ADDRESSING THE ENERGY-WATER NEXUS THROUGH R&D PLANNING AND POLICIES

SUMMARY REPORT

An event organised under the auspices of the

Experts' Group on R&D Priority Setting and Evaluation (EGRD)

28-29 May 2018

Brussels, Belgium

International Energy Agency (IEA)

The IEA is an autonomous agency established in November 1974. Its mandate is two-fold: to promote energy security amongst its member countries through collective response to physical disruptions in oil supply and to advise member countries on sound energy policy. The IEA carries out a comprehensive programme of energy co-operation among 29 advanced economies[1]. The Agency aims to:

- Secure member countries' access to reliable and ample supplies of all forms of energy; in particular, through maintaining effective emergency response capabilities in case of oil supply disruptions.
- Promote sustainable energy policies that spur economic growth and environmental protection in a global context – particularly in terms of reducing greenhouse-gas emissions that contribute to climate change.
- Improve transparency of international markets through collection and analysis of energy data.
- Support global collaboration on energy technology to secure future energy supplies and mitigate their environmental impact, including through improved energy efficiency and development and deployment of low-carbon technologies.
- Find solutions to global energy challenges through engagement and dialogue with non-member countries, industry, international organisations, and other stakeholders.

Since the 1980s, the IEA has continued to build good working relationships with countries beyond its membership, in particular major energy consuming, producing and transit countries. Countries with which the IEA seeks enhanced engagement including Accession countries Chile and Mexico, Association countries China, India, Indonesia, Morocco, and Singapore. Co-operation with these and other partner countries cover a wide range of activities, from joint workshops to in-depth surveys of specific energy sectors or data exchange. Combined, the IEA co-operates with more than 69 countries worldwide.

IEA Energy Technology Network

The IEA Energy Technology Network is an ever-expanding, co-operative group of more than 6,000 experts that support and encourage global technology collaboration. At the head of this vast network is the Committee on Energy Research and Technology (CERT).

Committee on Energy Research and Technology

Comprised of senior experts from IEA member governments, the Committee on Energy Research and Technology (CERT) considers effective energy technology and policies to improve energy security, encourage environmental protection and maintain economic growth. Under the guidance of the IEA Governing Board, the CERT oversees the technology forecasting, analyses and the research, development, demonstration and deployment (RDD&D) strategies of the IEA Secretariat, notably through its flagship publication, *Energy Technology Perspectives*, and the series of energy technology roadmaps. The CERT also provides guidance to its working parties and experts' groups to examine topics that address current energy technology, or technology policy, issues. The CERT is supported in its work through four topical working parties, including the EGRD.

Experts' Group on R&D Priority-Setting and Evaluation (EGRD)

The EGRD examines analytical approaches to energy technologies, policies, and R&D on targeted, timely topics. The results and recommendations support the Committee on Energy Research and Technology (CERT), feed into IEA analysis, enabling a broad perspective of energy technology issues.

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[11] Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Korea (Republic of), Luxembourg, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States; The European Commission also participates in the work of the IEA.

Addressing the Energy-Water Nexus through R&D Planning and Policies

Executive Summary

INTRODUCTION

On 28-29 May 2018 Delegates to the IEA Experts' Group on R&D Priority Setting (EGRD) held a workshop to gain further understandings of the issues of the energy-water nexus and to highlight best practices and opportunities. Technology experts from research entities, academia, and leading agencies across the world offered a wide range of perspectives and insights. The European Commission in Brussels hosted the event.

RATIONALE AND BACKGROUND

Energy access, energy security or the environmental impact of energy use may be affected by water availability. Fossil fuels require water for extraction, transport and processing. Thermal power plants (nuclear, fossil-fuels, bio-based fuels and concentrating solar) require water for cooling, and hydropower plants require robust river currents. Feedstock production for biofuels may depend on water for irrigation.

The availability of clean drinking water and sanitation services would simply not be possible without energy, whether in developed or developing countries. This includes pumping ground and surface water, treating and transporting water to end-users, and cleaning wastewater.

However, energy and water systems have been developed, managed and regulated independently and so have the technological solutions. In some cases the interactions between energy and water are considered, though largely on a regional or technology-by-technology basis.

Therefore, examining the interplay – the "nexus" – between energy and water enables a holistic management of natural resources and a systemic view of the complex and critical issues. Both technology-specific and systemic approaches are needed to address the issues, including developing new technologies and integrated approaches to efficient use of energy, water, or both. These inter-related issues are acute in populations that lack access to both energy and fresh water.

