emission Database for Global Atmospheric Research. http://edgar.jrc.ec.europa.eu/overview.php?v=CO2ts_pc1990-2015

European Commission (2016): *Energy Efficiency.* http://iet.jrc.ec.europa.eu/energyefficiency/sites/energyefficiency/files/files/documents/events/nl_-_energy_audits_madrid_20032014.pdf

European Commission (2017a): *Gas and oil supply routes.* https://ec.europa.eu/energy/en/topics/imports-and-secure-supplies/supplier-countries

European Commission (2017b): *Supplier countries.* https://ec.europa.eu/energy/en/topics/imports-and-secure-supplies/gas-and-oil-supply-routes

European Commission (2017c): *Fluorinated greenhouse gases*. https://ec.europa.eu/clima/policies/f-gas_en

European Commission (2017d): *Report: EU energy efficiency requirements for products generate financial and energy savings*. https://ec.europa.eu/energy/en/news/report-eu-energy-efficiency-requirements-products-generate-financial-and-energy-savings.

European Commission (2017e): *National Energy Efficiency Actions Plans and Annual Reports*. http://ec.europa.eu/energy/en/topics/energy-efficiency/energy-efficiency-directive/national-energy-efficiency-action-plans

European Commission (2017f): *Energy Security Strategy*. https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/energy-security-strategy.

European Environment Agency (2016): *Trends and projections in Europe 2016 - Tracking progress towards Europe's climate and energy targets.* https://www.eea.europa.eu/themes/climate/trends-and-projections-in-europe

European Parliament (2009): *Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products.* http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32009L0125

European Parliament (2016): *Energy poverty, protecting vulnerable consumers.* http://www.europarl.europa.eu/RegData/etudes/BRIE/2016/583767/EPRS_BRI(2016)583767_EN.pdf

Eurostat (2017a): Electricity price statistic. http://ec.europa.eu/eurostat/statistics-explained/index.php/Electricity_price_statistics

Eurostat (2017b): *Europe 2020 indicators - climate change and energy*. http://ec.europa.eu/eurostat/statistics-explained/index.php/Europe_2020_indicators_-_climate_change_and_energy

Frankfurt School-UNEP Centre/BNEF (2016): *Global Trends in Renewable Energy Investment 2016.* http://fs-unep-centre.org/sites/default/files/attachments/16008nef_smallversionkomp.pdf

Frankfurt School-UNEP Centre/BNEF (2017): *Global Trends in Renewable Energy Investment 2017.* http://fs-unep-centre.org/sites/default/files/publications/globaltrendsinrenewableenergyinvestment2017.pdf

GAZPROMNeft (2015): *GAZPromNeft 2015 Annual Report*. http://ir.gazprom-neft.com/fileadmin/user_upload/documents/annual_reports/gpn_ar15_full_eng.pdf.

GE - General Electric (2017): *GE Global Power Plant Efficiency Analysis*. http://www.gereports.com/wp-content/themes/ge-reports/ge-power-plant/dist/pdf/GE%20Global%20Power%20Plant%20Efficiency%20Analysis.pdf

Geissdoerfer M., Savaget P., Bocken N., Hultink E. (2017): The Circular Economy – A new sustainability paradigm?. In: *Journal of Cleaner Production*. 143: 757–768.

GFEI – Global Fuel Economy Initiative (2016): *International comparison of light-duty vehicle fuel economy, Ten years of fuel economy benchmarking*. http://www.globalfueleconomy.org/media/418761/wp15-ldv-comparison.pdf

GFEI (2017): *Global Fuel Economy Initiative*. http://www.globalfueleconomy.org/Pages/Homepage.aspx

GIZ – Deutsche Gesellschaft für Internationale Zusammenarbeit (2016): *Synergy and Dissemination of Experience. Kyiv*. http://eeim.org.ua/interview/ukrayinska-sinergiya-ta-poshirennya-dosvidu-kiyiv/

GIZ (2017): *Energy Efficiency in Public Buildings in Turkey*. https://www.giz.de/en/worldwide/32607.html

GMI - Global Methane Initiative (2014): *Global Methane Emissions and Mitigation Opportunities*. http://www.globalmethane.org/documents/analysis_fs_en.pdf.

GMI (2017). *Homepage*. https://www.globalmethane.org/partners/index.aspx

GTM Research (2015): *The US Installed 6.2GW of Solar in 2014, up 30% over 2013*. https://www.greentechmedia.com/articles/read/the-us-installed-6-2-gw-of-solar-in-2014-up-30-over-2013#gs.S06Oofg

KAPSARC – King Abdullah Petroleum Studies and Research Center (-): *Energy Productivity*. https://www.necst.eu/wp-content/uploads/PPT_Hobbs.pdf

IEA - International Energy Agency (2009): *Advancing near term low carbon technologies in Russia*. Paris: OECD/IEA https://www.iea.org/media/topics/cleanenergytechnologies/chp/profiles/russia.pdf

IEA (2011): *Energy Efficiency Policy and Carbon Pricing*. https://www.iea.org/publications/freepublications/publication/energy efficiency_Carbon_Pricing.pdf.

IEA (2012a): *Building Energy Efficiency Policies Database*. http://www.iea.org/beep/

IEA (2012b): World Energy Outlook 2012. http://www.worldenergyoutlook.org/weo2012/

IEA (2014a). *Capturing the Multiple Benefits of Energy Efficiency*. http://www.iea.org/publications/freepublications/publication/Captur_the_MultiplBenef_ofEnergyEficiency.pdf

IEA (2014b): *Energy Efficiency Indicators: Fundamentals on Statistics*. https://www.iea.org/publications/freepublications/publication/IEA_EnergyEfficiencyIndicatorsFundamentalsonStatistics.pdf.

IEA (2015a): *Energy Policies Beyond IEA Countries: Caspian and Black Sea Regions 2015*. http://www.oecd.org/publications/energy-policies-beyond-iea-countries-caspian-and-black-sea-regions-2015-9789264228719-en.htm

IEA (2015b): *$CO_2$ Emissions from Fuel Combustion*. http://www.oecd-library.org/docserver/download/6115291e.pdf?expires=1502895214&id=id&accname=ocid195767&checksum=0BF0BDA8D1AF28BE9364CF8FF98DE41B

IEA (2015c): *The 4E Energy Efficient End-use Equipment Programme. 2015 Annual Report*. http://www.iea4e.org/files/otherfiles/0000/0354/4E_Annual_Report_2015_FINAL.pdf

IEA (2015d): *Energy Efficiency Market Report 2015*. https://www.iea.org/publications/freepublications/publication/MediumTermEnergyefficiencyMarketReport2015.pdf.

IEA (2016a): *Energy Efficiency Market Report 2016*. https://www.iea.org/eemr16/files/medium-term-energy-efficiency-2016_WEB.PDF

IEA (2016b). *Next Generation Wind and Solar - From cost to value*. https://www.iea.org/publications/freepublications/publication/next-generation-wind-and-solar-power.html

IEA (2016c): *IEA Medium-Term Coal Market Report. 2016*. https://www.iea.org/newsroom/news/2016/december/medium-term-coal-market-report-2016.html

IEA (2016d): *Energy Technology Perspectives*. http://www.iea.org/etp/etp2016/

IEA (2016e): *Key world energy statistics 2016*. https://www.iea.org/publications/freepublications/publication/KeyWorld2016.pdf

IEA (2016f): *World Energy Outlook 2016 Excerpt - Water-Energy Nexus*. https://www.iea.org/publications/freepublications/publication/world-energy-outlook-2016---excerpt---water-energy-nexus.html

IEA (2017a): *IEA finds $CO_2$ emissions flat for third straight year even as global economy grew in 2016*. IEA Newsroom 17 March 2017. http://www.iea.org/newsroom/news/2017/march/iea-finds-co2-emissions-flat-for-third-straight-year-even-as-global-economy-grew.html

IEA (2017b): *Getting Wind and Solar onto the Grid*. http://www.iea.org/publications/insights/insightpublications/getting-wind-and-solar-onto-the-grid.html

IEA (2017c): *IEA Atlas of Energy*. http://energyatlas.iea.org/#!/tellmap/-297203538/1

IEA (2017d): *Energy Efficiency 2O17*. https://www.iea.org/publications/freepublications/publication/Energy_Efficiency_2017.pdf.

IEA (2017e): Homepage – The Energy Efficient End-Use Equipment Programme. https://www.iea-4e.org/

IEA (2017f): *Voluntary Energy Efficiency Agreements for 2017 – 2025*. https://www.iea.org/policiesandmeasures/pams/finland/name-23913-en.php

IIP - Institute for Industrial Productivity (2017): http://www.iipnetwork.org/IEE.

