



SETIS

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THE RELEVANCE OF THE WATER-ENERGY NEXUS FOR EU POLICIES

A photograph of water cascading over a dam spillway, creating a series of white, frothy waves. The water is a deep blue-green color, and the dam structure is visible in the background. The image is used as a background for the magazine cover.

SETIS Magazine

*The relevance of the water-energy nexus
for EU policies*

No. 18 - October 2018

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EDITORIAL

Policy makers are increasingly interested in the water-energy nexus. Significant amounts of water are used for extracting and transforming energy; and energy is used for collecting, pumping, treating and desalinating water. This interdependence implies that the management of energy and water should be addressed simultaneously, in order to increase energy efficiency in the water sector and reduce the water footprint of the energy industries.

The JRC¹ *WEFE Nexus project* (Water-Energy-Food- Ecosystems Nexus: Analysing solutions for securing supply), which began in January 2018, aims to improve the resilience of water-using sectors, allowing the JRC to leverage its capacity to integrate various policy aspects (agriculture, energy and environment) while addressing the specific needs of policy DGs.

In May 2018, the IEA's Experts' Group **workshop**² on *R&D Priority-Setting and Evaluation* explored opportunities to address the R&D planning and policies related to the energy-water nexus in a more effective way. The workshop's report identifies nexus-related challenges and opportunities and offers perspectives and best practices.

During the same month, the second Sentinel-3 satellite (part of the European Union's Copernicus programme) delivered its first data set. The satellite provides information about oceans and inland waters (areas, temperatures, quality and depth), vegetation, land use and many other aspects to the **Copernicus Global Land service**³.

Back in 2016, the JRC and the United States Department of Energy (DoE) jointly organised the workshop ***Understanding the Water-Energy Nexus: Integrated Water and Power System Modelling***⁴, where experts compared and exchanged state-of-the-art modelling methodologies and best practices, discussing problems and solutions. In December 2018, the DoE will organize a follow-up event, the *2nd High-Level Workshop on Understanding the Water-Energy Nexus: Integrated Water and Power System Modelling*. In this occasion, experts will discuss the results of the *Integrated Water and Power System Modelling Challenge*, in which different teams are modelling and analysing scenarios related to energy and water systems.

- 1 The Joint Research Centre is the Commission's science and knowledge service. The JRC employs scientists to carry out research in order to provide independent scientific advice and support for EU policy.
 - 2 <http://www.iea.org/workshops/addressing-the-energy-water-nexus-through-rd-planning-and-policies-.html>
 - 3 <https://land.copernicus.eu/global/>
 - 4 <https://ec.europa.eu/jrc/en/event/workshop/understanding-water-energy-nexusintegrated-water-and-power-system-modelling>
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NEWS

The European Strategic Energy Technology Plan (SET-Plan) aims to transform the way we produce and use energy in the EU, achieving EU leadership in the development of technological solutions to reach the 2020 and 2030 energy and climate goals. The SET-Plan, supported by its Strategic Energy Technologies Information System (SETIS), is the key implementing instrument of the European Commission's Energy Union Research and Innovation (R&I) Strategy.

The annual [EU Sustainable Energy Week](#)¹ took place in Brussels on 5-7 June, and involved over 60 sessions and 2,500 participants. The SET-Plan Secretariat organised the session, *Strategic Energy Technology Plan: from a joint vision into investments*, exploring answers to the following questions, highly pertinent given the current 'implementation stage' of the SET-Plan:

- How can public and private sources of finance support the execution of the Implementation Plans?
- Are innovators' financing needs sufficiently met by the existing funding framework?
- Is the current innovation ecosystem conducive to the required increase in R&I investments, or does it need to be improved?

This year's SET-Plan Conference will take place in Messe Wien in Vienna (Austria) on 20-21 November 2018. It will take stock of progress towards the SET-Plan priorities, following the finalisation of the relevant [Implementation Plans](#)², and aims to identify how publicly and privately funded R&I efforts, at European and national level, contribute to the EU's energy transition. It will highlight the importance of making synergies and developing partnerships among public and private actors to implement R&I activities with real impact. The discussions will address the challenges of meeting the objectives for 2030 and 2050, the financial instruments in support of R&I, the EU's position in the world, and the importance of engaging cities and regions. Registration opens soon and participation is free. You can find out more on the [conference website](#)³.

One SET-Plan Steering Group meeting took place during the second quarter of 2018. The main result was the endorsement of three new Implementation Plans. One regarding the [Initiative for global leadership in wind energy](#)⁴, another on [Bioenergy and renewable fuels for sustainable transport](#)⁵ and finally, [Europe to become a global role model in integrated, innovative solutions for the planning, deployment, and replication of Positive Energy Districts](#)⁶.

Another important outcome was the approval of the [forward-looking SET-Plan agenda 2018-2023](#)⁷ (Agenda 23), including activities to be carried out over the next five years to ensure the SET-Plan's success and impact over that period. The document is operational in nature and aims to record the actual working methods which can facilitate the delivery of the actions described in the various Implementation Plans. This document was jointly drafted by the SET-Plan countries and the European Commission, led by Austria and the Netherlands.

The afternoon session of the Steering Group meeting hosted representatives from the European Energy Research Alliance (EERA), who presented EERA's contribution to the SET-Plan Implementation Plans. Earlier in the meeting, SET-Plan countries debated and expressed their support for the participation of relevant stakeholders (EERA, ETIPs and other relevant players) during the upcoming Steering Group meetings.

1 <https://www.eusew.eu/>
 2 <https://setis.ec.europa.eu/actions-towards-implementing-integrated-set-plan/implementation-plans>
 3 <http://www.setplan2018.at/>
 4 https://setis.ec.europa.eu/system/files/setplan_wind_implementationplan_0.pdf
 5 https://setis.ec.europa.eu/system/files/setplan_bioenergy_implementationplan.pdf
 6 https://setis.ec.europa.eu/system/files/setplan_smartcities_implementationplan.pdf
 7 https://setis.ec.europa.eu/system/files/set-plan_agenda23.pdf

FOREWORD

THE RELEVANCE OF THE WATER-ENERGY NEXUS FOR EU POLICIES

Energy and water systems depend on each other in many ways. The power sector is a clear example, since almost all electricity generation technologies, as well as carbon capture and storage, use significant amounts of water. Water is necessary in the coal sector too, to extract oil and gas and to refine oil products into fuels and petrochemicals; it is also used to grow biomass for the bioenergy sector. Conversely, energy is required to extract, convey, deliver and treat water.

Most energy and climate projections suggest that the water-energy nexus will be affected by the shifting availability of water resources due to climate change and the increasing penetration of non-dispatchable renewable energy sources. It is therefore crucial to estimate these impacts: water resources shall be accurately incorporated into power systems operations and planning, water use shall be integrated into large-scale grid analyses, and market design studies will have to consider the value of water.

An evolving energy system may affect other sectors beyond the water-energy nexus. It is therefore necessary to establish appropriate allocations of water resources, whilst limiting any negative effect on natural ecosystems. Amongst the many concerned EU policies, we recall the [Water Framework Directive](#)¹ (amended several times since 2000); the Drinking Water Directive (for which the European Commission has recently proposed a [revision](#)²); the Common Agricultural Policy (for which several legislative proposals have been [put forward](#)³); and water diplomacy initiatives, particularly involving developing countries. Proper consideration of energy-related aspects into water system planning may help to better assess the impact of the nexus on many key policies.

Given the relevance of the water-energy nexus to several EU initiatives, Horizon 2020 (the current Framework Programme for Research and Innovation) supports related projects, from those aimed at reducing the water consumption of concentrating solar power plants to those which propose integrated approaches to energy, sustainable water management and climate change mitigation. Horizon Europe, the recently proposed 2021-2027 Framework Programme for Research and Innovation, aims at exploiting the synergies between sectors even further, which could be beneficial for water-energy nexus research.

The global profile of the issue offers many opportunities for international cooperation. For example, in the context of the [EU-US Energy Council](#)⁴, the US Department of Energy (DoE) and the European Commission have launched a collaboration on integrated water and power systems modelling. In 2016, the Commission's Joint Research Centre in Ispra hosted an expert workshop. Based on the participants' input, the DoE and the Commission are now supporting modellers in a challenge to show the way forward for the integration of their power and water system models. Modelling activities are underway and comparative exchanges are taking place between the teams. A second expert workshop will take place in the US in December 2018.

We welcome this new issue of the SETIS Magazine focussed on the water-energy nexus, which reflects the increasing importance of cross-sectorial and multidisciplinary approaches.

EUROPEAN COMMISSION'S DIRECTORATE-GENERAL FOR RESEARCH & INNOVATION (DG RTD)

This Commission department is responsible for the EU policy on research, science and innovation, with a view to creating growth and jobs and tackling our biggest societal challenges.

1 http://ec.europa.eu/environment/water/water-framework/index_en.html

2 EC Communication (2017) 753: Proposal for a Directive of the European Parliament and of the Council on the quality of water intended for human consumption

3 https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/future-cap_en

4 <https://ec.europa.eu/energy/en/topics/international-cooperation/united-states-america>



ARTICLE

THE WATER-ENERGY-FOOD-ECOSYSTEMS (WEFE) NEXUS PROJECT AT THE COMMISSION'S JOINT RESEARCH CENTRE (JRC)

Better together: the need for cross-sectoral collaboration

With the combined effects of growing population, rising incomes and expanding cities, demand for water will continue to grow, while in many regions water availability is becoming more uncertain. The pressure will be further exacerbated by climate change, which will strongly affect the EU's neighbouring regions, such as Africa and the Middle East. This increasing water stress will intensify competition between water users. A lack or an excess of water may undermine the functioning of the energy and food production sectors, with societal and economic effects. Energy and water are inextricably linked: we need '*water for energy*' for cooling, storage, biofuels, hydropower, fracking etc., and we need '*energy for water*' to pump, treat and desalinate. Without energy and water, we cannot satisfy basic human needs, produce food for a rapidly growing population and achieve economic growth. Producing more crops per drop to meet present and future food demands means developing new water governance approaches. At the same time, addressing the water needs of the energy and agriculture sectors should not have an unduly

negative effect on natural ecosystems that provide essential services, such as fish provisioning, flood protection, erosion prevention, pollination, and indeed water to users. These interactions have been so far largely underappreciated. Solutions need to focus on efficient and equitable allocation of water across all sectors, recognising at the same time that they should be tailored to the socio-economic and ecological specificities of a region. More integrated approaches are needed to take into account the interactions between water, energy and agriculture as well as household demand.