> **Energy-Water Nexus**
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> *"A set of interactions, comprising important drivers for the use of resources. Natural resources serve as direct input in the production processes of another resource or they can substitute the use of another resource. Indirect effects related to the specific use of resources also have to be taken into account because claims for a particular use of one resource can compete with other demands".*
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> -Bleischweitz and Miedzinski (2018).

ISSUES ADDRESSED

Experts from Europe, Japan and the United States shared best practice, highlighting areas for further research. Four presentations focussed entirely or in part on research activities of the IEA Technology Collaboration Programmes (TCPs).[2] Contributions addressed a wide range of issues:

- Frameworks for international co-operation
- Governance and regulation
- Integrated management of natural resources
- The important role of technology – for both energy and water
- Data collection and analysis

[2] The TCP on Bioenergy, the TCP on District Heating and Cooling (DHC TCP), the TCP on Greenhouse Gas R&D (GHG TCP), the TCP on Solar Heating and Cooling (SHC TCP), and the TCP on Concentrating Solar Power (SolarPACES TCP).

Understanding the energy-water nexus and the implications for an integrated energy system is in the exploratory phase - we are beginning to understand the stress-points, trade-offs and synergies as well as direct and indirect benefits. The energy-water nexus provides a holistic approach to address the Sustainable Development Goals (SDGs), for which energy is part of the solution to the water scarcity and water is part of the solution to a low carbon energy system. Yet each sector uses different technologies and involves different stakeholders and institutions which makes policy- and decision-making very complex. In addition the issues of the energy-water nexus are broader and more complex, interrelated to land use, food, materials and eco-systems.

Technology development

The various technologies that support energy-efficient water systems or water-efficient energy systems are at various stages of research, development, demonstration and deployment (RDD&D). Technologies cover smart water management for heating, water recovery and alternative cooling systems. Energy-efficient technologies include river thermal management, use and reuse of water in carbon capture and storage (CCS), reduced water use and recovery in households and industry, and saline sludge discharge from bioenergy processing. Cooling is a growing area of research. For example, cooling power plants with air is a promising technology in development, though further research – and funding - is needed.

Water-efficient systems include smart, low-temperature heating systems, efficient technologies to recycle industrial process water as well as new wastewater treatment technologies, in some cases resulting in the plant becoming a 'prosumer'[3] of excess heat and other resources as well as a producer of co-products, such as recovered energy, fertilizer.

Institutions, governance and regulation

Public-private partnerships (PPPs) play an important role in scaling up technologies from pilot to large-scale applications, but more could be done to accelerate the process, for example through innovation-driven public procurement. Technology push options should be combined with market pull options, at least at the more developed stages.

Proper management of river basins is a challenge and is the concern of one or several governments and the power sector. The early stage assessment of the Sava River Basin offers important lessons learned, highlighting the need to improve information about the nexus and relevant sectors. Cooperation in transboundary basins is challenging and time-consuming, but nonetheless necessary to improve overall resource use efficiency. Providing evidence for proper river basin management in a truly transboundary way is possible by integrating the natural, technical and life sciences in the social science context.