INOGATE (2016): *2016 Activity Completion Report. RESMAP Geospatial mapping for sustainable energy investment*. RWP.NEW (phase 1 – Georgia)RWP. 17 (phase 2 – Armenia, Azerbaijan, Moldova) http://www.inogate.org/documents/Final_ACR_RESMAP_26092016_FINAL.pdf

Independent (2015): *Fuel poverty killed 15,000 people last winter*. www.independent.co.uk/news/uk/home-news/fuel-poverty-killed-15000-people-last-winter-10217215.html

Institute of Environmental Economics (2013): *Energy Efficiency in Poland*. http://www.buildup.eu/sites/default/files/content/ee_review_poland_2013_eng.pdf

International Energy Charter (1994): *Energy Charter Treat: Protocol on Energy Efficiency and Related Environmental Aspects (PEEREA)*. http://www.energycharter.org/process/energy-charter-treaty-1994/energy-efficiency-protocol/

IPCC - Intergovernmental Panel on Climate Change (2014a): *Climate Change 2014: Summary for Policymakers*. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. https://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc_wg3_ar5_summary-for-policymakers.pdf

IPCC (2014b): *Climate Change 2014: Synthesis Report*. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp. https://www.ipcc.ch/pdf/assessment-report/ar5/syr/SYR_AR5_FINAL_full_wcover.pdf

IPCC (2014c): *Climate Change 2014: Mitigation of Climate Change*. http://www.ipcc.ch/report/ar5/wg3/.

IRENA – International Renewable Energy Agency (2016): *Renewable Energy Capacity Statistics 2015*. http://www.irena.org/DocumentDownloads/Publications/IRENA_renewable energy_Capacity_Statistics_2015.pdf

IRENA (2017a): *Preliminary Findings of the Gap Analysis for Central Asia*. Presented at the Regional Workshop on Reneable Energy in Central Asia, 26–27 April 2017, Abu Dhabi. http://www.irena.org/eventdocs/Central%20Asia%20Regional%20Workshop/1%20Session%20I%20Status%20and%20Priorities%20for%20Renewable%20Energy%20Development%20Gurbuz%20Gonul.pdf

IRENA (2017b): *Global Wind Atlas*. http://globalwindatlas.com/map.html

IRENA (2017c): *Bioenergy Simulator*. https://irena.masdar.ac.ae/bioenergy/

IRENA (2017d): *Renewable Energy Auctions*. http://www.irena.org/DocumentDownloads/Publications/IRENA_REAuctions_summary_2017.pdf.

ISO – International Standard Organisation (2011): *ISO 50001:2011*. https://www.iso.org/standard/51297.html

Jacobson et al. (2017): 100% Clean and Renewable Wind, Water, and Sunlight All-Sector Energy Roadmaps for 139 Countries of the World. In: *Joule* 1, 1–14 (2017). http://www.sciencedirect.com/science/article/pii/S2542435117300120

KAPSARC (2016): *Heating degree Day*. https://www.kapsarc.org/research/projects/global-degree-days-database/

Karatayev M. and Clarke M (2014): Current energy resources in Kazakhstan and the future potential of renewables: A review. In: *Energy Procedia*, 59(2014), 97-104.

Lopez Labs (2017): *Masonry Heater Fuel Crib Repeatability Testing*. http://heatkit.com/html/lopez2a.htm

Meibom P., Kiviluoma J., Barth R., Brand H., Weber C., and Larsen H. (2007): Value of electric heat boilers and heat pumps for wind power integration. In: *Energy*. Volume 10, Issue 4, pages 321–337, July/August 2007. http://onlinelibrary.wiley.com/wol1/doi/10.1002/we.224/abstract

Ministry of Energy and Natural Resources of Turkey (-): *Market transformation of energy efficient appliances in Turkey*. http://www.undp.org/content/dam/turkey/docs/projectdocuments/EnvSust/UNDP-TR-%20EVUDP%20ENG%20(1)_baskiyagiden.pdf

Ministry of Energy of Bulgaria (2011): *Energy from Renewable Sources Act*. https://www.me.government.bg/library/index/download/lang/en/fileId/167

Nazarbayev University (2016): *Energy Export Strategies of the Central Asian Caspian Region*. Presented at the 1st AIEE Energy Symposium Current and Future Challenges to Energy Security, Italy, Rome. http://www.aieeconference2016milano.eu/files/BAKDOLOTOV.pdf.

Neue Energien Forum Feldheim (2017): *The energy self-sufficient village*. http://nef-feldheim.info/the-energy-self-sufficient-village/?lang=en.

Nordic Counsil of Ministers Secretariat (2014): *A common Nordic end-user market: Consequences of the Energy Efficiency Directive*. http://www.diva-portal.org/smash/record.jsf?pid=diva2%3A733370&dswid=4459

NREL - National Renewable Energy Laboratory (2017): *Biofuels Atlas*. https://maps.nrel.gov.

Nyquist, Scott (2017): Peering into energy's crystal ball. In: *McKinsey Quarterly*. https://www.mckinsey.com/industries/oil-and-gas/our-insights/peering-into-energys-crystal-ball

Parkhomchik L., Simsek H.A., Nurbayev, D. (2016): Natural Gas Pipeline Infrastructure in Central Asia. In: *Eurasian Research Institute Weekly E-Bulletin*, 10.05.2016-16.05.2016, No: 67. http://www.ayu.edu.tr/static/aae_haftalik/aae_bulten_en_67.pdf

Parliament of Ukraine (2017): *Draft Law on the Electricity Market of Ukraine*. http://w1.c1.rada.gov.ua/pls/zweb2/webproc4_2?id=&pf3516=4493&skl=9

PBL Netherlands Environmental Assessment Agency (2016): *Trends in Global $CO_2$ Emissions 2016 Report*. http://edgar.jrc.ec.europa.eu/news_docs/jrc-2016-trends-in-global-co2-emissions-2016-report-103425.pdf.

Pelkmans, L., Šaša, D. (2014): *National policy landscapes: Croatia*. http://www.biomasspolicies.eu/wp-content/uploads/2013/09/National-Policy-Landscape-Croatia.pdf

REN21 – Renewable Energy Policy Network for the 21st Century (2017): *Global Status Report 2017*. http://www.ren21.net/gsr-2017/chapters/chapter_05/chapter_05/.

Reuters (2017): *Talk of Tokyo: LNG trio to test leverage in push to free-up purchases*. http://uk.reuters.com/article/uk-japan-gastech-preview-idUKKBN1740YW.

Rogner, R.F. Aguilera, C.L. Archer, R. Ber- tani, S. C. Bhattacharya, M. B. Dusseault, L. Gagnon, and V. Yakushev, Eds. (2012): *Global Energy Assesment*. Cambridge University Press and International Institute for Applied Systems Analysis, Cambridge, UK & New York, NY, Vienna, Austria

SEforAll – Sustainable Energy for All (2016): *Going Further Faster*. http://www.se4all.org/sites/default/files/2016_EUSEW.pdf

SMA Solar Technology AG (2011): *What does kilowatt peak (kWp) actually mean?* http://solar-is-future.com/faq-glossary/faq/photovoltaic-technology-and-how-it-works/what-does-kilowatt-peak-kwp-actually-mean/index.html

SPECA – Special Programme for Central Asia (2016): *Enhanced Competitiveness, Increased Trade and Economic Growth (2016-2020)*.

Spiegel (2016): *Rentnerin erstickt bei Brand. Tausende Spanier demonstrieren gegen Energiearmut*. www.spiegel.de/wirtschaft/soziales/spanien-tausende-demonstrieren-gegen-energiearmut-a-1122158.html;

Steven Sorrell (2007). *The rebound effect: An assessment of the evidence for economy-wide energy savings from improved energy efficiency*. UK Energy Research Centre. *http://www.ukerc.ac.uk/asset/3B43125E-EEBD-4AB3-B06EA914C30F7B3E/*

Strafor (2013): *Map - Central Asia-China Energy Infrastructure*. http://www.stratfor.com/sites/default/files/main/images/Central_Asia_pipelines_v5.jpg

Sustainable Development Knowledge Platform (2017): *Energy for Sustainable Development*. https://sustainabledevelopment.un.org/topics/energy.