Cross-sectoral partnership is a key feature of *Transforming our World: The 2030 Agenda for Sustainable Development*¹. The integration of cross-sectoral policies has also received expanding attention in the European Union strategies. The impact assessment accompanying the Communication, *Clean Energy For All Europeans*², emphasizes that the availability of water resources, in particular for hydropower, and extreme weather events are likely to affect the power supply in various ways, e.g. thermal generation threatened by a lack of cooling water.

1 <https://sustainabledevelopment.un.org/post2015/transformingourworld/publication>
2 EC Staff Working Document (2016) 410 final: Impact Assessment.

The EU Commissioners for agriculture and the environment have launched a Task Force on Water and Agriculture that is intended to **develop a long-term transition to sustainability for EU agriculture with regard to water issues**³. Building on early lessons learnt from energy, water and food security in developing countries, the Commission's Directorate-General for International Cooperation and Development (DG DEVCO) has started the Nexus Regional Dialogue Programme to develop policy recommendations and action plans for future investments in Africa, Latin America, Central Asia and the EU neighbourhood.

JRC delivering WEFE-Nexus assessments and solutions

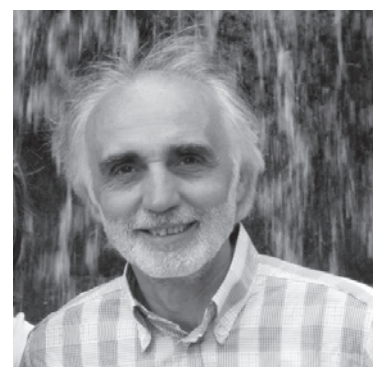
In this context, the goal of the JRC WEFE-Nexus project is to help, in a systemic way, the design and implementation of European policies and strategies that are dependent on water in order to identify areas for EU policy convergence, coordination and integration. By combining expertise and data from across the JRC, the WEFE-Nexus project provides support to several Commission DGs, informing cross-sectoral policymaking on how to improve the resilience of water-using sectors such as energy, agriculture and ecosystems. The specific objectives that will achieve the overall goal of the project are:

- Analysis of the most significant WEFE interdependencies by testing strategies, policy options and technological solutions under different socio-economic scenarios for Europe and beyond. The project will help implement several EU policies (e.g. the Common Agricultural Policy, the Water Framework Directive, the Energy Union and the EU Development Policy) as well as initiatives and agreements at international level (e.g. the Sustainable Development Goals and the Union for the Mediterranean).
- Evaluation of the cross-sectoral impacts of changing availability of water due to climate change, land use, urbanisation, demography in Europe and geographical areas of strategic interest for the EU (Africa and the EU's closest eastern and southern neighbours) by using an integrated approach, including the socio-economic dimension, to improve policy coherence, develop synergies and negotiate trade-offs.
- Delivery of country and regional scale reports, outlooks on anomalies in water availability, a toolbox for scenario-based decision-making, and science policy briefs connecting the project's outcomes to the policy process.

With an implementation plan until mid-2020, research is clustered around a number of Work Packages, each of them centred on a sub-set of thematic research questions, methods and tools. WEFE-Energy focuses on the assessment of the implications of water resource availability on power system economics and operations, mapping of energy demand by the water services and the water usage of energy technologies. WEFE-Agriculture gathers activities such as the integration of agro-economic and water models, impacts of irrigation and fertilization scenarios on crop water productivity, water quality and ecosystems, and management of the Knowledge Hub on Water and Agriculture. H2OCities will build indicators of urban water trends and pressures and coordinate the preparation of a report on WEFE best practices in the Mediterranean region. WEFE4Dev will analyse trade-offs and propose solutions (intervention projects) with a focus on continental Africa, and diagnostic overviews on major African trans-boundary river basins. WEFE 2030 will analyse trends in multi-sectoral planning of water demand and supply in the next decades, including estimations of pathways towards climate change adaptation.

While Work Packages drive work methodologically, WEFE-Nexus is characterised by high-level deliverables that require collaborative inputs for an analysis going beyond individual sectors, encompassing different sectors at once. The challenge is to build on sector-specific expertise and models from across the JRC and adapt them in order to be able to focus on trade-offs and synergies and identify interlinkages between development targets. To this end, multi-disciplinary competences have been pooled together from within five thematic JRC Directorates. For example, an assessment of hydropower as a factor of flexibility in power generation calls for an estimation of fresh water demands from the EU energy sector up to 2050. By combining hydrological and power system models, an analysis of the impact of projected changes in precipitation, temperature and discharge on hydropower generation has been carried out based on the latest *EU Energy Reference Scenario*⁴. Greece and the Iberian Peninsula have been selected as case studies, taking into account future water demand⁵.

The harvesting of explicit and tacit knowledge from different sources within the Commission and the international scientific community will be central to the WEFE-Nexus project. This will permit a better understanding of the demand for knowledge from policymakers and stakeholders, and integrate the various requests in a coherent research framework, for a coordinated JRC delivery of cross-sectoral WEFE-Nexus assessments and solutions.



GIOVANNI BIDOGLIO

Giovanni Bidoglio currently leads the Water and Marine Resources Unit at the Joint Research Centre of the European Commission, where he provides science-based support to the implementation of EU Directives related to water resources and marine and coastal environments. This includes supporting the international initiatives of the Commission and contributing to the integration of water resource-efficiency considerations into sectoral EU policy areas (agriculture, industry, energy, trade, environment and development cooperation), i.e. the WEFE Nexus. His research interests include the sustainable management of water resources, mapping of ecosystem services provided by freshwater, coastal and marine ecosystems, modelling of bio-geochemical fate and hydrological processes of pollutants, environmental risk assessment, environmental monitoring and innovation in water.

³ EC Staff Working Document (2017) 153: Agriculture and Sustainable Water Management in the EU.

⁴ <https://ec.europa.eu/energy/en/data-analysis/energy-modelling>

⁵ See R. Fernández-Blanco, K. Kavvadias, and I. Hidalgo Gonzalez, 'Quantifying the water-power linkage on hydrothermal power systems: A Greek case study,' Applied Energy, vol. 203, pp. 240–253; and Fernandez Blanco Carramolino, R., Kavvadias, K., Adamovic, M., Bisselink, B., de Roo, A., Hidalgo Gonzalez, I., The water-power nexus of the Iberian Peninsula power system: WATERFLEX project, EUR 29127 EN, Publications Office of the European Union, Luxembourg, 2017, ISBN 978-92-79-80209-6, doi:10.2760/739963, JRC109944



Carmen Marques

Policy Coordinator

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Energy Diplomacy Officer

TALKING TO SETIS

ABOUT ENERGY AND WATER DIPLOMACY

What are energy and water diplomacy and why do they matter?

We take it as a given that successfully addressing truly global challenges such as energy security and water scarcity means the EU cannot act on its own, but it can try to lead the way. Global challenges require joint action on the part of the international community, and preferably the whole international community. Therefore, the EU seeks to use its diplomatic tools in order to get everyone on board, particularly the biggest countries, and to support the most vulnerable ones. In practice, this means ensuring that water and energy-related issues are included, high on the agenda, in our bilateral dialogues with third countries and in multilateral fora. In this way we aim to stress the importance of energy and water as critical elements in external relations and to ensure that the international community takes an integrated approach in addressing them. We believe that 21st century diplomacy is about seeing the whole picture, with all of its interdependencies between different elements, meaning extending diplomacy to areas and actors well beyond 'traditional' inter-state relations. This approach should allow us not only to create bridges and interconnections with third countries, but also to strengthen the EU's role as a global actor.

In an attempt to define the two different but interrelated elements of the water-energy nexus, water diplomacy serves to achieve peaceful, inclusive and sustainable water cooperation between cities, regions and countries. There is no doubt that water is directly related to peace and security, especially in view of the fact that every third person in the world, or 2.1 billion people, lack access to potable water at home, and that 365,000 children under the age of five die every year from diarrhoea. Water scarcity and risks related to water are rising in all regions, with Sub-Saharan Africa as the most vulnerable, due to natural disasters, climate change, pollution and increasing strains on water resources related to the growing water demands of an ever increasing world population. The challenge is enormous – it is estimated that by 2025, half of the world's population could be exposed to water stress conditions¹.

As for energy diplomacy, it is a broad effort to link foreign policy with the challenges and opportunities created in the energy sector, which lies at the heart of all modern economies. It is concerned with the notion of energy access, which centres on the need of all

humans to have access to some form of energy, and the concept of energy security, aiming to provide a reliable and affordable supply of energy to citizens. The need for sustained diplomatic efforts is amply illustrated by the fact that over 1 billion people still lack access to electricity². Increasingly, energy diplomacy is also concerned with the geopolitical impact of the ongoing technology- and policy-driven transition to a low carbon future. The pace and scope of the spread of renewables worldwide are increasing, making it probable that by 2040, renewables will become the third source of energy in the global energy mix, equalling the share of oil and gas together³.

The overall aim of the EU's diplomatic efforts is to combine actions to catalyse progressive development strategies, with dialogue and advocacy to promote uptake of policies which have been proven to work in other parts of the world – not least in the EU itself – and where we believe we can help share the benefits of our own experience, adapted to local circumstances.

What are the policy objectives and priorities?