Data and analysis

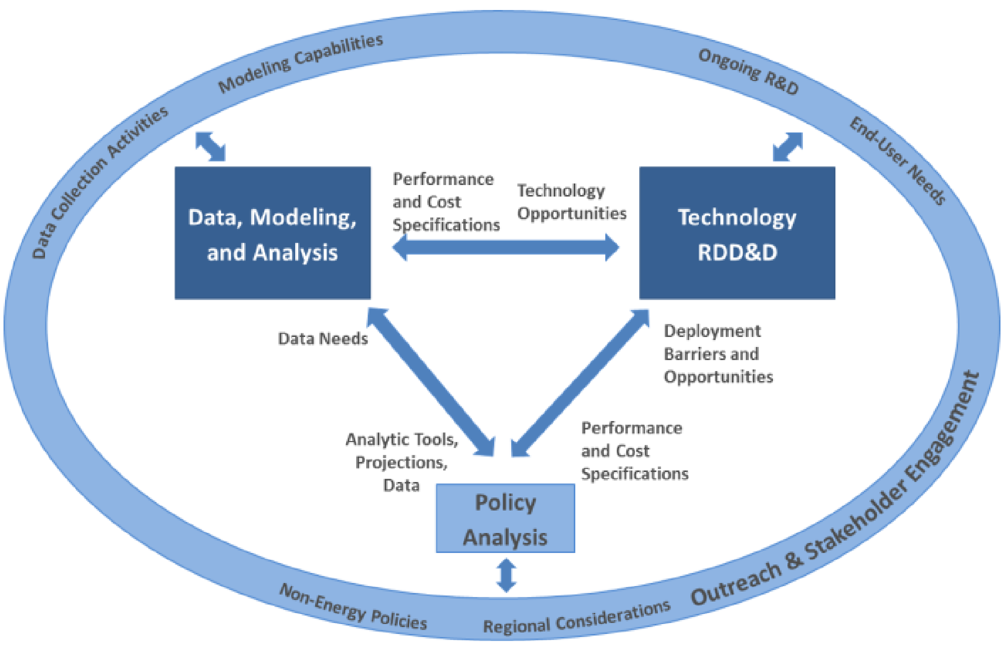
Policy- and decision-making related to the energy-water nexus concerns many levels - regional, national, local (including islands) and even a single plant. Modelling and data analysis can provide much-needed scientific-based evidence to support these efforts provided they are driven by user-needs. The idea is not to develop a comprehensive energy-water nexus model but rather to link different models (directly or indirectly) while carefully balancing model complexity and reliable results. Access to reliable and valid data is a challenge in particular in the water sector and the non-power sectors. Sound decision-support tools go beyond modelling and data analysis and could include quantitative and qualitative scenarios, stakeholder analysis, and risk assessment. Open-source data and models facilitate knowledge creation and diffusion, making it easier to validate results and develop common standards and statistics.

[3] Prosumers are consumers that produce electricity (e.g. residential rooftop solar photovoltaic panels) for resale into the electricity network.

RECOMMENDATIONS

- *For both energy and water the availability of the other is critical. To effectively manage resources, analysis of integrative policies and their impact are needed.*
- *Applying multi-disciplines/multi scale treatment of technical applications, power production, water treatment, water savings and cooperate internationally to avoid overlap and create synergies.*
- *Sharing best practices, knowledge exchange and governance at different scales, being cities, industries, regions or cross-border river basins.*
- *Improving modelling work and data quality related to the nexus by striking a balance between fundamental advances and needs-driven outcomes. International cooperation in the field is essential.*

Figure 1. Energy-Water Nexus Focus Areas



Source: United States Department of Energy.

Workshop participants focused on water for energy, energy for water and integrated systems as well as policy and framework conditions surrounding the inter-related issues. Further details of the issues addressed are provided on the following pages.[4]

[4] All presentations are available on the workshop web page.

Proceedings

SETTING THE SCENE

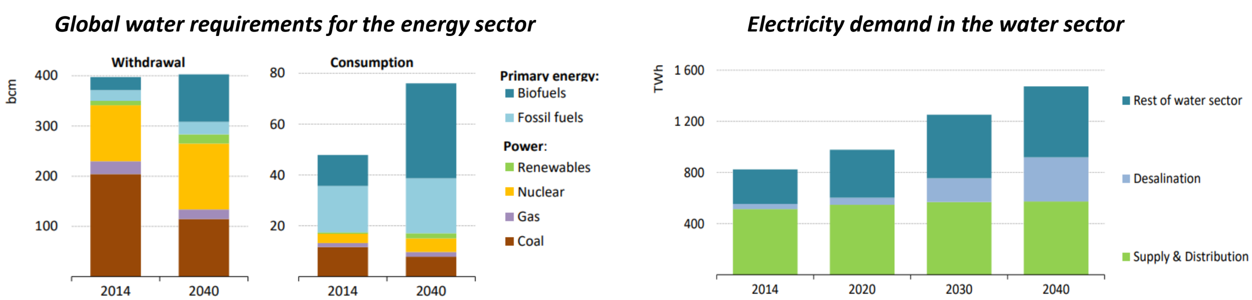
Key messages

- *Energy used to supply water is set to increase rapidly over the coming decades, particularly for desalination, large-scale water transfer and wastewater treatment.*
- *The challenge is to ensure that the development of integrated modelling, data and platforms is driven by users' needs and considers the context (small communities or larger regions).*
- *Developing and monitoring data coverage and quality are key elements to building balanced and representative models that enable robust projections*