The New York Times (2017): *Germany Strikes Offshore Wind Deals, Subsidy Not Included*. https://www.nytimes.com/2017/04/14/business/energy-environment/offshore-wind-subsidy-dong-energy.html?mcubz=0

United Kingdom DECC – Department of Energy and Climate Change (2012): *Energy Efficiency Statistical Summary*. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/65598/6918-energy-efficiency-strategy-statistical-summary.pdf

United Kingdom Government (2014): *Government Community Energy Strategy. People powering change*. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/275164/20140126_Community_Energy_Strategy_summary.pdf

Ukraine (2014): *Ukraine National Renewable Energy Action Plan 2014*. https://www.iea.org/policiesandmeasures/pams/ukraine/name-131666-en.php

UNDP – United Nations Develoment Programme (2014): *Sustainable Energy and Human Development in Europe and the CIS*. http://www.tr.undp.org/content/dam/turkey/docs/Publications/EnvSust/UNDP,2014-Sustainable%20Energy%20and%20Human%20Development%20in%20Europe%20and%20the%20CIS.pdf

UNECE – United Nations Economic Commission for Europe (2013): *Good practices for energy-efficient housing in the UNECE region*. https://www.unece.org/fileadmin/DAM/hlm/documents/Publications/good.practices.ee.housing.pdf

UNECE (2014): *Revised recommendations of the United Nations Economic Commission for Europe to the United Nations Framework Convention on Climate Change on how carbon capture and storage in cleaner electricity production and through enhanced oil recovery could be used in reducing GHG emissions*. https://www.unece.org/fileadmin/DAM/energy/se/pdfs/comm23/ECE.ENERGY.2014.5_e.pdf

UNECE and REN21 (2015a): *UNECE Renewable Energy Status Report 2015*. https://www.unece.org/fileadmin/DAM/energy/se/pdfs/gere/publ/2015/web-REN21-UNECE.pdf

UNECE (2015b): *Best Policy Practices for Promoting Energy Efficiency*. https://www.unece.org/fileadmin/DAM/UNECE_Best_Practices_in_energy efficiency_publication_1_.pdf

UNECE (2015c): Tools for analyzing the water-food-energy-ecosystems nexus. http://www.unece.org/fileadmin/DAM/env/water/nexus/Nexus_tools_final_for_web.pdf

UNECE (2015d): *Reconciling resource uses in transboundary basins: assessment of the water-food-energy-ecosystems nexus*.

http://www.unece.org/fileadmin/DAM/env/water/publications/WAT_Nexus/ece_mp.wat_46_eng.pdf

UNECE (2016): *Best Practice Guidance for Effective Methane Drainage and Use in Coal Mines*. 2nd edition. https://www.unece.org/fileadmin/DAM/energy/cmm/docs/BPG_2017.pdf.

UNECE and REN21 (2017a): *UNECE Renewable Energy Status Report 2017*. https://www.unece.org/fileadmin/DAM/energy/se/pp/renew/Renewable_energy_report_2017_web.pdf

UNECE (2017b): *Survey on Methane Management*. http://www.unece.org/energywelcome/areas-of-work/energysedocscmmx-long/survey-on-methane-management.html.

UNECE (2017c): *Deployment of Renewable Energy: The Water-Energy-Food-Ecosystem Nexus Approach to Support the Sustainable Development Goals*. http://www.unece.org/fileadmin/DAM/energy/se/pdfs/gere/publ/2017/DeploymentOfRenewableEnergy_TheWaterEnergyFood.pdf

UNECE (2017d): *Reconciling Resource Uses in Transboundary Basins: Assessment of the Water-Food-Energy Ecosystems Nexus in the Sava River Basin*. http://www.unece.org/index.php?id=45241

UNECE (2017e): *Framework guidelines for energy efficiency standards in buildings*. https://www.unece.org/fileadmin/DAM/energy/se/pdfs/geee/geee4_Oct2017/ECE_ENERGY_GE.6_2017_4_EEBuildingGuidelines_final.pdf

UNECE (2017f): Policy Brief: *Assessment of the water-food-energy-ecosystems nexus and the benefits of transboundary cooperation in the Drina River Basin*. ECE/MP.WAT/NONE/6.

UNECE (2017g): Benefit of transboundary cooperation on water-energy nexus for renewable energy development, Fourth session of the Group of Experts on Renewable Energy (Geneva, 2-3 November 2017). Basin specific technical reports are available at: http://www.unece.org/env/water/publications/pub.html

UNECE (2017h): *Methane management in extractive industries – best practices in the gas sector*. ECE/ENERGY/2017/9, para.4. https://www.unece.org/fileadmin/DAM/energy/se/pdfs/comm26/ECE_ENERGY_2017_9e.pdf

UN ESCWA - Economic and Social Commission for Western Africa and UNECE (2016): *Promoting Renewable Energy Investments for Climate Change Mitigation and Sustainable Development*. *Georgia Case Study*. Presented at session "Enabling Policies to Promote Financing Renewable Energy Investments", 7th International Forum for Energy for Sustainable Development, 19-20 September 2016. https://www.unescwa.org/events/enabling-policies-promote-financing-renewable-energy

UNFCCC – United Nations Framework Convention on Climate Change (1992): *United Nations Framework Convention on Climate Change*. https://unfccc.int/resource/docs/convkp/conveng.pdf

UNFCCC (2016): *Aggregate effect of the intended nationally determined contributions: an update. United Nations Framework Convention on Climate Change Secretariat*. http://unfccc.int/resource/docs/2016/cop22/eng/02.pdf

UNFCCC (2017a): *UNFCCC Data Interface*. http://unfccc.int/ghg_data/items/4133.php

UNFCCC (2017b): *INDC Registry*. http://www4.unfccc.int/submissions/indc/Submission%20Pages/submissions.aspx

UNFCCC (2017c): *Interim NDC Registry*. http://www4.unfccc.int/ndcregistry/Pages/Home.aspx

UNFCCC (2017d): *Nationally Determined Contributions (NDCs)*. http://unfccc.int/focus/items/10240.php

UNIDO – United Nations Industrial Development Organisation (2015): *The UNIDO Programme on Energy Management System Implementation in Industry*. https://www.unido.org/fileadmin/user_media_upgrade/What_we_do/Topics/Energy_access/11._IEE_EnMS_Brochure.pdf

USAID - United States Agency for International Development (2017): *USAID and Habitat for Humanity Macedonia. Residential Energy Efficiency Revolving Fund*. https://getwarmhomes.org/our-approach/usaid-project-macedonia/

US DOE - United States Department of Energy (2017): *Revolution Now*. https://energy.gov/eere/downloads/revolutionnow-2016-update.

US EIA – United States Energy Information Administration (2016a): United States Crude Oil and Natural Gas Proved Reserves. https://www.eia.gov/naturalgas/crudeoilreserves/

US EIA (2016b): *Annual Coal Report 2016*. https://www.eia.gov/coal/annual/

US EIA (2017): *Total Carbon Dioxide Emission from the Consumption of Energy 2014*. https://www.eia.gov/beta/international/data/browser/#/?pa=0000000000000000000000000002&c=1438j018006gg614a080a4sa00e8ag00og0004gc01ho1ggjo&ct=0&vs=INTL.44-8-ALB-MMTCD.A&vo=0&v=H&start=1980&end=2014.

US EPA - United States Environmental Protection Agency (2016): *International Coal Mine Methane Projects List*. https://www.epa.gov/sites/production/files/2016-05/coalprojectlist.xlsx

US EPA (2017): *Global Mitigation of Non-$CO_2$ Greenhouse Gases: 2010-2030*. https://www.epa.gov/global-mitigation-non-co2-greenhouse-gases/global-mitigation-non-co2-greenhouse-gases-2010-2030-3

SManalysis (2009): *The Balkan natural gas pipelines*. http://smarkos.blogspot.ch/2009/11/balkan-natural-gas-pipelines-nov-28.html.

Vilgerts Legal and Tax (2015). Renewable energy in Belarus: new tariffs 2015. In: *Insider Energy*. http://www.vilgerts.com/wp-content/uploads/2015/10/Insider.Vilgerts-Renewable-Energy-Belarus.New-Tariffs.Oct2015.Eng_.pdf

WEF - World Economic Forum (2015): *Future of Electricity*. http://www3.weforum.org/docs/WEFUSA_FutureOfElectricity_Report2015.pdf

WoodMackenzie (2017a) : *Central Asia-Centre Pipeline*. https://www.woodmac.com/reports/upstream-oil-and-gas-central-asia-centre-pipeline-9544435

WoodMackenzie (2017b): *Energy market disruption and the role of power markets: are the markets prepared?* https://www.woodmac.com/reports/power-markets-energy-market-disruption-and-the-role-of-power-markets-are-the-markets-prepared-49588535

World Bank (2013): *Tajikistan's Winter Energy Crisis. Electricity Supply and Demand Alternatives*. http://documents.worldbank.org/curated/en/500811468116363418/pdf/796160PUB0REPL00Box377374B00PUBLIC0.pdf

World Bank (2016): *Republic of Uzbekistan. Scaling up Energy Efficiency in Buildings*. Report No: ACS19957. August 2016 https://openknowledge.worldbank.org/bitstream/handle/10986/25093/ACS19957.pdf?sequence=4&isAllowed=y

World Bank and International Energy Agency (2017a): *Global Tracking Framework. Progress toward Sustainable Energy*. http://gtf.esmap.org/downloads

World Bank (2017b): *Global Solar Atlas*. http://globalsolaratlas.info

World Bank (2017c): *World Development Indicators*. http://data.worldbank.org/data-catalog/world-development-indicators (as of 13 April 2017).