The policy objectives of EU Water Diplomacy are neatly set out in the Foreign Affairs Council Conclusions of July 2013. These highlight the potential of water diplomacy to help safeguard security, development, prosperity and the human rights of water and sanitation. The EU has a substantive commitment to address the root causes of water challenges across the world, particularly through its work on development and the environment, as well as its assistance for water and sanitation, in order to achieve the sustainable development goals, including ensuring access to drinking water for all by 2030. One of the objectives of EU water diplomacy is to engage proactively in trans-boundary water security challenges with the aim of promoting collaborative and sustainable water management arrangements and to encourage regional and international cooperation on water.

When it comes to EU energy diplomacy, our aim is to represent the external interest of the EU's Energy Union, and in this context, to provide energy security to our citizens through diversification of energy sources, suppliers and routes. In a broader perspective, the EU seeks to engage in bilateral and multilateral formats in order to: first, provide energy access to those without it in different parts of the world; second, to reinforce the global energy transition while supporting the EU's ambitious sustainability

1 Progress on drinking water, sanitation and hygiene. Joint Monitoring Programme 2017 update and SDG baselines World Health Organization, 2017

2 Energy Access Outlook 2017, International Energy Agency, 2017.

3 2018 BP Energy Outlook

goals and the competitiveness of its economy; and third, to strengthen the EU's role in the global energy architecture, including in building the global liquefied natural gas (LNG) market. The political framework for the EU's energy diplomacy was laid down in the *Foreign Affairs Council Conclusions* of July 2015 and in the accompanying Action Plan. Energy diplomacy was also listed in the EU Global Strategy of 2016⁴ as a new field of EU external action, next to economic diplomacy and cultural diplomacy.

How are these policies interrelated?

Water and energy policies are not only inextricably linked, but together they play an important role in many sectors: food security, the environment, human rights, transport, trade, agriculture, migration and conflict prevention. Energy is an integral part of water processing: you need energy to pump water, treat waste water, irrigate crops and for desalination. The same applies to water: you need water to extract energy sources (fossil fuels are particularly water-intensive), to produce electricity and to cool nuclear plants. Therefore, an integrated approach to the management of water and energy resources – the water-energy nexus, or more comprehensively, the water-energy-food nexus – is essential to policy-making in order to address the challenge of fulfilling simultaneous demands for huge increases in water, energy and food supplies in a sustainable manner. This challenge is especially pertinent in view of the projected increase of the world's population to nearly 10 billion by 2050, resulting in at least 50% increase in food production (since 2013), stimulating demand for water and energy⁵. It is expected that by 2035, energy consumption will increase by 35% (since 2010), leading to an 85% increase in **water consumption increase**⁶.

“Energy is an integral part of water processing”

Recognising the need for a holistic and integrated approach, the EU set itself the objective of supporting governments to devise sustainable responses to food production and the use of water and energy through development, diplomacy and scientific cooperation⁷. We also support efforts in multilateral formats, as in the case of the UN's 2030 Agenda, where water and energy are specifically targeted under goals 2 and 6, and which recognises the importance of these resources in advancing sustainable development and eradicating poverty.

How are these policies implemented?

First, through sectoral and policy dialogues. The EU has a long tradition of energy and water cooperation, including vast experience in managing trans-boundary waters. We have developed energy dialogues and water dialogues with third countries such as India, China and Iran. The dialogues serve as a platform for identifying policy synergies and designing joint actions. Just one example of many is the last EU-China Summit in Beijing on July 2018, where the EU and China adopted a joint statement on climate change and clean energy, and confirmed the importance of cooperation on water, including through the China-Europe Water Platform.

Water and energy aspects are also present in political dialogues with third countries and regions. In 2016 the EU co-launched a specific programme on the water-energy-food security nexus, the *'Nexus Dialogues'*. It is designed to stimulate five regional dialogues in Africa (southern Africa and the Niger Basin), Latin America, Central Asia (the Aral Sea region) and the MENA region. These dialogues involve various stakeholders, including national and regional policymakers, the private sector, academia and civil society. Without cross-border dialogue, resource scarcity, whether related to energy, water or food, risks becoming a source of tension, rather than an agent for cooperative exchange. What are the main outcomes of the Nexus? In the Niger Basin alone, the Nexus has engaged representatives of the water, energy, agriculture and environment sectors and screened 350 cross-border development projects, 246 of them climate-related.

Second, through international structures. In its support for international governance and law in the areas of energy and water, the EU promotes accession to international organisations and agreements. As regards energy, the EU is a member of dozens of multilateral organisations and fora primarily focused on or closely related to energy, such as the G7, G20, Energy Charter, IRENA (the international renewable energy agency) and the Clean Energy Ministerial and Mission Innovation, and participates in the work of many others, including the International Energy Agency. When it comes to water, the EU focuses particularly on the UNECE Convention on the Protection and Use of Transboundary Watercourses and International Lakes as well as the UN Convention on the Law of Non-Navigational Uses of International Watercourses. Through its delegations around the world, and often with the support of EU Member State embassies, the EU actively advocates ratification of these international conventions. We just completed a series of diplomatic démarches in dozens of capitals around the world in favour of the global scope of the UNECE convention.



BEATA SLOMINSKA

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⁴ A Global Strategy for the European Union's Foreign And Security Policy

⁵ The Future of Food and Agriculture. Trends and Challenges. Food and Agriculture Organisation of United Nations, Rome, 2017.

⁶ IEA 2012 in Thirsty Energy: Securing Energy in a Water-Constrained World. World Bank Group, August 29, 2013.

⁷ Under the framework of the EU Global Strategy of 2016

Third, in action. Through its development cooperation, the EU supports access to water and sanitation as well as reliable and sustainable energy. In addition to the bilateral cooperation of the EU Member States, the EU has provided more than 2.2 billion Euros to water and sanitation projects in more than 62 countries worldwide since 2007, connecting more than 70 million people to improved drinking water and more than 24 million people to sanitation facilities. The EU's development assistance on sustainable energy has amounted to over 4 billion Euros since 2005.

A very recent and pertinent example of an integrated and long-term EU approach is the Gaza photovoltaic solar field project, linking four areas of cooperation: energy (renewables), water, humanitarian support and conflict prevention. The EU-funded Southern Gaza Desalination Plant will bring fresh water to nearly 14% of the population by 2020 (the plant currently provides water to 75,000 people; 250,000 is the target by 2020) and has the potential to mitigate societal and political tensions in a highly vulnerable area, where 97% of water resources are unfit for consumption.

What are the main areas of future interest?

In our view, a long term perspective and strategic planning are key to extrapolating from the challenges and trends we observe today to the policymaking of tomorrow. The complexity of the water-energy nexus, influenced by many external factors, such as population growth, rate of urbanisation, climate disasters and regional and global instabilities, necessitates a holistic and forward-looking approach. It means that when planning energy and water diplomacy today, we focus on the world of tomorrow. What is the world

of tomorrow? Let's take an example of a megatrend that we closely follow – the energy transition from fossil fuels to renewables. This phenomenon should not be viewed as a mere change from one set of technologies to another, but rather as a multilayered process, having a profound impact on the world's energy architecture. It may change balances of power by redistributing profits from current fossil fuels exporters to raw materials and technology producers

When planning energy and water diplomacy today, we focus on the world of tomorrow

for renewables. The transition may also result in the loosening of current energy dependencies and the creation of new ones, leaving an imprint on economies and societies, potentially even causing or aggravating social unrest in already vulnerable regions – if it is not foreseen and managed well. What will the long-term impact of energy transition on the water-energy nexus be? How should we use the opportunities it creates to improve energy and water access in the most vulnerable regions? In which formats and with whom should we engage to tap the full potential of the energy transition and at the same time mitigate negative consequences? These are the types of question which are crucial to thinking ahead about our future diplomatic efforts in pursuit of our energy and water policies in the coming years and decades.



CARMEN MARQUES

Carmen Marques is Policy Coordinator on Environment at the European External Action Service. She joined the European Commission in 1987 as a coordinator of relations with the European Parliament in development policy. Subsequently, she worked as a European official in foreign policy for different regions (Africa, Eastern Europe, Central Asia, Caucasus and Latin America) and topics (legal and institutional matters, human rights and democracy, climate change). Prior to her current assignment, she provided support to EU delegations across the world on infrastructure and the promotion of colocation projects with EU Member States and institutions. She graduated from Harvard (LLM 1986) and obtained a PhD in international environmental law from Complutense University of Madrid.





ARTICLE

QUANTIFYING THE TRADE-OFFS IN THE WATER AND ENERGY NEXUS

Can we ensure a sustainable energy and water future?

The trade-offs between energy and water have been gaining international attention in recent years, as resource demand grows and governments struggle to ensure a reliable supply. Significant amounts of water are needed in almost all energy generation processes, from generating hydropower, to cooling and other purposes in thermal power plants, to extracting and processing fuels. Conversely, the water sector needs energy to extract, treat and transport water. Both energy and water are used in the production of crops, including those used to produce biofuels. This relationship is what is known as the water-energy nexus.

Despite such resource interdependencies, energy planners and governments often make decisions without accounting for existing and future water constraints, and vice versa. It is important to analyse and understand the trade-offs as we move towards the achievement of the [Sustainable Development Goals \(SDGs\)](#)¹, to avoid incoherent policies and strategies across sectors. For example, biofuels might be an effective way of reducing greenhouse gas (GHG) emissions in the transport sector, however, if the biofuels are irrigated, it may add to water scarcity and cause water demand conflicts by competing with food production for water and

land. We need to leverage synergies and foster integrated solutions to ensure that the achievement of one SDG does not hinder the achievement of another.