Discussion

According to the IEA *World Energy Outlook (2016)* energy used to supply water is set to increase rapidly over the coming decades. The largest demand is expected from desalination, large-scale water transfer and wastewater treatment. The interdependencies between energy and water are expected to intensify as the water needs for energy is expected to rise, mainly for production of fossil fuels and biofuels and power plant operation. Technologies provide solutions to manage strains in the energy and water sectors, and in some cases can ‘leapfrog’ current systems by, for example, recuperating the energy content of wastewater, improving efficiency or using alternative water sources in the energy sector. As energy and water demand increases and energy-water linkages intensify, integrated resource management is pivotal to realising many of the Sustainable Development Goals, or SDGs. Several countries have progressed towards energy neutrality in wastewater treatment - showing that it is possible - and that the benefits are considerable.[5]

Figure 2. Forecasted energy and water demand 2014-2040



Source: IEA (2016), World Energy Outlook 2016, New Policies Scenario

Given the large share of hydropower in renewable energy supply worldwide, availability of hydropower is key to achieving the SDGs. Modelling water resources, in particular resources which cross geopolitical boundaries, enables governments to plan appropriately. The Japanese National Institute for Environmental Studies (NIES) examines the frontiers of global hydrological modelling, water scarcity assessment and the water-energy nexus. The latest hydrological models cover multiple water sources and end-use sectors. High-quality spatio-temporal resolution highlights causes of water scarcity such as imbalances in geographical and temporal distribution and increases in consumption. Water scarcity assessments are often based on socioeconomic scenarios which address, to varying degrees, adaptation and mitigation challenges. All scenarios show a general increase in water stress. However,

[5] See World Energy Outlook: Water and Sustainable Development Goals by Ms. Molly Walton, IEA.

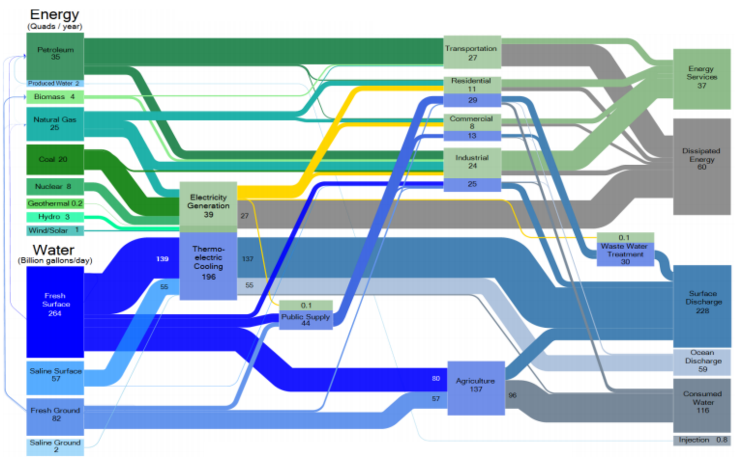
socioeconomic effects outweigh climate effects. For both the energy and water sectors excellent studies have been performed but further modelling of the impact of climate change on the nexus is needed.[6]

The Water-Energy-Food-Ecosystems (WEFE) nexus project of the Joint Research Centre of the European Commission (EC) gathers scientific-based evidence (data, models) for policy-making through impact assessments at the continental-, regional- and small-scale within Europe and Africa. In Europe this covers the expected fresh water consumption for the energy sector 2000-2050. The regional analysis aims at understanding the impacts of water resources on power system operation, and vice versa. Analysis at the smallest scale includes islands where significant desalination capacity is needed (e.g. Baleares Islands). For models, striking the balance between model complexity and "better" results should be combined with a smooth implementation and interaction between models. For data, availability and coverage (e.g. water infrastructure and demand and non-power energy sectors) is equally as important as ensuring data quality.[7]

Using latent heat from natural water bodies for local or district energy is technologically feasible and established in many countries. According to the Swiss Federal Institute of Aquatic Science and Technology, there is significant further potential to provide district heating. Using the case of Switzerland, recuperating the latent heat reduces the long-term warming of lakes and rivers due to climate change, and was not found to have a negative effect on the ecological integrity of the water body.[8]

The United States Department of Energy (USDOE) uses data and modelling to understand vulnerabilities and opportunities in the coupled energy-water system at multiple scales and targets investment in technology R&D and policy engagement to address the vulnerabilities and opportunities. The Sankey diagram in Figure 3 shows recent intersecting energy and water flows at a national level. The USDOE is also examining the implications of multi-sector change over time and regional variability. There is a similar level of complexity in the U.S. in policy and planning. For example, USDOE has developed a beta database of state water policies that affect energy, comprising more than 1,700 entries. In the meantime, USDOE is investing in R&D that addresses water-efficient cooling for thermoelectric plants, energy efficient desalination and water treatment, and energy recovery from liquid waste streams.[9]

Figure 3. US Estimated Energy-Water Flow Diagram, 2011



Source: United States Department of Energy.