World Bank (2017d): *Stuck in Transition: Reform Experiences and Challenges Ahead in the Kazakhstan Power Sector*. http://documents.worldbank.org/curated/en/104181488537871278/pdf/113146-PUB-PUBLIC-PUBDATE-2-27-17.pdf

World Bank (2017e): *World Development Indicators: Trends in greenhouse gas emissions*. http://wdi.worldbank.org/table/3.9#

WEC - World Energy Council (2016): *World Energy Resources. Waste to Energy. 2016*: https://www.worldenergy.org/wp-content/uploads/2017/03/WEResources_Waste_to_Energy_2016.pdf

WHO - World Health Organisation (2007): *Housing Energy and Thermal Comfort: A Review of 10 Countries within the WHO European Region*. http://www.euro.who.int/__data/assets/pdf_file/0008/97091/E89887.pdf

Yashchenko I. (2016): *Status of coal mine methane degasification and utilization in Ukraine*. Presented at the UNECE Group of Expert on Coal Mine Methane, Eleventh Session, Geneva, 24-25 October 2016. https://www.unece.org/fileadmin/DAM/energy/se/pp/coal/cmm/11cmm_gmi.cs_oct2016/5_Ukraine_GMI.pdf

# Endnotes

1. The Global Tracking Framework reports have been published in 2013, 2015, and 2017, following the initiation of the Sustainable Energy for All (SEforALL) Initiative in December 2010. The third report in 2017 links tracking of SEforALL with the tracking of SDG 7, with involvement of the five Regional Commissions. The global and five regional reports are published online: http://gtf.esmap.org
2. Target 7.1 and 7.3 are the same as the SEforALL targets 1 and 3. Target 7.2 differs as the SEforALL renewables target aims to "double the share of renewable energy in the global energy mix".
3. GDP, PPP (constant 2011 international USD).
4. As defined by the International Energy Agency (IEA), total primary energy supply (TPES) (in terajoules [TJ]) is production plus net imports minus international marine and aviation bunkers plus/minus stock changes. *Data sources*: Energy balances from the IEA, supplemented by UN Statistical Division for countries not covered by IEA.
5. World Bank and International Energy Agency (2017a): Global Tracking Framework. Progress toward Sustainable Energy. http://gtf.esmap.org/
6. World Bank (2017c): World Development Indicators: http://data.worldbank.org/data-catalog/world-development-indicators (as of 13 April 2017).
7. The sub-regions in this report differ from the 2017 GTF which divided the UNECE region in four sub-regions. While the sub-regions Western and Central Europe, Southeast Europe and North America remain the same, the 2017 GTF sub-region "Central Asia, Caucasus, Eastern Europe, Israel, Russian Federation, and Turkey" was further split into four regions Caucasus, Central Asia including Turkey, Eastern Europe including Israel, South-east Europe, and the Russian Federation.
8. World Bank et al. (2017a).
9. World Bank et al. (2017a).
10. Data presented here are based on 2014, following the tracking period of 2012-2014 for the 2017 GTF report. At the writing of the global GTF report, no more recent data were available. The results presented in this report are hence limited with a view towards more recent developments across the energy sector.
11. No data available for Andorra, Liechtenstein, Monaco, and San Marino.
12. EIA (2017): *EIA's AEO2017 projects the United States to be a net energy exporter in most cases.* https://www.eia.gov/todayinenergy/detail.php?id=29433
13. IEA (2017c): *IEA Atlas of Energy*. http://energyatlas.iea.org/#!/tellmap/-297203538/1
14. European Commission (2017a): *Gas and oil supply routes.* https://ec.europa.eu/energy/en/topics/imports-and-secure-supplies/supplier-countries
15. European Commission (2017b): *Supplier countries.* https://ec.europa.eu/energy/en/topics/imports-and-secure-supplies/gas-and-oil-supply-routes
16. Parkhomchik L., Simsek H.A., Nurbayev, D. (2016): Natural Gas Pipeline Infrastructure in Central Asia. In: *Eurasian Research Institute Weekly E-Bulletin*, 10.05.2016-16.05.2016, No: 67. http://www.ayu.edu.tr/static/aae_haftalik/aae_bulten_en_67.pdf
17. Parkhomchik et al (2016). Wood Mackenzie (2017a) : *Central Asia-Centre Pipeline.* https://www.woodmac.com/reports/upstream-oil-and-gas-central-asia-centre-pipeline-9544435
18. SPECA (2016): *Enhanced Competitiveness, Increased Trade and Economic Growth (2016-2020).*
19. SE4All tracking is replaced by SDG 7 tracking which are the same indicators. The methodology and data sources for the GTF indicators can be reviewed in Annex IV.
20. Total final energy consumption (TFC) is the sum of energy consumption by the different end-use sectors, excluding non-energy uses of fuels. TFC is broken down into energy demand in the following sectors: industry, transport, residential, services, agriculture, and others. It excludes international marine and aviation bunkers, except at world level where it is included in the transport sector. *Data sources*: Energy balances from IEA, supplemented by United Nations Statistical Division for countries not covered by IEA.
21. SE4All (2016): *Going Further Faster*. http://www.se4all.org/sites/default/files/2016_EUSEW.pdf
22. United Kingdom DECC (2012): *Energy Efficiency Statistical Summary*. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/65598/6918-energy-efficiency-strategy-statistical-summary.pdf
23. Nyquist, Scott (2017): Peering into energy's crystal ball. In: *McKinsey Quarterly*. https://www.mckinsey.com/industries/oil-and-gas/our-insights/peering-into-energys-crystal-ball
24. KAPSARC (-): *Energy Productivity.* https://www.necst.eu/wp-content/uploads/PPT_Hobbs.pdf
25. As reported in World Bank et al (2017a).
26. Definition as used in GTF 2017. Primary energy intensity is the ratio of TPES to GDP measured at PPP in constant 2011 USD (MJ/2011 PPP$). Throughout this document references to USD use 2011 values calculated on the basis of purchasing power parity (PPP).
27. The 1.0% increase in energy intensity in 2010 resulted from the global financial crisis as economic activity decreased slightly faster than energy demand.
28. One exajoule equals 1018 (one quintillion) joules.
29. Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Republic of Moldova, the Russian Federation, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan.
30. World Bank (2017): *Indicator "Manufacturing, value added (% of GDP)".* https://data.worldbank.org/indicator/NV.IND.MANF.ZS?end=2016&locations=-BY-UA&start=1989&view=chart
31. As reported in World Bank et al. (2017a).
32. The ranking of Iceland as an energy-intense economy shows the shortcomings of using energy intensity as an indicator for energy effciciency. The high reliance on geothermal electricity with efficiency ratings of 10% is the reason for its high energy intensity, despite numerous energy saving programmes http://energyatlas.iea.org/#!/tellmap/-297203538/1.