Trade-offs of the water-energy nexus

Given that almost all energy generation processes require water, its availability is a necessary condition for reaching universal energy access worldwide. At the same time, universal energy access can contribute to better water access (by facilitating water extraction, treatment, and delivery) and [water security](#)². Whereas insufficient or intermittent electricity access can limit water availability by restricting pumping, treatment, and distribution, reliable and affordable access can ensure a continuous supply of the required quantities of safe water as well as wastewater treatment services. Improved energy access can also support the use of energy-intensive technologies such as desalination and more powerful groundwater pumps, which is expected to expand rapidly as easily accessible freshwater resources are depleted. However, unless renewable energy is used, these energy-intensive technologies would increase the energy needs and GHG emissions of the water sector. Moreover, if energy resources are developed without monitoring pollution or taking into account water needs, energy access can have a negative impact on water resources. The energy sector not

1 <https://sustainabledevelopment.un.org/post2015/transformingourworld/publication>

2 For a further discussion on the topic, check the subsection on 'Energy and Water' of chapter 6 'Cross-cutting issues of energy: Exploring the nexus of water, food, health, and gender' of the report 'Sustainable Energy for All 2015—Progress Toward Sustainable Energy', International Energy Agency (IEA) and the World Bank, 2015.

only withdraws and consumes water – thus altering water flow patterns and limiting the water available for other users – it also generates large amounts of wastewater that can pollute water resources if not managed properly.

On the other hand, water-related risks can affect the energy sector and slow or hinder progress towards universal energy access. Opportunities for power generation or energy extraction might be constrained by changing water supply patterns due to increased floods and droughts, by reallocation of water resources into other sectors, or by new regulations. We have already seen [examples of water shortages shutting down thermal power plants in India and decreasing energy production in power plants in the United States](#)³. Climate change is further intensifying energy insecurity, with changing rainfall and surface runoff averages, increased water temperatures, and increased probability of extreme weather conditions. For example, a study⁴ found that in Europe, where thermal power plants account for 78% of the electricity produced and 43% of total freshwater withdrawals, power plants' capacity could decrease from between 6.3% to 19% during the summer (depending on the cooling system type and climate scenario for 2031–2060).

The way forward

Sustainable energy planning should take into account its water use and needs. Results from the World Bank's Thirsty Energy initiative show that accounting for the regional variability of water supply and the associated costs of water supply infrastructure for energy can significantly impact energy planning, especially in a water-scarce country like South Africa. The work highlights the importance of the spatial component of energy and water resources and its potential impact on the overall cost of different energy technologies. The results also show that specific energy sector policies can have significant implications for new investments in water supply infrastructure and, in some cases, can strand water supply investments (and vice versa). However, if decision makers plan in a more integrated manner, they can ensure the robustness of water supply for energy and for other water users, thus maximizing the value of both energy and water infrastructure investments.

Win-win solutions are possible. As shown in the [Thirsty Energy reports](#)⁵, if water needs and water supply costs are taken into account, energy policies to mitigate climate change impacts could reduce both CO₂ emissions and water use by the energy sector. Investing now in renewables such as solar PV and wind, that require little or no water to generate electricity, can help not only to mitigate but also to help adapt to climate change in the future. Besides weighing energy sources, policymakers should also focus on boosting energy efficiency both in the supply

and demand side, which also results in [lower GHG emissions and water use](#)⁶.

Infrastructure investments made today are therefore critical. Choices and decisions matter about which energy extraction facilities to develop and where, which power plants to build, which to retire, and which energy or cooling technologies to deploy and develop. Energy infrastructure is designed to last for decades and thus, when decisions are made, future water availability should be taken into account, including climate change impacts and future competing water demands across sectors.

In summary, decisions in one sector can have unintended consequences in another, and integrated solutions are crucial to ensure a more sustainable future for all. Understanding the water-energy interrelationship is critical to building more resilient and sustainable energy and water systems.



ANNA DELGADO

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DIEGO RODRÍGUEZ

Diego Rodríguez is currently a Senior Water Resources Management Specialist based in the World Bank's office in Mexico City, where he is responsible for the coordination, strategic dialogue, formulation and supervision of lending operations, and the design and implementation of sectoral, policy, and analytical studies. He is also the task team leader of 'Thirsty Energy', a

World Bank initiative on the quantification of the trade-offs of the energy-water nexus, and leads the team responsible for formulating and implementing the decision tree framework for incorporating resilience and climate and non-climatic uncertainty into water resource planning and investment project design. He is currently engaged in Kenya, Nepal and Mexico. Prior to joining the World Bank, he worked at the Danish Hydraulic Institute and the Inter-American Development Bank. He has more than 25 years of experience in sectoral, operational, policy and strategy development in water supply, sanitation, and water resources management. He holds a PhD in Economics (Water), an MA in Applied Economics and a BSc in Economics.

³ See Thirsty Energy infographic: <http://www.worldbank.org/en/news/feature/2014/01/16/infographic-thirsty-energy-energy-and-water-interdependence>

⁴ van Vliet, et al, 2012. Vulnerability of US and European electricity supply to climate change. *Nature Climate Change*. p. 1546

⁵ All Thirsty Energy material can be found at: www.worldbank.org/thirstyenergy

⁶ For a further discussion check the Special Feature on 'Energy Access and the Energy-Water Nexus' of the Sustainable Energy Access Report, ESMAP, The World Bank Group.



ARTICLE

ENERGY'S ROLE IN ACHIEVING UNIVERSAL ACCESS TO CLEAN WATER AND SANITATION

Article re-printed from: <https://www.iea.org/newsroom/news/2018/march/commentary-energy-has-a-role-to-play-in-achieving-universal-access-to-clean-water.html>

More than 2.1 billion people drink contaminated water. More than half the global population – about 4.5 billion people – lack access to proper sanitation services. More than a third of the global population is affected by water scarcity, and 80% of wastewater is discharged untreated, adding to already problematic levels of water pollution. It is clear that the world has a water problem – but energy can be a part of the solution.

“It is clear that the world has a water problem – but energy can be a part of the solution”

Energy is essential to water supply, to move water to where it is needed and to collect and treat water and wastewater. Water is required for almost all aspects of energy supply, from electricity generation to oil supply

and biofuels cultivation. This *interdependency*¹ has been a focus of analysis at the International Energy Agency, and the *World Energy Outlook (WEO)*² found that, on aggregate, energy consumption in the water sector globally is roughly equal to that of Australia today, mostly in the form of electricity, but also diesel used for irrigation pumps and gas in desalination plants. Our analysis also found that the energy sector³ accounts for roughly 10% of total water withdrawals and 3% of total water consumption worldwide.

With both water and energy needs set to increase, these linkages will intensify going forward. Our analysis found that the amount of energy used in the water sector is projected to more than double by 2040, while the amount of water consumed in the energy sector (i.e. withdrawn but not returned to source) could rise by almost 60% over the same period.

What then might be the impact on energy demand of achieving Sustainable Development Goal (SDG)

1 <https://www.iea.org/weo/water/>

2 WEO-2016 Special Report: Water-Energy Nexus, International Energy Agency (IEA), 2016.

3 Excluding hydropower which returns much of the water it withdraws to the river; however its water consumption is highly site-specific and the measurement methodology is not yet agreed upon.

6 (providing clean drinking water and sanitation for all)⁴, and what impact might the water-energy nexus have on the attainment of other United Nations SDGs? The answers to these questions will depend on how this nexus is managed.

Advancements in technology offer new options for managing potential strains on energy and water and could allow countries to leapfrog in terms of the solutions used to achieve SDG 6. For example, building new wastewater capacity that capitalises on the energy efficiency and energy recovery⁵ opportunities being pioneered by utilities in the European Union and the United States could help temper the associated rise in energy demand from providing sanitation for all and reducing the amount of untreated wastewater⁶. In some cases, achieving these targets could even produce energy: WEO analysis found that utilising the energy embedded in wastewater alone could meet more than half of the electricity required globally for wastewater treatment.

There is significant scope to use water more efficiently in the energy sector⁷. The availability of water is an increasingly important measure for assessing the physical, economic and environmental viability of energy projects. Improving the efficiency of the power plant fleet, deploying more advanced cooling systems for thermal generation and making greater use of alternative water sources and water recycling can all help the energy sector lower its water use.

‘The availability of water is an increasingly important measure for assessing the physical, economic and environmental viability of energy projects’

Beyond SDG 6, the achievement of other energy-related SDGs, including taking urgent action on climate change (SDG 13) and providing energy for all (SDG 7)⁸, will depend on understanding the integrated nature of water and energy.

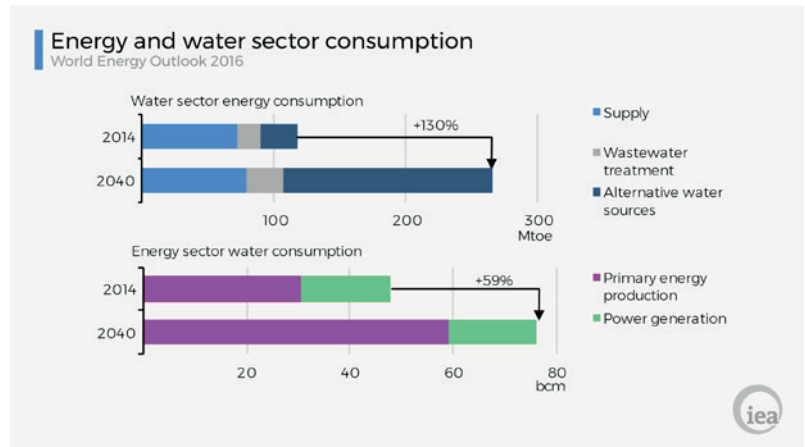


Figure: World energy and water sector consumption. Source: IEA, 2016

The more a decarbonisation pathway relies on biofuels production, the deployment of concentrating solar power, carbon capture or nuclear power, the more water it consumes. If not properly managed, this means that a lower carbon pathway could exacerbate water stress or be limited by it.

There is also a significant overlap between those who lack access to energy and those who lack access to water. WEO analysis⁹ has shown that decentralised renewable systems (off-grid and mini-grids) are the lowest cost option for providing a majority of the new rural connections needed to achieve SDG 7.1.1 (electricity for all). Pairing these systems with filtration technologies or water pumps can provide access to both electricity and safe drinking water¹⁰. Similarly, linking a toilet with an anaerobic digester can produce biogas which can help achieve SDG 7.1.2 (clean cooking for all).