[6] See Frontiers of Global Hydrological Modeling, Water Scarcity Assessment, and Water-Energy Nexus Study by Dr. Naota Hanasaki, National Institute for Environmental Studies of Japan.
[7] See Managing Energy and Water through Modelling, by Dr. Ignacio Hidalgo González, Joint Research Centre, EC.
[8] See Using Surface Waters for Heat Management by Dr. Alfred Wüest, Ecole Polytechnique Fédérale de Lausanne.
[9] See The Energy-Water Nexus at US DOE and the US-EU Integrated Water and Power Systems Modeling Challenge by Dr. Diana Bauer, United States Department of Energy.

1. WATER FOR ENERGY

Key messages

- *The technologies that support water-efficient energy systems range from basic research to deployment – with each representing specific challenges and opportunities.*
- *Effective management and planning of water bodies is crucial to energy: they provide latent heating/cooling, enable electricity production and improve fuel processing (CCS and bioenergy).*
- *International cooperation can advance research and facilitate capacity building.*

Discussion

The session explored both technology specific and systemic perspectives on water for energy. The primary focus was on the supply side.

Seasonal forecasts of hydroelectric production enable utilities to manage the risks of supply disruption, for example in the case of drought or severe winters where water bodies freeze. These issues are examined in ongoing research projects of the Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA). The Added Value of Seasonal Climate Forecasting for Integrated Risk Assessment (SECLI-FIRM) aims to demonstrate whether improved climate forecasts (three months in advance) add practical and economic value to decision-making processes and outcomes in both the energy and water sectors. Another project, Climate services for Ocean energy (S2S4E), creates an operational climate service for utilities by investigating the extent improved hydro-meteorological forecasts can optimise hydropower production. The results show that it is indeed possible to forecast the weather for the next three months, with practical applications for the agriculture industry (grape, olive and durum wheat).[10]

.Combining power plants with carbon capture systems reduces CO_2 emissions but may intensify the water usage, which could be controversial, particularly in regions already suffering from water stress. Results from a study of current practice carried out by the IEA Technology Cooperation Programme on Greenhouse Gas R&D (GHG TCP)[11] shows that water consumption may be reduced by using advanced cooling systems or by recovering water from the flue gas. In addition, the GHG TCP conducted an evaluation of the benefits of extracting, processing and re-using the formation water from the geological storage[12]. Re-using the extracted water reduces the water consumption in the entire CCS chain, and may also produce a water surplus. However, the costs and efficiencies of the energy-water-CCS nexus are highly dependent on techno-economic site characteristics. The effect of carbon capture on power plant water requirements is not a constraint - and there are mitigation options. A GHG TCP technical study[13] currently underway will evaluate techno-economic water usage along the whole CCS chain in different locations. Conclusions will provide guidance on optimising local water-energy-CCS nexus solutions.[14]

The vast majority (99%) of the coal-fired power plants in the United States rely on water cooling. Current dry cooling technologies are generally more expensive and can result in a decrease in power output.[15] Using recycled water reduces fresh water consumption but results in a net increase in electricity

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[10] See Managing the impact of drought through seasonal forecasts of hydroelectric production by Dr. Marcello Petitta and Matteo de Felice, ENEA.

[11] Technical Report 2010/05, *Water Usage and Loss Analysis of Bituminous Coal Fired Power Plants with CO_2 Capture* (www.ieaghg.org)

[12] Technical Report 2012/12, *Extraction of Formation Water from CO_2 Storage* (www.ieaghg.org)

[13] The contractor carrying out this study ("*Understanding the Cost of Reducing Water Usage in Coal and Gas Fired Power Plants with CCS*") is the Commonwealth Scientific and Industrial Research Organisation (CSIRO) of Australia. Final results are expected in June 2019.

[14] See Overview of the water-energy-CCS nexus by Dr. Monica Garcia, TCP on Greenhouse Gas R&D (GHG TCP).