33. Economidou, M., N. Labanca, L. Castellazzi, T. Serrenho, P. Bertoldi, P. Zancanella, D. Paci, S. Panev, and I. Gabrielaitiene (2016). Assessment of the First National Energy Efficiency Action Plans under the Energy Efficiency Directive. Synthesis Report. European Commission, Joint Research Center (JRC) Science for Policy Report. Ispra, Italy. http://publications.jrc.ec.europa.eu/repository/bitstream/JRC102284/jrc102284_jrc%20synthesis%20report_online%20template.pdf.
34. Economidou et al. (2016).
35. As reported in World Bank et al (2017a).
36. Within the GTF, renewable energy consumption includes "renewable energy consumption of all technology: hydro, biomass, wind, solar, liquid biofuels, biogas, geothermal, marine and renewable wastes". Modern renewable energy consumption is defined as „total renewable energy consumption minus traditional consumption/use of biomass. It covers all forms of renewable energy directly measured, including wind, hydro, solar, geothermal, marine, biogas, liquid biofuel, renewable energy waste, and modern biomass". Traditional renewable energy consumption is defined as "Final consumption of traditional uses of biomass. Biomass uses are considered traditional when biomass is consumed in the residential sector in non-Organisation for Economic Co-operation and Development (OECD) countries. It includes the following categories in IEA statistics: primary solid biomass, charcoal and non-specified primary biomass and waste.".
37. As reported in World Bank et al. (2017a).
38. European Environment Agency (2016): *Trends and projections in Europe 2016 - Tracking progress towards Europe's climate and energy targets.* https://www.eea.europa.eu/themes/climate/trends-and-projections-in-europe
39. Eurostat (2017b): *Europe 2020 indicators - climate change and energy*. http://ec.europa.eu/eurostat/statistics-explained/index.php/Europe_2020_indicators_-_climate_change_and_energy
40. European Environment Agency (2016).
41. According to the GTF 2017, modern renewable energy consumption includes solar, wind, biomass, geothermal, hydro, liquid biofuels, biogas, marine, and renewable wastes, without traditional energy which is defines as solid biomass when consumed in the residential sector in non-Organisation for Economic Cooperation and Development (OECD) countries.
42. IEA (2016e): Key World Energy Statistics.
43. The renewable power capacity data shown in these tables represents the maximum net generating capacity of power plants and other installations that use renewable energy sources to produce electricity (IRENA Statistics). this incluces Hydro (small and large), pumped storage and mixed plants, marine energy, geothermal, solar photovoltaic (PV), concentrated solar power (CSP), wind (on/off shore), and bioenergy (solidas biomass, renewable waste, biogas, and liquid biofuels).
44. IRENA (2015): *Renewable Energy Capacity Statistics 2015.* http://www.irena.org/DocumentDownloads/Publications/IRENA_renewable energy_Capacity_Statistics_2015.pdf.
45. Frankfurt School-UNEP Centre/BNEF (2016): *Global Trends in Renewable Energy Investment 2016.* http://fs-unep-centre.org/sites/default/files/attachments/16008nef_smallversionkomp.pdf; Frankfurt School-UNEP Centre/BNEF (2017): *Global Trends in Renewable Energy Investment 2017.* http://fs-unep-centre.org/sites/default/files/publications/globaltrendsinrenewableenergyinvestment2017.pdf
46. UNECE and REN21 (2017a): *UNECE Renewable Energy Status Report.* https://www.unece.org/fileadmin/DAM/energy/se/pp/renew/Renewable_energy_report_2017_web.pdf.
47. Bloomberg New Energy Finance (2017): *New Energy Outlook 2017*. https://about.bnef.com/new-energy-outlook/
48. Sustainable Development Knowledge Platform (2017): *Energy for Sustainable Development.* https://sustainabledevelopment.un.org/topics/energy
49. IRENA (2017a): *Preliminary Findings of the Gap Analysis for Central Asia*. Presented at the Regional Workshop on Reneable Energy in Central Asia, 26–27 April 2017, Abu Dhabi. http://www.irena.org/eventdocs/Central%20Asia%20Regional%20Workshop/1%20Session%20I%20Status%20and%20Priorities%20for%20Renewable%20Energy%20Development%20Gurbuz%20Gonul.pdf
50. World Bank (2013): *Tajikistan's Winter Energy Crisis. Electricity Supply and Demand Alternatives.* http://documents.worldbank.org/curated/en/500811468116363418/pdf/796160PUB0REPL00Box377374B00PUBLIC0.pdf
51. UNECE and REN21 (2017a): *UNECE Renewable Energy Status Report.* https://www.unece.org/fileadmin/DAM/energy/se/pp/renew/Renewable_energy_report_2017_web.pdf
52. Eurostat (2017a): *Electricity price statistic*. http://ec.europa.eu/eurostat/statistics-explained/index.php/Electricity_price_statistics
53. Deutscher Bundestag (2017): *Energiearmut im Winter in Deutschland*. http://dip21.bundestag.de/dip21/btd/18/113/1811351.pdf.
54. Spiegel (2016): *Rentnerin erstickt bei Brand. Tausende Spanier demonstrieren gegen Energiearmut.* www.spiegel.de/wirtschaft/soziales/spanien-tausende-demonstrieren-gegen-energiearmut-a-1122158.html; Independent (2015): *Fuel poverty killed 15,000 people last winter*. www.independent.co.uk/news/uk/home-news/fuel-poverty-killed-15000-people-last-winter-10217215.html
55. WHO (2007): *Housing Energy and Thermal Comfort: A Review of 10 Countries within the WHO European Region.* http://www.euro.who.int/__data/assets/pdf_file/0008/97091/E89887.pdf
56. UNECE and REN21 (2015a): *UNECE Renewable Energy Status Report 2015.* https://www.unece.org/fileadmin/DAM/energy/se/pdfs/gere/publ/2015/web-REN21-UNECE.pdf
57. A limited number of combustion tests point to efficiencies similar to other controlled combustion stoves; generally above 60% and up to 72%.
58. KAPSARC (-).
59. KAPSARC (-).
60. IPCC (2014a): *Climate Change 2014: Summary for Policymakers.* Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. https://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc_wg3_ar5_summary-for-policymakers.pdf
61. IPCC (2014b): Intergovernmental Panel on Climate Change (IPPC) (2014a): *Climate Change 2014: Synthesis Report.* Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp. https://www.ipcc.ch/pdf/assessment-report/ar5/syr/SYR_AR5_FINAL_full_wcover.pdf

## Endnotes

62. IEA (2015a): *Energy Policies Beyond IEA Countries: Caspian and Black Sea Regions 2015*. http://www.oecd.org/publications/energy-policies-beyond-iea-countries-caspian-and-black-sea-regions-2015-9789264228719-en.htm
63. Fluorinated gases ('F-gases') are a family of man-made gases used in a range of industrial applications. Because they do not damage the atmospheric ozone layer, they are often used as substitutes for ozone-depleting substances. However, F-gases are powerful greenhouse gases, with a global warming effect up to 23 000 times greater than carbon dioxide ($CO_2$), and their emissions are rising strongly. Source: European Commission (2017c): *Fluorinated greenhouse gases*. https://ec.europa.eu/clima/policies/f-gas_en
64. IEA (2015b): *$CO_2$ Emissions from Fuel Combustion*. http://www.oecd-library.org/docserver/download/6115291e.pdf?expires=1502895214&id=id&accname=ocid195767&checksum=0BF0BDA8D1AF28BE9364CF8FF98DE41B-
65. Data source: IEA World Energy Balances. Calculations exclude emission data for Andorra, Liechtenstein, Monaco and San Marino. Data include only $CO_2$ emissions from fossil fuel combustion, not any other GHG emissions and fugitive emissions such as CH4 emission from coal mining. For comparison: in 2012, the UNECE share in global GHG emissions was 31.5% (Source: World Bank World Develpoment indicator).
66. $CO_2$ emissions from fuel combustion only.
67. United States Energy Information Administration (US EIA) (2017): Total Carbon Dioxide Emission from the Consumption of Energy 2014. https://www.eia.gov/beta/international/data/browser/#/?pa=0000000000000000000000002&c=1438j018006gg614a080a4sa00e8ag00og0004gc01ho1ggjo&ct=0&vs=INTL.44-8-ALB-MMTCD.A&vo=0&v=H&start=1980&end=2014. No data for Andorra, Monaco and San Marino available. Excluding other GHG emissions.
68. IEA (2015b).
69. Another possible data source is the Emission Database for Global Atmospheric Research (EDGAR4) which has been developed jointly by the European Commission's Joint Research Centre (JRC) and the PBL Netherlands Environmental Assessment Agency. EDGAR4 provides global anthropogenic emissions of greenhouse gases CO2, CH4, N2O, HFCs, PFCs and SF6 and of precursor gases and air pollutants CO, NOx, NMVOC, SO2 and the aerosols PM10, PM2.5, BC, OC, per source category, at country level. See edgar.jrc.ec.europa.eu . However, only total greenhouse gas emissions are given, with no specific data for the energy sector only. Another option are the emission data from the Global Carbon Project http://cdiac.ornl.gov/GCP/
70. This includes all GHG emissions within the energy sector, excluding LULUCF: $CO_2$, CH4, N2O, and aggregate F-gases in t $CO_2$ equivalent. The energy sector includes: energy industries, manufacturing industries and construction, transport, fugitive emissions from fuels, $CO_2$ transport and storage, as well as other and non-specified sectors. Note: The reporting and review requirements for GHG inventories are different for Annex I and non-Annex I Parties within the Kyoto Protocol.
71. Data Source: European Commission Joint Research Center (2014): GHG ($CO_2$, CH4, N2O, F-gases) emission time series 1990-2012 per region/country. http://edgar.jrc.ec.europa.eu/overview.php?v=GHGts1990-2012&s ort=asc3. Excludes data for Andorra and Liechtenstein.
72. UNECE et al. (2015a).
73. IEA (2016d): *Energy Technology Perspectives*. http://www.iea.org/etp/etp2016/
74. World Bank (2016): *Republic of Uzbekistan. Scaling up Energy Efficiency in Buildings*. Report No: ACS19957. August 2016. https://openknowledge.worldbank.org/bitstream/handle/10986/25093/ACS19957.pdf?sequence=4&isAllowed=y
75. Deutsche Energie-Agentur (DENA) (2010): Identifying Energy Efficiency potential in Russian Local and District Heating Networks. In UNDP (2014): *Sustainable Energy and Human Development in Europe and the CIS*. http://uabio.org/img/files/news/pdf/undp2014-sustainable-energy-cis.pdf
76. IEA (2009): *Advancing near term low carbon technologies in Russia*. Paris: OECD/IEA https://www.iea.org/media/topics/cleanenergytechnologies/chp/profiles/russia.pdf
77. DENA (2010).
78. UNDP (2014): *Sustainable Energy and Human Development in Europe and the CIS*. http://www.tr.undp.org/content/dam/turkey/docs/Publications/EnvSust/UNDP,2014-Sustainable%20Energy%20and%20Human%20Development%20in%20Europe%20and%20the%20CIS.pdf
79. IEA (2012): World Energy Outlook 2012. http://www.worldenergyoutlook.org/weo2012/
80. Meibom P., Kiviluoma J., Barth R., Brand H., Weber C., and Larsen H. (2007): Value of electric heat boilers and heat pumps for wind power integration. In: *Energy*. Volume 10, Issue 4, pages 321–337, July/August 2007. http://onlinelibrary.wiley.com/wol1/doi/10.1002/we.224/abstract
81. Bashmakov (2009): Resource of energy efficiency in Russia: scale, costs, and benefits. Energy Efficiency 2, 369–386. www.mdpi.com/jour- nal/sustainability. in section 7.6.2 Climate Change 2014: Mitigation of Climate Change. Intergovernmental Panel on Climate Change. http://www.ipcc.ch/report/ar5/wg3/
82. Rogner, R.F. Aguilera, C.L. Archer, R. Ber- tani, S. C. Bhattacharya, M. B. Dusseault, L. Gagnon, and V. Yakushev, Eds. (2012): *Global Energy Assesment*. Cambridge University Press and International Institute for Applied Systems Analysis, Cambridge, UK & New York, NY, Vienna, Austria.
83. IPCC (2014a).
84. European Commission (2012): Article 14 of the Energy Efficiency Directive: Promotion of the efficiency of heating and cooling. In: EU Energy Efficiency Directive. 2012/27/EUhttps://ec.europa.eu/energy/sites/ener/files/documents/Art%2014_1Hungary%20Reporten.pdf
85. European Commission (2012).
86. UNECE et al. (2015a).
87. UNECE et al. (2017a).
88. European Parliament (2016): *Energy poverty, Protecting vulnerable consumers*. http://www.europarl.europa.eu/RegData/etudes/BRIE/2016/583767/EPRS_BRI(2016)583767_EN.pdf.
89. UNECE et al. (2015a).
90. European Parliament (2016).
91. EFPEEP (2015): European Fuel Poverty and Energy Efficiency Project.. https://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/epee_european_fuel_poverty_and_energy_efficiency_en.pdf
92. Cold@home Today (2017): *Homepage*. http://www.coldathome.today/.