It is evident that understanding and accounting for the water-energy nexus is important for the achievement of the SDGs. This is why the IEA's Sustainable Development Scenario¹¹, which presents an integrated approach to achieving the main energy-related SDG targets on climate change, air quality and access to modern energy, will add a water dimension this year. Understanding the implications for the energy sector of ensuring clean water and sanitation for all will provide policymakers with a clearer picture of what they need to do to hit multiple goals with an integrated and coherent policy approach.

Note: The WEO's work on water as part of the Sustainable Development Scenario will be part of WEO-2018, to be released on 13 November, 2018.



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4 <http://www.undp.org/content/undp/en/home/sustainable-development-goals/goal-6-clean-water-and-sanitation.html>

5 <https://www.iea.org/newsroom/news/2017/march/commentary-waste-not-want-not.html>

6 Target 6.2— universal access to sanitation and Target 6.3- halving amount of untreated wastewater released

7 Target 6.4—increasing water-use efficiency across all sectors

8 <http://www.iea.org/sdg/>

9 WEO-2017 Special Report: Energy Access Outlook, International Energy Agency (IEA). 2017.

10 Target 6.1—clean drinking water for all

11 <https://www.iea.org/newsroom/news/2017/november/a-new-approach-to-energy-and-sustainable-development-the-sustainable-development.html>

A hand in a light-colored lab coat sleeve holds a clear plastic bottle, pouring liquid into a metal rack. The background is a blurred laboratory with various glassware and equipment. A teal banner is at the top, and large white text is overlaid on the center.

Pedro Linares

Prof. of Industrial Engineering

Zarrar Khan

Postdoctoral Researcher

TALKING TO SETIS

ABOUT MODELLING THE ENERGY, WATER AND FOOD NEXUS

Why do we need to model the interactions between energy, water, and food?

Modelling the interactions between energy, water and food is important because the three resources are interdependent, and changes in one sector, as a result of policies, climate change or growing demands, can have serious implications for the others. These

‘The next few decades will see the global population reach 9 billion, with estimates showing up to 30% increases in the water, energy and food sectors globally’

concerns become more critical as populations grow and regions develop, with corresponding increases in consumption and pollution. Energy systems need water throughout their lifecycles, during raw material extraction, power plant cooling, hydropower generation

and biofuel irrigation, for example. Water systems use energy for extracting and pumping source water, for desalination, for water purification and for the delivery and distribution of water. The food sector uses both energy and water extensively for irrigation, harvesting, distribution, processing, packaging and storage. The next few decades will see the global population reach 9 billion, with estimates showing up to 30% increases in the water, energy and food sectors globally, and much higher increases in emerging economies like Brazil and India. In addition, climate change will reduce the availability of water in many regions, including hydroelectricity. As these resources become more stressed, the interdependencies between the sectors become more critical, as does the need to model and understand these interdependencies.

What kind of question can be answered by these models?

With concerns increasing about these nexus issues, several modelling efforts have been initiated, accounting for different levels of interdisciplinary linkage across a range of spatial and temporal scales. Such models bring additional insights into the implications of policies in one sector on the others. For example, a nexus model can help compare differences in water demands when considering new energy capacity technology investments in, say, a gasworks, nuclear plant or wind farm. At the same time, a nexus model would be able to explore solutions for providing additional water by different means, such as desalination instead of transferring water via pipelines. Each of these water investments would have their own corresponding impacts on the energy system, and therefore on carbon emissions. The implications of various irrigation methods or crop choices on energy and water systems can also be analysed. Nexus models thus provide a holistic analysis by capturing inter-sectoral dynamics in policies, subsidies, changing climates and socio-economic pathways across the water-energy-food sectors.

The issue of adapting to climate change showcases the power of these models very well. Climate change will affect water availability, energy supply and demand, and food production. Addressing the three sectors together will allow us to adapt better, and more efficiently.

How can model-based results pave the way for understanding future energy and water demands?

Nexus analysis provides additional information which might otherwise be overlooked when considering future demands. For example, studies have shown



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ZARRAR KHAN

Zarrar Khan is a postdoctoral research associate at the JGCRI at PNNL and an expert in the modelling of interconnected energy and water systems. He completed his PhD in the Erasmus Joint Doctorate programme, 'Sustainable Energy Technologies and Strategies' (SETS), organised by Universidad Pontificia Comillas, TU Delft, and KTH. His Ph.D. research involved the development of a fully integrated hard-linked water-energy optimisation model that was used to analyse water, energy, and climate adaptation strategies in Spain. He received his master in Geotechnical Engineering from Cornell University and has a Bachelors in Engineering and Environmental studies from Dartmouth College.

that energy efficiency improvements in certain regions can decrease water demands by up to 15%. And electricity subsidies for farmers have a direct impact on over-pumping of groundwater as seen in some regions in India. The choice of a technology mix to meet future demands in one sector has a direct impact on the other sectors, and these dynamics

‘Studies have shown that energy efficiency improvements in certain regions can decrease water demands by up to 15%’

are captured by nexus models. Thus, future energy, water or agricultural expansion plans can be combined in nexus models to get a complete picture of the implications and trade-offs, for example when considering coal, gas or renewables in the energy sector; desalination or re-use expansion in the water sector; increasing irrigation efficiency; or replacement of certain water-intensive crops.

How can these models help us to make more energy/water-conscious decisions?

Traditionally, decisions in the water, energy and food sectors are to a large extent made independently by sector-specific agencies or ministries, seldom communicating or sharing data and information with each other. This is partly because of the complexity of each of these systems, and the differences in the physical, spatial and temporal characteristics of each. Nexus models are not meant to replace the more detailed sector-specific methodologies, but should ideally serve as an additional layer, bringing together insights from the individual sector models, harmonising differences, identifying synergies and highlighting potential conflicts. Thus, a nexus framework promotes a more holistic analysis of traditional problems. For example, in a country like Pakistan, which is considering exploiting its previously untapped coal reserves (one of the largest in the world) to address growing energy concerns, a nexus approach would serve well to highlight the water implications of such a large scale strategy in an already severely water-stressed region. Similar decisions in other sectors, such as expanding irrigation systems, investing in desalination or growing biofuel-crops, would all benefit from the holistic perspective offered by a nexus framework.





ARTICLE

EUROPEAN CLIMATIC ENERGY MIXES: A PROOF-OF-CONCEPT CLIMATE SERVICE TO ASSESS FUTURE RENEWABLE ENERGY MIXES IN EUROPE WITHIN THE COPERNICUS CLIMATE CHANGE SERVICE

The electric energy sector is undergoing a major transformation. The established model, of traditional thermal power plants providing most of the 'firm' power to match variable levels of demand, is being challenged by the steadily increasing share of power supply from temporally-variable renewable energy sources, such as wind and solar power (e.g. REN21 2018¹). Demand variability is also increasing as a result of the widespread use of embedded small-scale generation (e.g., rooftop solar PV) and air conditioning, and can further change in response

‘The established model is being challenged by the steadily increasing share of power supply from temporally-variable renewable energy sources’

to price signals. This transformation in the energy sector is taking place against a variable and changing climate. Given the weather- and climate-dependency

of both renewable energy and demand it is important to develop robust climate-based tools that can assist energy planners, market operators and policymakers.

In order to assist the energy sector in understanding the role of climate on energy systems, and uptaking this climate information, the [EU Copernicus Climate Change Service \(C3S\)](#)² has taken as one of its foci the development of climate services for the energy industry, such as through the European Climatic Energy Mixes (ECEM) project. The C3S ECEM's aim has been to produce a proof-of-concept climate service, or Demonstrator, to enable the energy industry and policymakers to assess how well different energy supply mixes in Europe could meet demand, over different time horizons (from seasonal to long-term decadal planning), focusing on the role climate has on the mixes. This objective has been tackled through a close interaction with stakeholders, in a framework that allows for co-design of the service.

The [C3S ECEM project](#)³ started in November 2015, and represents a collaboration between teams from the University of East Anglia (UEA, UK), Electricité De France (EDF, France), the Met Office (UK), MINES ParisTech/Armines (France), the University of Reading

¹ Renewables 2018 Global Status Report (Paris: REN21 Secretariat).

² <http://climate.copernicus.eu>

³ For more information, see: <http://ecem.climate.copernicus.eu/> (from Troccoli et al. 2018, Advanced in Science and Research, to appear).

(UK) and the Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA, Italy). The project had a duration of 29 months.

The specific underlying challenges motivating C3S ECEM are:

- To describe the ways in which energy supply and demand over Europe are affected by the spatial and temporal variations of their climate drivers
- To produce scenarios that demonstrate how different energy supply mixes can meet demand at the European scale, particularly given the projected high level of highly climate-sensitive renewable energies.

The C3S ECEM had a strong programme of stakeholder engagement activities. Input collected via workshops, one-to-one meetings with experts, advisory committee interaction, email surveys, webinars and interactions at key conferences and seminars has been key in developing the **Demonstrator**⁴. This is the tool that collects the output produced by C3S ECEM and presents it in a user-friendly and interactive format, and it therefore constitutes the essence of the C3S ECEM proof-of-concept climate service. For instance, the approach taken in each workshop has considered the expected audience and, especially, the level of progress of the project, starting from a simple wireframe of the Demonstrator presented during the first workshop.