[15] Note that there are trade-offs among capital cost, operating cost, and efficiency penalty for dry cooling systems, and the level of trade-off depends on climate conditions and altitude.

consumption (pumping and treatment). Further R&D is needed on promising technologies such as air-cooled heat exchangers (alone and with cool storage), supplemental cooling using waste heat from stack gas, radiative cooling and hydrogen dioxide recovery. More efficiency in power generation is linked to lower cooling water requirements. For this reason the objective of the USDOE's Advanced Research on Dry Cooling (ARID) programme under the Advanced Research Projects Agency-Energy (ARPA-E) is to develop cooling technologies that dissipate no net water to the atmosphere, result in no loss of efficiency for the power plant and result in a less than 5% increase in the levelised cost of electricity (LCOE). In addition, the ARID programme aims at developing technologies for a new generation of high-temperature, high-efficiency, modular and more compact power systems that are twice as efficient as current fuel-to-power options - and with a substantially reduced water and energy footprint.[16]

Improving the environmental footprint of bioenergy in the agricultural sector is possible. For this reason the Global BioEnergy Partnership (GBEP) Activity Group 6, led by the Bioenergy TCP, examined the link between bioenergy production and water consumption. Eleven countries across six continents shared best practice. Highlighted case studies include selection of short rotation poplar genotypes that maximise biomass production while treating wastewater and landfill sites (United States); concentrating vinasse (by-product of ethanol) to increase yield, lower water use and avoid contamination of surrounding water bodies (Paraguay); biogas from livestock waste to be re-used as fertilizer and to reduce water pollution (China); and planting integrated tree crops to maintain agricultural productivity on dry lands by reducing soil degradation and reducing saline groundwater discharge into surrounding water bodies (Australia). This work shows an encouraging variety of water-efficient and positive water-balance bioenergy options, both in terms of supply and geographical distribution. However, there are significant barriers to deployment of these practices. A repository of these and other case studies would raise awareness of the benefits to other countries worldwide.[17]

2. ENERGY FOR WATER

Key messages

- *Well-functioning water cycles are decisive for sanitation and health and should not be considered through market mechanisms alone.*
- *Many promising technologies could substantially decrease energy consumption in the water sector such as lowering temperatures in residential heating, applying low-exergy water recycling technologies in industry or developing new wastewater treating systems for recovering valuable resources and energy with novel separation technologies such as membranes.*
- *PPPs play an important role in scaling up technologies from pilots to large-scale applications. Innovation-driven public procurement effectively stimulates PPPs.*

Discussion

The session focused on energy for – and from – water, highlighting examples of R&D contributions to incremental improvements of water systems as well as more integrated approaches to transforming infrastructure systems at different levels.

Increasing the share of renewable energies in buildings is a priority when designing low-energy buildings. However this can be challenging when considering the heating requirements of hot water for space heating as well as domestic use. Experts from the Technical University of Dresden participated in the study, Low-Temperature District Heating for Future Energy Systems, organised under the auspices of the TCP on District Heating and Cooling (DHC TCP). For space heating it is possible to reduce energy demand by one-third (from the standard 250 to 80 kWh in low-energy buildings) by lowering the water

[16] See the ARPA-E ARID programme.

[17] See Positive bioenergy and water relationships by Ms. Constance Miller, GBEP and FAO.

temperature that is circulated through radiators or under the floor to 25°C. Unfortunately water domestic use requires a temperature close to 60°C which increases the energy demand (22% for existing buildings; 52% for new buildings). Results showed that through improved wall insulation and by separating the pipes of the two circuits, the energy loss from domestic hot water circuit was reduced to approximately 55°C which was sufficient to protect hygiene of drinking water. However, monitoring and maintenance during operation is necessary to ensure adequate temperatures.[18]

The energy and water sectors share many similarities but are profoundly different. There are synergies but also potential conflicts for example for urban planning. Research at the Technical University of Denmark examines 'smart water cities', or cities which are able to integrate intelligent water management into urban development. Examples highlighted from case studies worldwide include assessing the value of water storage, drainage soakaways, and relieving pressure on urban sewer systems during storms by channelling excess water to areas where flooding would not cause widespread damage. The research examines socio-economic issues such as the potential direct and indirect benefits and market value of green and blue solutions such as recreation. In summary, saving money should not prevent creating value. The water sector may not always have a clear business model and therefore may not have a market value per se. And water savings in the energy sector are relatively low. Yet there are clear synergies between water storage and transportation. However, urban planners need to balance urban density and allocating space for water treatment.[19]