93. Anderson W., White V., Finney A. (2010): 'You just have to get by': Coping with low incomes and cold homes. Uniersity of Bristol. https://core.ac.uk/download/pdf/29025974.pdf.
94. Brunner K., Spitzerb M., Christanell A. (2012): *Experiencing fuel poverty. Coping strategies of low-income households in Vienna/Austria*. http://www.sciencedirect.com/science/article/pii/S0301421511009748
95. European Parliament (2016).
96. United Kingdom Government (2014): *Community Energy Strategy. People powering change. 2014*. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/275164/20140126_Community_Energy_Strategy_summary.pdf
97. IEA (2014a): *Capturing the Multiple Benefits of Energy Efficiency*. http://www.iea.org/publications/freepublications/publication/Captur_the_MultiplBenef_ofEnergyEficiency.pdf
98. Out of the 18 countries that reported a rate below 98 % in 2014. The 36 countries that reached a rate above 98% in 2014 are not considered in the projections.
99. IEA (2014a).
100. As energy consumers save on energy cost through energy efficiency, they may spend their savings on other energy-intensive activities, or increase their demand for the new service, thereby countering the potential savings of energy. This is called the rebound effect. In: IEA (2011): *Energy Efficiency Policy and Carbon Pricing*. https://www.iea.org/publications/freepublications/publication/EE_Carbon_Pricing.pdf.
101. *Steven Sorrell (2007). The rebound effect: An assessment of the evidence for economy-wide energy savings from improved energy efficiency. UK Energy Research Centre. http://www.ukerc.ac.uk/asset/3B43125E-EEBD-4AB3-B06EA914C30F7B3E/*
102. IEA (2014a).
103. IEA (2014b): *Energy Efficiency Indicators: Fundamentals on Statistics.* https://www.iea.org/publications/freepublications/publication/IEA_EnergyEfficiencyIndicatorsFundamentalsonStatistics.pdf.
104. Institute of Environmental Economics (2013): *Energy Efficiency in Poland*. http://www.buildup.eu/sites/default/files/content/ee_review_poland_2013_eng.pdf
105. UNECE (2013).
106. UNECE (2017e): *Framework guidelines for energy efficiency standards in buildings.* https://www.unece.org/fileadmin/DAM/energy/se/pdfs/geee/geee4_Oct2017/ECE_ENERGY_GE.6_2017_4_EEBuildingGuidelines_final.pdf
107. European Parliament (2009): *Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products.* http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32009L0125.
108. IEA (2016a): *Energy Efficiency Market Report 2016*. https://www.iea.org/eemr16/files/medium-term-energy-efficiency-2016.
109. European Commission (2017d): *Report: EU energy efficiency requirements for products generate financial and energy savings.* https://ec.europa.eu/energy/en/news/report-eu-energy-efficiency-requirements-products-generate-financial-and-energy-savings.
110. IEA (2017e): Homepage – The Energy Efficient End-Use Equipment Programme. https://www.iea-4e.org/
111. IEA (2015c): *The 4E Energy Efficient End-use Equipment. 2015 Annual Report*. http://www.iea4e.org/files/otherfiles/0000/0354/4E_Annual_Report_2015_FINAL.pdf.
112. Ministry of Energy and Natural Resources of Turkey (-): *Market transformation of energy efficient appliances in Turkey*. http://www.undp.org/content/dam/turkey/docs/projectdocuments/EnvSust/UNDP-TR-%20EVUDP%20ENG%20(1)_baskiyagiden.pdf
113. GFEI (2016): *International comparison of light-duty vehicle fuel economy, Ten years of fuel economy benchmarking*. http://www.globalfueleconomy.org/media/418761/wp15-ldv-comparison.pdf
114. GFEI (2017): Global Fuel Economy Initiative. http://www.globalfueleconomy.org/Pages/Homepage.aspx
115. The GFEI is a partnership of the IEA, UNEP. and other organistions, and works to secure real improvements in fuel economy, and the maximum deployment of existing fuel economy technology in vehicles across the world. See website for more information: https://www.globalfueleconomy.org/
116. GFEI (2016).
117. GFEI (2016).
118. IEA (2017d): *Energy Efficiency 2O17*. https://www.iea.org/publications/freepublications/publication/Energy_Efficiency_2017.pdf.
119. IPCC (2014a).
120. WEC (2016): *World Energy Resources. Waste to Energy. 2016*. https://www.worldenergy.org/wp-content/uploads/2017/03/WEResources_Waste_to_Energy_2016.pdf.
121. IIP (2017): *Website*. http://www.iipnetwork.org/IEE.
122. IEA (2012)
123. IEA (2017f): *Voluntary Energy Efficiency Agreements for 2017 – 2025.* https://www.iea.org/policiesandmeasures/pams/finland/name-23913-en.php; Energy Efficiency Agreements Finland (2017): *Energy efficiency agreements 2017-2025*. http://www.energiatehokkuussopimukset2017-2025.fi/en/
124. European Commission (2016): *Energy Efficiency.* http://iet.jrc.ec.europa.eu/energyefficiency/sites/energyefficiency/files/files/documents/events/nl_-_energy_audits_madrid_20032014.pdf
125. For more information about the activities of the UNECE Group of Experts on Energy Efficieincy please visit https://www.unece.org/energyefficiency.html.
126. See more details under ISO (2011): ISO 50001:2011. https://www.iso.org/standard/51297.html.
127. UNIDO (2015): *The UNIDO Programme on Energy Management System Implementation in Industry*. https://www.unido.org/fileadmin/user_media_upgrade/What_we_do/Topics/Energy_access/11._IEE_EnMS_Brochure.pdf
128. GIZ (2016): *Synergy and Dissemination of Experience. Kyiv*. http://eeim.org.ua/interview/ukrayinska-sinergiya-ta-poshirennya-dosvidu-kiyiv/; GIZ (2017): *Energy Efficiency in Public Buildings in Turkey*. https://www.giz.de/en/worldwide/32607.html.
129. BPIE I24c (2016): Scaling up Deep Energy Renovation, Unleashing the Potential through Innovation and industrialization. Building Performance Institute of Europe and Industrial Innovation for Competitiveness. http://bpie.eu/wp-content/uploads/2016/11/cover-i24c.png