To provide the key ingredients to the Demonstrator, the C3S ECEM project produced reference data sets for climate variables based on the ERA-Interim reanalysis. Subsequently, energy variables were created by transforming the bias-adjusted climate variables using a combination of statistical and physically-based models. These energy variables include: electricity demand, and generation from wind power, solar power and hydropower. A comprehensive set of measured energy supply and demand data was also collected from various sources including **ENTSO-E**⁵, **e-Highway 2050**⁶, **EUROSTAT**⁷, World Bank, national Transmission System Operators (TSOs)

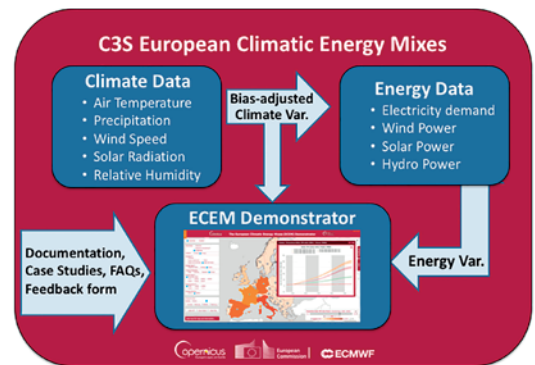


Figure 1: Overview of the C3S ECEM project. Source: C3S ECEM project

data not contained in the **ENTSO-e dataset**⁸, the **WindPower database**⁹ and data from **EMHIRES**¹⁰ and other projects. These data have been critical in providing a reference to assess the robustness of the model used to convert climate into electric energy variables. The main elements of C3S ECEM are shown in Figure 1¹¹.

Climate and energy data have been produced both for the historical period (1979-2016) and for future projections (from 1981 to 2100, to also include a past reference period, but focusing on the 30-year period 2035-2065). The skill of current seasonal forecast systems for climate and energy variables has also been assessed. Data are provided for the European domain, in a multi-variable, multi-timescale view of the climate and energy systems. It can therefore help in anticipating important climate-driven changes in the energy sector, through either long-term planning or medium-term operational activities. For instance, it can be used to investigate the role of temperature on electricity demand across Europe, as well as its interaction with the variability of renewable energies generation. Figure 2 shows an example of how solar power scenarios for the next decades are represented within the C3S ECEM Demonstrator¹².

The C3S ECEM Demonstrator is constituted of a visual tool to display and investigate climate and energy data, along with a comprehensive set of documentation such as fact-sheets, methods and assumptions, key messages, **event case studies**¹³ and frequently asked questions. It also has the option to enter feedback for the developers of the

4 <http://ecem.wemcouncil.org/>

5 The European Network of Transmission System Operators for Electricity: <https://www.entsoe.eu/>

6 e-Highway 2050 was an EU project (2012-2015), participated in by a large number of Transmission System Operators (TSOs), energy companies and research institutions, that investigated a number of scenarios for power production across Europe: <http://www.e-highway2050.eu>

7 <http://ec.europa.eu/eurostat/data/database>

8 <https://transparency.entsoe.eu/>

9 <http://www.thewindpower.net>

10 European Meteorological derived high-resolution renewable energy source generation time series: <https://ec.europa.eu/jrc/en/scientific-tool/emhires>

11 Climate data of relevance to the energy sector (top left) are first bias-adjusted and then converted into energy variables through statistical modelling or transfer functions. Climate and energy variables (var.) produced by the C3S ECEM are presented via the Demonstrator (inset Figure expanded as Figure 2) together with a wide range of documentation.

For more information, see: <http://ecem.climate.copernicus.eu/> (from Troccoli et al. 2018, Advanced in Science and Research, to appear).
12 It shows solar power for France for the projection period (RCP8.5) for the five e-Highway2050 scenarios described in the text (time series plot) and for Europe (underlying map) for year 2050 for the first e-Highway2050 scenario (purple line in the time series). Comprehensive documentation about the Demonstrator is available at the bottom left hand side of the Demonstrator (<http://ecem.wemcouncil.org/>, this figure has been produced from the Demonstrator).

13 Silva, V. and A. Burtin (2015) Technical and Economic Analysis of the European System with 60% RES, EDF Technical Report.

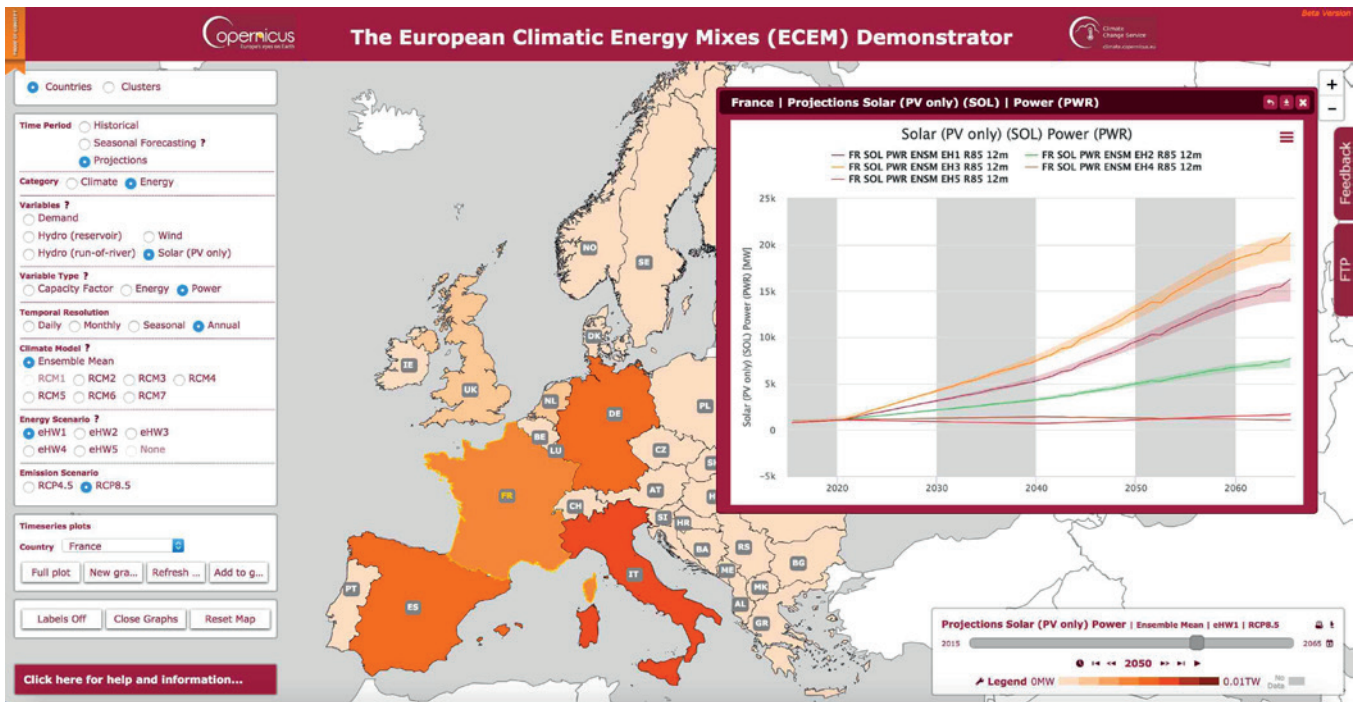


Figure 2: Screenshot of the C3S ECEM Demonstrator. Source: C3S ECEM project

Demonstrator to take on board. However, response to users' queries, data updates or fixes are not acted upon within set time frames. In this sense, this is a proof-of-concept climate service, rather than a fully-fledged (operational and/or commercial) climate service. The C3S ECEM Demonstrator is viewed as a building block for the C3S operational service for the energy sector which is currently being developed.

Article based on:
<https://www.adv-sci-res.net/15/191/2018/>



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Professor Alberto Troccoli is based at the University of East Anglia's School of Environmental Sciences and is also the Managing Director of the World Energy & Meteorology Council. He has about 25 years of experience in several aspects of meteorology and climate and, in the last decade, their applications, particularly to the energy sector. He has worked at several leading institutions such as NASA, ECMWF (UK), the University of Reading (UK) and CSIRO (Australia). He has led a number of projects and capacity building activities, particularly in the area of meteorology and energy. He is currently the leader of the EU H2020 project The Added Value of Seasonal Climate Forecasting for Integrated Risk Management (SECLI-FIRM) project, and of the C3S Energy activity. He served as a leader of the Australian Solar Energy Forecasting System project in collaboration with the Australian Energy Market Operator (AEMO), the US National Renewable Energy Laboratory, the Bureau of Meteorology and two Australian Universities, which has produced an operational system run by AEMO. Alberto is the chief editor and an author of four books: *Seasonal Climate: Forecasting and Managing Risk* (2008), *Management of Weather and Climate Risk in the Energy Industry* (2009), *Weather Matters for Energy* (2014), *Weather & Climate Services for the Energy Industry* (2018). He is the main author of the UN-led Global Framework for Climate Services (GFCS) Energy Sector implementation plan. He attended the May 2015 WMO Congress as an invited expert on energy sector matters and he is regularly invited internationally to give talks on energy and climate. He is the convener of the International Conference Energy & Meteorology (ICEM) series. Alberto holds a PhD in physical oceanography from the University of Edinburgh (UK).



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TALKING TO SETIS

ABOUT THE WANDEL PROJECT:

WATER RESOURCES AS AN IMPORTANT FACTOR FOR THE GLOBAL ENERGY SYSTEM TRANSITION (ENERGIEWENDE) AT LOCAL AND GLOBAL SCALE

How might water resources affect the global energy transition?

Energy generation uses water locally (at the place where energy is generated) but also at a distance, where the (raw) material is produced or extracted, e.g. to build a thermal plant or produce the fertiliser used in biomass production. Different energy systems have different water needs, locally and globally. Conducting a water footprint analysis along the entire energy supply chain, i.e. including local and distant water needs, allows for the comparison of water used per generated unit of energy across different energy systems. Depending on water availability, the amount of water required may or may not restrict energy generation locally and globally. Differences in water demand are to be expected between different regions and energy systems, and will likely influence the long-term sustainability of energy generation, depending on the system and the availability of water. Examples include the predicted shortage of cooling water, with increasing climate change affecting water quantity and temperature, which further influences the effectiveness of thermal plants. These water constraints may limit the expansion of thermal energy production and thus accelerate the Energiewende.