Wastewater treatment plants represent 20% of municipal energy consumption but this can be reduced by optimising planning, implementing new processes and managing heat losses. Two recent projects led by AEE INTEC for the TCPs on Solar Heating and Cooling (SHC TCP) and Concentrating Solar Power (SolarPACES TCP) examined the considerable potential energy savings in this area. Combining improved processes with solar thermal technologies increases the efficiency gains. These improvements can transform wastewater treatment plants from energy consumer to energy (electricity and heat) and nutrient 'prosumers'. Membrane distillation is a promising new technology for wastewater treatment as well as for other energy-intensive industries such as food, chemicals, pulp and paper and bio refineries. A number of projects use membrane distillation to recover valuable liquids and minerals for reuse – for example as fuel for ammonia fuel cells.[20]

A new, efficient wastewater plant introduces a natural, energy-neutral method of aerobic granular sludge. The granules have excellent setting properties which enables a much smaller plant, easy to operate and with lower energy and chemical consumption and at lower cost (Nereda, Netherlands, Royal HaskoningDHV). The smaller (up to four times) scale of the Nereda design liberates much needed space in densely-populated urban areas. Despite the 15 years to move from the original concept (Delft University of Technology) to pilot scale, the Nereda plant design has been acknowledged as best practice and a game-changing technology. The PPP National Nereda Development Programme has been a catalyst in scaling up the technology and enabling deployment. The Nereda plant illustrates the contribution of scientific research to developing game-changing and truly sustainable technologies. While society would benefit from rapid implementation of such innovations, the challenge remains how to minimize administrative hurdles for tenders not only within Europe, but for deploying technologies 'elsewhere proven' into markets worldwide. In both cases PPPs have a role to play. [21]

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[18] See Energy efficiency and hygiene in drinking water installations in apartment buildings by Dr. Karin Ruhling, Technical University of Dresden.
[19] See Linking of water and energy models and objectives in an urban context by Prof. Karsten Arnbjerg-Nielsen, DTU.
[20] See Solar thermal energy and waste water management in industrial processes by Dr. Christoph Brunner, AEE INTEC.
[21] See Efficient waste water plants – the case of Nereda by Mr. Andreas Giesen, Royal Haskoning DHV.

3. INTEGRATED APPROACHES

Key messages

- *A key challenge of the energy-water nexus is the policy interdependency.*
- *Modelling and testing show promising application for efficient water resource management and the impact on thermal power cooling.*
- *Innovative processes combine energy recovery with energy use and result in robust wastewater plants.*

Discussion

The session focused on integrated approaches to energy and water (energy for and from water): R&D programmes, operation of complex systems and new integrative technologies.

The USDOE has identified priority directions for further basic and applied research: advanced materials, waste heat recovery, cooling technologies, alternative fluids, and process efficiency. The USDOE also contributes to international projects. The US-Israel Integrated Energy and Desalination Design Challenge has supported desalination system designs that enable flexible demand response and ancillary services to improve interoperability between desalination and the electric grid under various water and electricity conditions. The US-China Clean Energy Research Centre Energy and Water Track examines water use reduction in thermoelectric plants, climate impact modelling, treatment and management of non-traditional waters, better hydropower design and operation and data analysis for decision-making. The U.S.-EU Integrated Power and Water Modelling Challenge has supported integrated modelling efforts that capture dynamic connections between water and power systems, including those that enable flexible operations.[22]

The impact of water scarcity on power generation in Europe and the United States and the possible effect on plans for power plants in other regions is under study at ETH Zurich. A key challenge of the energy-water nexus is the policy interdependency. Smart management of water resources is possible by scheduling reservoir releases (1% of current flow). Technologies that replace water in cooling thermal power plants (dry, wet, once-through) should be combined with policies that monitor river temperatures, levels and the possible effects on wildlife. Once-through cooling is highly sensitive to water temperature changes while wet-cooling is more resilient to water temperature changes. The model shows that by relaxing water policies through smart water management and water temperature constraint relaxation, this results in a nearly 7% increase in converted energy and stable thermal power plant outputs. However during periods of drought, systemic monitoring of power reliability is needed.[23]