130. BPIE et al. (2016).
131. Energysprong (2017): *Homepage*. *http://energiesprong.nl/transitionzero/*
132. World Bank (2016).
133. European Commission (2017e): *National Energy Effciency Actions Plans and Annual Reports*. http://ec.europa.eu/energy/en/topics/energy-efficiency/energy-efficiency-directive/national-energy-efficiency-action-plans.
134. ENOVA (2017): *Homepage*. http://www.enr-network.org/enova.html
135. UNECE has not reviewed these policies, as this is a significant task and well beyond the scope of this report.
136. The 2006 EU Directive on Energy End-Use Efficiency and Energy Services (Energy Services Directive) requires Member States to submit NEEAP in 2007, 2011 and 2014. In the first NEEAP, each Member State should have adopted an overall national indicative savings target for end-use sectors of 9% or higher, to be achieved in 2016, and with an intermediate target for 2010.
137. International Energy Charter (1994): *Energy Charter Treat: Protocol on Energy Efficiency and Related Environmental Aspects (PEEREA)*. http://www.energycharter.org/process/energy-charter-treaty-1994/energy-efficiency-protocol/
138. Through the implementation of PEEREA, the Energy Charter provides its member countries with a menu of good practices and a forum in which to share experiences and policy advice on energy efficiency issues. There are two types of reviews conducted by the Energy Charter in its member countries: regular monitoring based on a standard review format and in-depth energy efficiency reviews.
139. Approximately every four years, the policies of individual member countries are reviewed in-depth by a team of peers led by the IEA. The country review are available online: https://www.iea.org/publications/countryreviews/
140. http://www.iea.org/policiesandmeasures/
141. Blok, K., Hofheinz, P., Kerkhoven, J. (2015): *The 2050 Energy Productivity and Economic Prosperity Index. How Efficiency Will Drive Growth, Create Jobs and Spread Wellbeing Throughout Society.* https://www.ecofys.com/files/files/the-2015-energy-productivity-and-economic-prosperity-index.pdf
142. WoodMackenzie (2017b): *Energy market disruption and the role of power markets: are the markets prepared?* https://www.woodmac.com/reports/power-markets-energy-market-disruption-and-the-role-of-power-markets-are-the-markets-prepared-49588535
143. "Distributed", "decentralized" or "off-grid" generation (or energy) is defined as the "installation and operation of electric power generation units connected directly to the distribution network or connected to the network on the customer site of the meter" with the purpose to "provide a source of active electric power. This type of more local generation is different from the common system of centralized supply including large-scale fossil fuel fired power plants, and hydro power, as well as large-scale renewable energy such as off-shore wind, which require transmission lines to transport the power produced over vaster distances.
144. Ackermann T., Andersson G., Soder L. (2001): Distributed Generation: A Definition. In: *Electric Power System Research*, Vol. 57 (2001), pp. 195-204.
145. IEA (2017b): *Getting Wind and Solar onto the Grid*. http://www.iea.org/publications/insights/insightpublications/getting-wind-and-solar-onto-the-grid.html-
146. Parliament of Ukraine (2017): *Draft Law on the Electricity Market of Ukraine*. http://w1.c1.rada.gov.ua/pls/zweb2/webproc4_2?id=&pf3516=4493&skl=9.
147. Neue Energien Forum Feldheim (2017): *The energy self-sufficient village.* http://nef-feldheim.info/the-energy-self-sufficient-village/?lang=en.
148. DkVind (2017): *Danmarks Vindmollering (Danish Wind Turbine Owner's Association).* http://dkvind.dk/html/eng/cooperatives.html#sthash.ze1WdtmC.dpuf
149. UN ESCWA and UNECE (2016): *Promoting Renewable Energy Investments for Climate Change Mitigation and Sustainable Development*. *Georgia Case Study*. Presented at session "Enabling Policies to Promote Financing Renewable Energy Investments", 7th International Forum for Energy for Sustainable Development, 19-20 September 2016. https://www.unescwa.org/events/enabling-policies-promote-financing-renewable-energy
150. Domac, J.; Risovic, S., Šegon, V., Pentek, T., Šafran, B., Papa, I. (2015): *Can biomass triger an energy-wise transition in Croatia and rest of Southeastern Europe?*. http://www.sumari.hr/sumlist/pdf/201505610.pdf
151. Pelkmans, L., Šaša, D. (2014): *National policy landscapes: Croatia.* http://www.biomasspolicies.eu/wp-content/uploads/2013/09/National-Policy-Landscape-Croatia.pdf
152. Cosic, B. (2013): *Status of Bioenergy in Croatia*. Presented at the Workshop –International cooperation in the Field of Bioenergy October 22-23, 2013. http://iet.jrc.ec.europa.eu/remea/sites/remea/files/files/documents/events/cosic.pdf
153. Pelkmans et al. (2014).
154. Lopez Labs (2017): *Masonry Heater Fuel Crib Repeatability Testing*. http://heatkit.com/html/lopez2a.htm
155. Kilowatt peak stands for peak power. This value specifies the output power achieved by a Solar module under full solar radiation (under set Standard Test Conditions). Solar radiation of 1,000 watts per square meter is used to define standard conditions. Peak power is also referred to as "nominal power" by most manufacturers. Since it is based on measurements under optimum conditions, the peak power is not the same as the power under actual radiation conditions. In practice, this will be approximately 15-20% lower due to the considerable heating of the solar cells. Source: SMA Solar Technology AG (2011).
156. According to global distribution of solar potential expressed in photovoltaic electricity output. Source: World Bank (2017b): *Global Solar Atlas*. http://globalsolaratlas.info
157. BSW-Solar (2015): *Statistische Zahlen der deutschen Solarstrombranche (Photovoltaik)*. German Solar Industry Association (BSW-Solar).
158. IRENA (2017b): *Global Wind Atlas*. http://globalwindatlas.com/map.html
159. NREL (2017): *Biofuels Atlas*. https://maps.nrel.gov.
160. IRENA (2017c): *Bioenergy Simulator*. https://irena.masdar.ac.ae/bioenergy/
161. Government of Kazakhstan (2013): *National Concept for Transition to a Green Economy up to 2050*. Decree of the President of the Republic of Kazakhstan dated February 20, 2013.
162. Karatayev M. and Clarke M. (2014): Current energy resources in Kazakhstan and the future potential of renewables: A review. In: *Energy Procedia,* 59(2014), 97-104.
163. WEF (2015): *Future of Electricity*. http://www3.weforum.org/docs/WEFUSA_FutureOfElectricity_Report2015.pdf

164. IEA (2016b). *Next Generation Wind and Solar - From cost to value.* https://www.iea.org/publications/freepublications/publication/next-generation-wind-and-solar-power.html
165. IEA (2016b).
166. IEA (2016d).
167. IEA (2016f): *World Energy Outlook 2016 Excerpt - Water-Energy Nexus.* https://www.iea.org/publications/freepublications/publication/world-energy-outlook-2016---excerpt---water-energy-nexus.html
168. IEA (2016c): *IEA Medium-Term Coal Market Report 2016.* https://www.iea.org/newsroom/news/2016/december/medium-term-coal-market-report-2016.html
169. According to IRENA Statistics, 195 MW of new hydro have been installed in 2016.
170. GE (2017): *GE Global Power Plant Efficiency Analysis.* http://www.gereports.com/wp-content/themes/ge-reports/ge-power-plant/dist/pdf/GE%20Global%20Power%20Plant%20Efficiency%20Analysis.pdf
171. World Bank et al. (2017a).
172. World Bank et al. (2017a).
173. Ministry of Energy of Bulgaria (2011): *Energy from Renewable Sources Act. h*ttps://www.me.government.bg/library/index/download/lang/en/fileId/167
174. Ukraine (2014): *Ukraine National Renewable Energy Action Plan 2014*. https://www.iea.org/policiesandmeasures/pams/ukraine/name-131666-en.php
175. Vilgerts Legal and Tax (2015). Renewable energy in Belarus: new tariffs 2015. In : *Insider Energy*. http://www.vilgerts.com/wp-content/uploads/2015/10/Insider.Vilgerts-Renewable-Energy-Belarus.New-Tariffs.Oct2015.Eng_.pdf.
176. The New York Times (2017): *Germany Strikes Offshore Wind Deals, Subsidy Not Included.* https://www.nytimes.com/2017/04/14/business/energy-environment/offshore-wind-subsidy-dong-energy.html?mcubz=0.
177. Clean Energy Wire (2016): *EEG reform 2016 – switching to auctions for renewables.* https://www.cleanenergywire.org/factsheets/eeg-reform-2016-switching-auctions-renewables.
178. IRENA (2017d): *Renewable Energy Auctions.* http://www.irena.org/DocumentDownloads/Publications/IRENA_REAuctions_summary_2017.pdf.
179. Nazarbayev University (2016): *Energy Export Strategies of the Central Asian Caspian Region*. Presented at the 1st AIEE Energy Symposium Current and Future Challenges to Energy Security, Italy, Rome. http://www.aieeconference2016milano.eu/files/BAKDOLOTOV.pdf.
180. European Commission (2017f): *Energy Security Strategy*. https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/energy-security-strategy.
181. European Commission (2014). *In-depth study of European Energy Security.* http://ec.europa.eu/energy/sites/ener/files/documents/20140528_energy_security_study.pdf
182. US EIA (2016a): *United States Crude Oil and Natural Gas Proved Reserves*. https://www.eia.gov/naturalgas/crudeoilreserves/
183. US DoE (2017): Revolution Now. https://energy.gov/eere/downloads/revolutionnow-2016-update.
184. GTM Research (2015): *The US Installed 6.2GW of Solar in 2014, up 30% over 2013.* https://www.greentechmedia.com/articles/read/the-us-installed-6-2-gw-of-solar-in-2014-up-30-over-2013#gs.S06Oof.
185. GAZPROMNeft (2015): *GAZPromNeft 2015 Annual Report.* http://ir.gazprom-neft.com/fileadmin/user_upload/documents/annual_reports/gpn_ar15_full_eng.pdf.
186. European Commission (2014).
187. European Commission (2014).
188. Reuters (2017): *Talk of Tokyo: LNG trio to test leverage in push to free-up purchases*. http://uk.reuters.com/article/uk-japan-gastech-preview-idUKKBN1740YW
189. European Commission (2014).
190. PBL Netherlands Environmental Assessment Agency (2016): *Trends in Global $CO_2$ Emissions 2016 Report*. http://edgar.jrc.ec.europa.eu/news_docs/jrc-2016-trends-in-global-co2-emissions-2016-report-103425.pdf
191. IEA (2016c).
192. IEA (2016c).
193. Frankfurt School-UNEP Centre/BNEF (2017).
194. IEA (2017a): *IEA finds $CO_2$ emissions flat for third straight year even as global economy grew in 2016*. IEA Newsroom 17 March 2017. http://www.iea.org/newsroom/news/2017/march/iea-finds-co2-emissions-flat-for-third-straight-year-even-as-global-economy-grew.html
195. GTM Research (2015).
196. US EIA (2016b): *Annual Coal Report 2016.* https://www.eia.gov/coal/annual/
197. US EIA (2016b).
198. IEA (2014a).
199. IEA (2014a).
200. World Bank (2017e): *World Development Indicators: Trends in greenhouse gas emissions.* http://wdi.worldbank.org/table/3.9#
201. IEA (2017a).
202. IEA (2017a).
203. UNFCCC (2017b): *INDC Registry*. http://www4.unfccc.int/submissions/indc/Submission%20Pages/submissions.aspx
204. UNFCCC (2017c): *Interim NDC Registry*. http://www4.unfccc.int/ndcregistry/Pages/Home.aspx
205. UNFCCC (2017d): *Nationally Determined Contributions (NDCs)*. http://unfccc.int/focus/items/10240.php
206. European Commission and Latvia (2015): *Intended Nationally Determined Contribution of the EU and its Member States*. http://www4.unfccc.int/submissions/INDC/Published%20Documents/Latvia/1/LV-03-06-EU%20INDC.pdf.
207. European Commission and Latvia (2015).