What are the goals of the WANDEL project?

WANDEL¹ systematically compares different energy systems in terms of their local and distant impacts on water resources along the entire energy supply chain, by comparing water needs with locally available water resources. Thus, the project will demonstrate how energy generation affects water resources locally and regionally (illustrative for four different energy systems using four case studies in Germany, Brazil and Morocco). It also investigates the remote effects on regions around the world from the perspective of water availability. The project will work on developing new strategies to reduce these impacts and avert water constraints. WANDEL adopts an interdisciplinary approach with multiscale consideration of the direct and indirect effects of energy generation on water resources. It aims to link data-based and model-based analyses of various energy scenarios with their direct and long-distance effects on the water sector.

How can energy and water policies benefit from this project?

WANDEL will use the case studies to map out regulatory and technical solutions for reducing negative



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Dr. Flörke leads the research group, Global and Regional Dynamics – Water (GRID-W), at the Center for Environmental Systems Research, University of Kassel, Germany. Her research concentrates on the identification and quantification of the consequences of global change for the environment and for societies,

related to water in particular. The principal goal is to develop and evaluate strategies that help to prevent its negative impacts. She works on the application and development of the global water modelling framework, WaterGAP3, to simulate changes of the hydrological cycle, water use, and in-stream concentrations. She has gained broad experience in international and European research projects and has been involved in managing a number of interdisciplinary projects addressing scenario development as well as water and climate change issues.



ZITA SEBESVARI

Dr. Sebesvari heads the Environmental Vulnerability and Ecosystem Services (EVES) Section at the United Nations University, Institute for Environment and Human Security (UNU-EHS). She is an ecologist and environmental scientist with a focus on research and decision support in the context of ecosystem-based disaster risk reduction

(Eco-DRR) and adaptation (EbA), guided by social-ecological vulnerability and risk assessments, including drought risk. Her research also focuses on soil and water resources use and degradation in the context of the 2030 Agenda for Sustainable Development, which includes analysing trade-offs among different goals such as those on water (SDG 6) and energy (SDG 7). Dr. Sebesvari also serves as a Lead Author in the IPCC Special Report on Ocean and the Cryosphere in a Changing Climate (SROCCC, Chapter 4). With regard to the WANDEL project, Dr. Sebesvari leads the case study in Brazil, focusing on biomass (sugarcane)-based energy production.

impacts and will develop a set of indicators specifically designed to target synergies and trade-off in the water-energy nexus. The indicators will contribute to the assessment of different energy systems in terms of their impact on water resources, and conversely, will also allow for the characterisation of the impacts of water scarcity on energy generation.

¹ <https://bmbf-grow.de/en/joint-research-projects/wandel>



ARTICLE

SEEKING SUSTAINABLE CLEWs – CLIMATE, LAND, ENERGY AND WATER STRATEGIES:

AN INTEGRATED SYSTEMS APPROACH TO MEET SUSTAINABLE DEVELOPMENT CHALLENGES

What is the CLEWs approach?

CLEWs¹ stands for 'Climate, Land, Energy and Water systems'. It is a modelling framework first introduced by the International Atomic Energy Agency in 2009² and later by a multi-United Nations agency application to Mauritius³. It takes inspiration from global integrated assessment models made popular in the *Limits to Growth study*⁴ that tried to assess the integrated nature of development.

Climate, land, energy and water systems are closely linked. An impact in one can affect the other. A (climate induced) change in weather affects water supply. Water is needed for power plant cooling, to generate hydro, to maintain forests etc. At the same time, if we run out of fresh water, it needs to be desalinated. The former affects energy supply, the latter affects energy demand. The compounding impacts happen at the same time and can be disproportionate. For instance, in California there have been droughts that have led to investment in highly energy-intensive desalination. But this is at a time when electricity

generation is strained as there is lower hydropower generation. The power system becomes strained at a time when it is needed most. The same is happening in Europe. During recent years power plants across Europe have been at risk of being shut down due to warm temperatures and low river levels. This is either as the water used to cool them becomes dangerously hot to the ecosystems in the rivers to which it is returned, or that (often in the south) there is simply not enough water in the rivers to provide cooling. However, as there is a rise in temperature, at exactly the same time, people start to draw more power as they turn up air-conditioners. This results in power supply shortages. Another example: in a country like Sweden, where summer water restrictions are encouraged, forests have been at risk of fire due to high temperatures and unusually low rain. Further, forests (together with wastes) account for 25% of the country's total primary energy supply (TPES). Thus, climate impacts water, land, and the energy system, causing re-enforcing stresses that current planning methods do not typically capture.

1 www.CLEWs.online

2 IAEA, I.A.E.A., 2009. Annex VI: Seeking Sustainable Climate, Land, Energy and Water Strategies (CLEWs), in: Nuclear Technology Review 2009. IAEA, Vienna.

3 Howells, M., Hermann, S., Welsch, M., Bazilian, M., Segerström, R., Alfstad, T., Gielen, D., Rogner, H., Fischer, G., Velthuisen, H. van, Wiberg, D., Young, C., Roehrl, R.A., Mueller, A., Steduto, P., Ramma, I., 2013. Integrated analysis of climate change, land-use, energy and water strategies. *Nat. Clim. Change* 3, 621–626.

4 Meadows, D.H., Meadows, D.H., Randers, J., Behrens III, W.W., 1972. *The limits to growth: a report to the club of Rome* (1972).

CLEWs has been developed to understand how these systems work together to deliver the services we need to survive. The *'delivery chains'* in those systems consist of interlinked activities. They originate from natural resources and ecosystems (such as the rain or forests described above). These are extracted, processed and transported to provide products and services (such as food and water, lighting, cooling, etc.). Those chains are shaped by economics, technology and policies — notably to ensure secure supplies.

The intricate links between energy, water, land use and climate (as well as the broader environment) systems have been well documented for a long time. However, society's *'delivery chains'* have traditionally been managed individually (or in related groups). Initially, interactions between many chains were largely inconsequential — their supplies were abundant and our demand was small. For practical reasons, separate management also allows for delineated responsibility and focused planning. Hence, at all governmental levels, we find authorities for energy, water, agriculture and so on, each tasked with their own sectoral mandates. Such mandates often do not include any assessments of the impacts of action in one sector on others. A notable exception is the European Commission's Strategic Environmental Assessments⁵. These assessments are required for certain types of public plans and programmes (for example, on land use, transport, waste and water management, energy and agriculture).

Although practical, delineation generally discourages coordination. At best, it misses synergies; at worst it creates stresses and conflict. Sectoral interdependencies are increasing. We require increasingly staggering amounts of water to provide food and energy. Water systems require (and can produce) large quantities of energy. At the same time, these sectors affect and are vulnerable to a changing climate.

A CLEWs analysis starts with a clear representation of the interactions between Climate, Land, Energy and Water systems through the following linked delivery chains from *'resource to service'*. I list a few below:

- **1) Energy delivery chains and links**

Energy is required for almost all activities. It powers appliances and machinery to provide services such as lighting, cooking, transport, heating, mechanisation and more. It is extracted from renewable or depletable⁶ energy sources – such as fossil or nuclear.

It impacts land, which is needed for wind farms and solar panels and which is scarred by activities such as mining. In the case of biofuels, cultivable land is required, reducing its availability for other

crop production or ecosystem support. (Biomass is often collected for fuelwood in poor regions with growing populations, contributing to deforestation and land degradation).

After energy is extracted, it is processed into forms which are easier to use or transport. For hydropower, water is collected in reservoirs – or through-run of river power plants – and electricity generated. (Electricity can be used to power a number of services). This again requires the use of land and the altering or management of water flows. When flooded in dams, vegetation becomes trapped, and decomposing vegetation releases GHGs such as methane. Other transformations take place too. Crude oil and bio-fuel feeds (as well as coal and natural gas) can be transformed into gasoline or diesel for cars and many fuels are used directly (such as coal, gas or fuelwood). Generally, burning fuel to generate electricity (and many other energy transformations) requires large quantities of water for cooling. Or it requires water in its processes, as is the case with oil refining. And where fossil fuels are burned, GHG emissions such as CO₂ are released⁷.

Fuels are then transported and distributed and converted into the *'energy services'* mentioned earlier. This is done by appliances or machinery. In this context we will pay special attention to the use of biofuels for transportation, water pumping for irrigation; chemical processes for fertiliser manufacture and (to cope with climate change induced temperature changes) air-conditioning. In most cases GHG (and other) pollutants are emitted directly if non-renewable fuels are burned.

As you will no doubt have picked up – energy (the E in CLEWs) – is closely interwoven with the other systems. Let's take water next.

- **2) Water delivery chains and links**

Water, like energy, is required for life and needed for a number of essential services. Broadly speaking, there are three sources: sea, local precipitation and fossil. Seawater can be desalinated using energy for evaporation or reverse osmosis – this requires large quantities of energy. Local precipitation charges basins, and fossil water is often pumped (or *'mined'*). Where desalinated water or other supplies are far from demand, water is pumped or fed to users via canals or rivers, and is also stored in reservoirs and dams. The pumping can require significant quantities of energy, depending on the context. (India, for example, uses 20-30% of all its electricity just on water pumping!)

⁵ Howells, M., Rogner, H.-H., 2014. Assessing integrated systems. Nat. Clim. Change 4, 246.

⁶ Note that where a renewable resource such as wood-fuel is depleted faster than it is regrown, it is also in a sense depletable – especially where land is damaged due to overuse.

⁷ Note on CCS.

In the power sector, users include thermal power plants⁸, which use water for cooling, as well as hydropower plant. Further significant quantities of water are required for other energy processing, such as refining or the manufacture of synthetic fuels.

Water has a particularly important role to play in agriculture. Where local precipitation is insufficient, the land is often irrigated. The availability of irrigation water together with sufficient nutrients can transform marginal lands into cultivable land. (Conversely, over-fertilisation and irrigation can damage land). Irrigation can be gravity- or mechanically based, the latter using oil or electricity.