In wastewater plants current sludge management options include incineration, landfilling and application as agricultural fertilizer. Due to environmental and health concerns and restrictive regulation, new options need to be developed. The Technical University of Denmark is studying prototype technologies to manage sludge. A two-stage gasifier of sludge pellets enables higher energy efficiencies and a lower tar content which enables use as bio-ash for farming. The pre-treated sludge is ideal for decentralised combined heat and power (CHP). The low-temperature circulating fluidized bed gasifier transforms low-grade biomass and waste into usable fuel for large-scale power plants, and the AquaGreen gasifier, a small-scale innovation, dries the sludge before gasification to improve energy recovery. Reducing ash is another important element in the life-cycle treatment of sludge. These technologies optimise energy recovery, reduce energy use and increased robustness at municipal

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[22] See The Energy-Water Nexus at US DOE and the US-EU integrated water and power system modelling challenge by Dr. Diana Bauer, US Department of Energy.

[23] See Water-Energy Nexus: Impact on Electrical Energy Conversion and Mitigation by Smart Water Resources Management, by Dr. Blaže Gjorgiev and Dr. Giovanni Sansavini (ETH Zurich).

wastewater treatment plants. While the business case is sound and there may be huge benefit for the society, more efforts are needed to deploy these technologies.[24]

4. GOVERNANCE AND REGULATIONS

Key messages

- *The governance of natural resources is necessary to understand why nexus issues exist and how they can be overcome.*
- *It is important to consider the impact of the energy-water nexus on related sectors and ecosystems.*
- *Practical solutions are possible provided they are based on research evidence and that the benefits are clearly communicated to all stakeholders.*

Discussion

The session addressed framework conditions for managing the water and the energy sectors, primarily from the perspective of hydropower and river basins. Given the large share of hydropower in renewable energy supply worldwide, availability of hydropower resources is key to achieving the SDGs.

As many water resources are shared between neighbouring countries, or between regions in the same country, co-operation is needed but often lacking. In order to develop hydro resources sustainably the International Hydropower Association (IHA), together with a multi-stakeholder group, spearheaded the creation of the Hydropower Sustainability Assessment Protocol. The Protocol is a useful tool to assess the sustainability of a hydropower project while fostering transboundary and inter-sectoral co-operation. This helps create a platform for dialogue among project developers and hydropower operators. Since 2014 40 assessments comprising 24,000 MW of power have been undertaken. The Early Stage tool of the Protocol was first applied to assess a multipurpose scheme in the Sava River basin. It helped to provide guidance on the different options of hydropower development and flood protection and control.[25] [26] In the Zambezi river basin[27] the Protocol helped hydropower operators to develop management systems and actions plans to address gaps identified in the internal assessments. Lessons learned showed that the Protocol provided a neutral platform to discuss difficult issues and challenges and enabled a more efficient management of resources. Based on the Zambezi pilot, developers and operators agreed to share progress annually with other stakeholders in the basin.

Countries or regions sharing water resources also share a number of challenges: water availability and pollution; direct and indirect effect on ecosystems; flood risks; gaps and overlaps in institutional mandates; and conflicting policies, policy timelines, implementation and environmental regulation. The Water Convention of the United Nations Economic Commission for Europe (UNECE) provides a framework to improve water management co-operation. The "Water-Food-Energy-Ecosystems Nexus in Transboundary Basins" project comprises scientific analysis and a platform for dialogue to optimise resource management and foster transboundary and intersectoral co-operation. To date five river basins and one aquifer were assessed. Lessons learned show that ecosystems are central to the transboundary nexus (and agriculture is a strategic issue) and cooperation is necessary to improve efficient management and use of the resources. Science can provide evidence but analyzing the existing

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[24] See Pyrolysis and Thermal Gasification of Sludge by Jesper Ahrenfeldt, Danish Technical University.
[25] The Sava River flows through Slovenia, Croatia, along the northern border of Bosnia and Herzegovina, and through Serbia.
[26] See Designing collaborative and adaptive approaches to river basin development by Cristina Diez-Santos, International Hydropower Association.
[27] The Zambezi River is shared among eight riparian countries: Angola, Botswana, Malawi, Mozambique, Namibia, Tanzania, Zambia and Zimbabwe.

governance issues is necessary to understanding how they can be overcome. And solutions are implemented when the benefits are well understood and clearly communicated.[28]

[28] See Energy-Water-Ecosystems Nexus: reducing transboundary tensions by Lucia de Strasser, UNECE.