208. Eurostat (2017b).
209. UNFCCC (1992): *United Nations Framework Convention on Climate Change*. https://unfccc.int/resource/docs/convkp/conveng.pdf
210. Climate Action Tracker (2017): *Effect of current pledges and policies on global temperature*. http://climateactiontracker.org/global.html
211. Climate Action Tracker (2017): *Tracking (I)NDCs*. http://climateactiontracker.org/indcs.html
212. Based on cumulative forcing over 100 and 20 years, respectively. Source: IPPC (2014b).
213. US EPA (2017): *Global Mitigation of Non-$CO_2$ Greenhouse Gases: 2010-2030*. https://www.epa.gov/global-mitigation-non-co2-greenhouse-gases/global-mitigation-non-co2-greenhouse-gases-2010-2030-3
214. United States EPA (2016): *International Coal Mine Methane Projects List*. https://www.epa.gov/sites/production/files/2016-05/coalprojectlist.xlsx
215. See for example: (a) United Nations Framework Convention on Climate Change, available at: http://unfccc.int/files/essential_background/background_publications_htmlpdf/application/pdf/conveng.pdf, see in particular Article 4, Article 10, and Article 12 of the Convention; (b) US Environmental Protection Agency, Greenhouse Gas Reporting Program available at: https://www.epa.gov/ghgreporting. See also 40 CFR Part 98 available at: https://www.ecfr.gov/cgi-bin/text-idx?SID=3c71c656d3f1a8cdf64a78060d713bf9&tpl=/ecfrbrowse/Title40/40cfr98_main_02.tpl; and (c) Norwegian Environmental Agency 2016: "Cold venting and fugitive emissions from Norwegian offshore oil and gas activities – summary report". The report presents a survey and mapping of direct methane and NMVOC emissions from Norwegian offshore infrastructure, an updated estimate of emission inventories, proposals for improved future quantification of the emissions, and an assessment of emission abatement opportunities. It identifies a total of 48 potential emission sources. http://www.miljodirektoratet.no/no/Publikasjoner/2016/Juni-2016/Cold-venting-and-fugitive-emissions-from-Norwegian-offshore-oil-and-gas-activities--summary-report/
216. UNECE (2017h): *Methane management in extractive industries – best practices in the gas sector*. ECE/ENERGY/2017/9, para.4. https://www.unece.org/fileadmin/DAM/energy/se/pdfs/comm26/ECE_ENERGY_2017_9e.pdf
217. Bondarak J. (2016): *Poland Coal Sector Update*. Presented at the Global Methane Initiative Coal Subcommittee Meeting 24 October 2016. https://www.unece.org/fileadmin/DAM/energy/se/pp/coal/cmm/11cmm_gmi.cs_oct2016/4_GMI_Poland_coal.pdf
218. Yashchenko I. (2016): *Status of coal mine methane degasification and utilization in Ukraine*. Presented at the UNECE Group of Expert on Coal Mine Methane, Eleventh Session, Geneva, 24-25 October 2016. https://www.unece.org/fileadmin/DAM/energy/se/pp/coal/cmm/11cmm_gmi.cs_oct2016/5_Ukraine_GMI.pdf
219. IEA (2016a).
220. *Geissdoerfer M., Savaget P., Bocken N., Hultink E. (2017): The Circular Economy – A new sustainability paradigm?. In: Journal of Cleaner Production. 143: 757–768.*
221. Giordano, et al. (2013) in IEA (2016a).
222. IGRAC in IEA (2016a).
223. UNECE (2017d): Reconciling Resource Uses in Transboundary Basins: Assessment of the Water-Food-Energy Ecosystems Nexus in the Sava River Basin. http://www.unece.org/index.php?id=45241. UNECE (2017c): *Deployment of Renewable Energy: The Water-Energy-Food-Ecosystem Nexus Approach to Support the Sustainable Development Goals.* http://www.unece.org/fileadmin/DAM/energy/se/pdfs/gere/publ/2017/DeploymentOfRenewableEnergy_TheWaterEnergyFood.pdf; UNECE (2017f): *Policy Brief: Assessment of the water-food-energy-ecosystems nexus and the benefits of transboundary cooperation in the Drina River Basin*. ECE/MP.WAT/NONE/6.
224. UNFCCC (2016). *Aggregate effect of the intended nationally determined contributions: an update. United Nations Framework Convention on Climate Change Secretariat*. http://unfccc.int/resource/docs/2016/cop22/eng/02.pdf;
225. UNECE (2014): *Revised recommendations of the United Nations Economic Commission for Europe to the United Nations Framework Convention on Climate Change on how carbon capture and storage in cleaner electricity production and through enhanced oil recovery could be used in reducing GHG emissions.* https://www.unece.org/fileadmin/DAM/energy/se/pdfs/comm23/ECE.ENERGY.2014.5_e.pdf.
226. US EPA (2017).
227. Calculations made on the basis of the 100-year global warming potentials
228. IPCC (2014c): *Climate Change 2014: Mitigation of Climate Change*. http://www.ipcc.ch/report/ar5/wg3/.
229. The United States EPA lists Recommended Technologies to Reduce Methane Emissions at the following site. https://www.epa.gov/natural-gas-star-program/recommended-technology-reduce-methane-emissions
230. UNECE (2017b): *Survey on Methane Management.* http://www.unece.org/energywelcome/areas-of-work/energysedocscmmx-long/survey-on-methane-management.html.
231. UNECE (2016): *Best Practice Guidance for Effective Methane Drainage and Use in Coal Mines*. 2nd edition. https://www.unece.org/fileadmin/DAM/energy/cmm/docs/BPG_2017.pdf.
232. UNECE (2015d): Reconciling resource uses in transboundary basins: assessment of the water-food-energy-ecosystems nexus. http://www.unece.org/fileadmin/DAM/env/water/publications/WAT_Nexus/ece_mp.wat_46_eng.pdf
233. See tools listed under UNECE (2015c): Tools for analyzing the water-food-energy-ecosystems nexus. http://www.unece.org/fileadmin/DAM/env/water/nexus/Nexus_tools_final_for_web.pdf
234. INOGATE (2016): *2016 Activity Completion Report. RESMAP Geospatial mapping for sustainable energy investment.* RWP.NEW (phase 1 – Georgia)RWP. 17 (phase 2 – Armenia, Azerbaijan, Moldova) http://www.inogate.org/documents/Final_ACR_RESMAP_26092016_FINAL.pdf.
235. UNECE (2017c): *Deployment of Renewable Energy: The Water-Energy-Food-Ecosystem Nexus Approach to Support the Sustainable Development Goals.* http://www.unece.org/fileadmin/DAM/energy/se/pdfs/gere/publ/2017/DeploymentOfRenewableEnergy_TheWaterEnergyFood.pdfM UNECE (2015d): UNECE (2017g): Benefit of transboundary cooperation on water-energy nexus for renewable energy development, Fourth session of the Group of Experts on Renewable Energy (Geneva, 2-3 November 2017). Basin specific technical reports are available at: http://www.unece.org/env/water/publications/pub.html
236. UNECE et al. (2017a).
237. World Bank et al. (2017a).

**Global Tracking Framework:**

UNECE Progress in Sustainable Energy

Information Service
United Nations Economic Commission for Europe

Palais des Nations
CH - 1211 Geneva 10, Switzerland
Telephone: +41(0)22 917 44 44
E-mail: info.ece@unece.org
Website: http://www.unece.org

Layout and Printing at United Nations, Geneva – 1735291 **(E)** – February 2018 – 1,016 – **ECE/ENERGY/108**