Water has a high potential for purification and recycling, however, the majority of water that is returned to the atmosphere does so via seawater evaporation. Other causes of water loss include transpiration through plant growth as well as evaporation during irrigation, distribution, storage and other uses such as power generation. With excessive evaporation, quantities of water available for direct use can be harmfully reduced.

Again, the links between the W (water) in CLEWs and the other systems are clear.

• 3) Weather and climate

It is understood that the climate is being affected by releases of greenhouse gasses from the burning of fossil fuels and chemical processes. Examples include fossil fuel power production, fertiliser production, crude oil and biomass refining, transport and land cultivation. Thus, there is a significant drive to adopt energy technologies which mitigate or reduce the quantities of CO₂ emitted. Examples include renewable energy such as hydropower, wind and biofuels (such as diesel or ethanol produced from crops) as well as nuclear. Another method of reducing CO₂ emissions is to capture them in forests or using carbon sequestration and storage technologies.

The climate, as it has done in the past, is changing, and this is associated with changes in weather patterns. When droughts occur, water for electricity generation is limited; demand for irrigation increases, forests become vulnerable and desertification can take place. Conversely, flooding can damage cropland, infrastructure and human settlements.

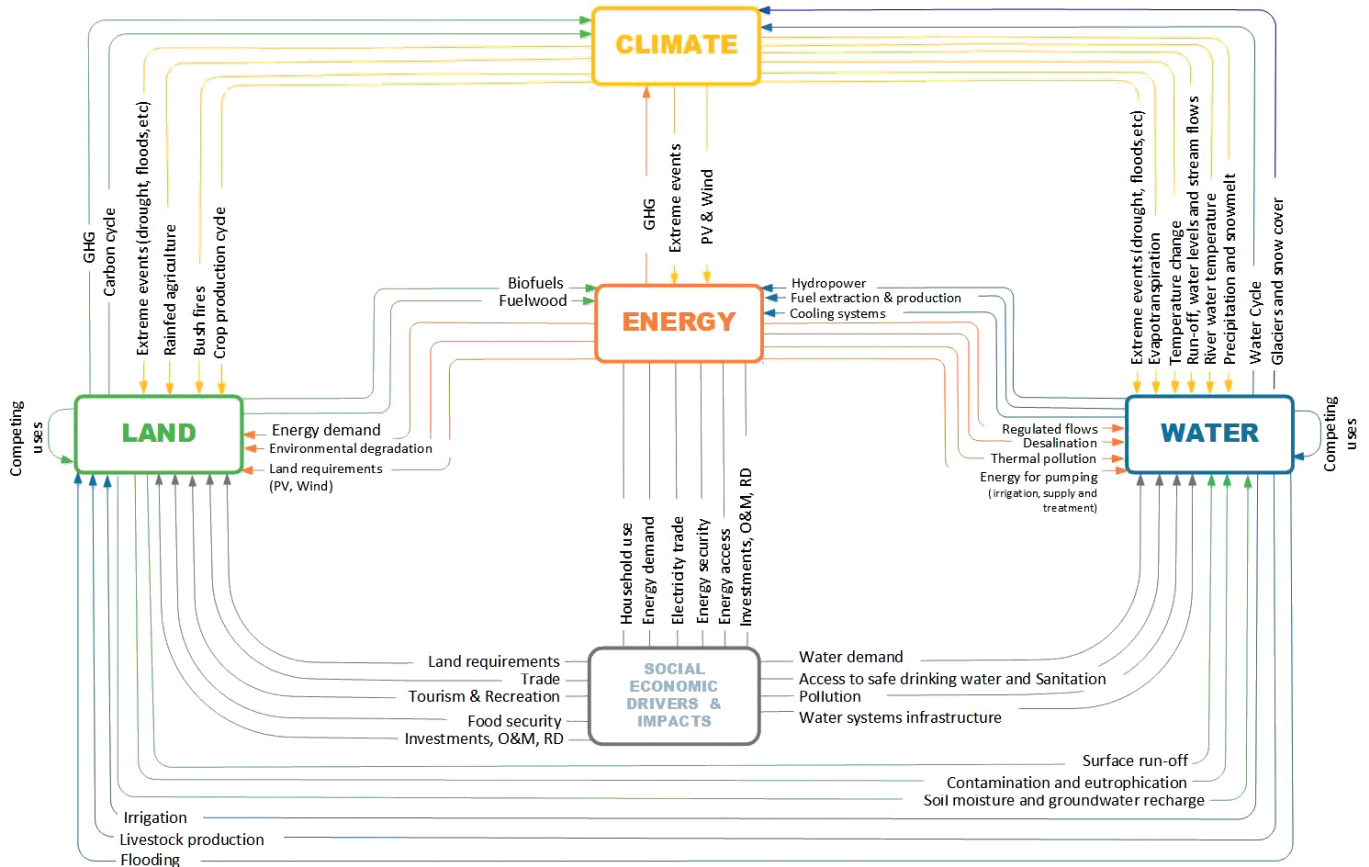


Figure 1. A reference Resource to Service system (RRSS) diagram. Source: CLEW

⁸ The US Geological Survey (USGS 2004) estimates that over 50% of freshwater withdrawals were for the cooling of thermal power plant (with the majority of that water returned after use).

The link between Climate, the C in CLEWs, and the other systems is again transparent. And that moves us on to the 'L' in CLEWs, Land.

- **4) Land delivery chains and links**

Very broadly speaking, land (which can be cultivated) falls into four categories: deserts, marginal, cultivable and forests or other natural vegetation such as savannahs. The quantity of cultivable land increases as forests are cleared, or marginal lands and deserts are claimed by irrigation and fertilisation.

The quantity of land available is limited. Thus, depending on the value of its produce, competition for its use can be high. Some typical land uses include livestock, crops for fuel processing, food and other products, wood fuel and infrastructures such as roads, cities, canals and dams. Where practices are poor, land can be damaged as overgrazing, over-cropping, over-fertilisation and fuelwood harvesting takes place. As vegetation changes – e.g. dense forests for crops – significant quantities of GHG emissions can also be released. Land can also be damaged through excessive silting, ground-water removal and erosion relating to agricultural activities and weather patterns.

Clearly the CLEW systems are interwoven – however, to turn this into something we can use, we need to map these systems and delivery chains.

To do so we sketch a RRSS or '*Reference Resource to Service System*' diagram. The RRSS is useful as a tool to visualise relations which need parametrising as simplified mathematical expressions. Each line represents a '*flow*' and each '*box*' an activity – or group of activities – which accounts for some change to that flow. This approach is common, particularly in energy modelling activities (where the RRSS is reduced and known as a Reference Energy System (RES)).

This mapping typically starts a CLEWs analysis. The CLEWs framework can be applied to different cases by defining the flows and activities that are related – and needed for the analysis at hand. The analyst calibrates the levels of: each flow (in terms of physical quantities); activities in terms of their historical production capacities (where systems of equipment are used); costs of operation and investment; as well as mass and energy balance relations⁹ etc. Depending on the price and affordability of the services produced, they are used by the socio-economy. As demands by the socio-economy grow, each

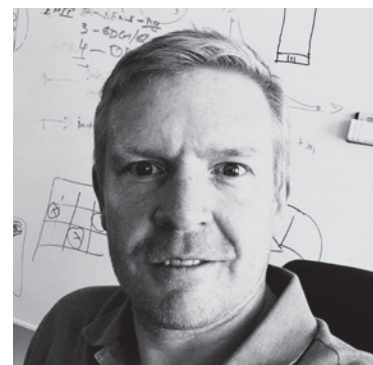
system adapts to meet them. While meeting the demands, flows and activities may be limited by physical or financial limits. There may also be interactions between the supply chains for services and the manner in which they are provided. Taken together, the chains of the **CLEW system**¹⁰ can be mapped and quantified. After that they are modelled. Representing all of these systems together forms an integrated model which is then used to determine scenarios of how to meet these future needs. This is done while navigating the constraints inherent in and between the systems and chains represented. (Note that the modelling can be done by taking several sector models and passing data between them. It can be done in a single spreadsheet. Often, in our case, we use a free open source model generator with a pre-set generic structure).

The level of detail, complexity, model choice and scenarios investigated are often a function of the policy question that needs to be addressed. And, in my opinion, there are many models that can be used and configured. What is critical is to co-develop the problem description, undertake clear mapping and then apply the most appropriate tools. In a nutshell I would call that the '*CLEWs*' framework.

What kind of policy questions can be addressed by CLEWs?

There are several that are typically taken on. They include:

- **Policy assessments:** in the context of limited resources and constraints it is important for the policymaker to ensure that the policies adopted are as effective as possible. If multiple outcomes can be achieved by a single policy, it may be a far more effective development driver than if only a single objective or system was considered in isolation¹¹ which shows by combining a number of analyses that multiple benefits can significantly improve the development or counter-development. An aim of the CLEWs framework is to provide a more complete, multi-system policy assessment.
- **Facilitating policy harmonisation and integration:** there are many instances of contradictory policies throughout governments. The government of India, for example, has provided free electricity to pump irrigation water to grow crops to feed the poor. But those subsidies cause water to be extracted faster than it is replenished, dropping water tables, damaging land and straining the power grid. In time, the



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⁹ Such as, for example, thermodynamic efficiency, which relates energy flows out of an activity to energy flows coming into it

¹⁰ More information on CLEWs is available at www.clews.online

¹¹ Howells, M., Laitner, J., 2003. A Technical Framework for Industrial Greenhouse Gas Mitigation in Developing Countries. Proc. Am. Council. Energy-Effic. Econ. 2003 Summer Study Ind. Energy Effic.

very resources needed for the poor will become damaged and unaffordable. An objective, integrated CLEWs tool would help individual policymakers assess the impact of their policies on the goals of other policies. Thus, different policy goals can be traded off transparently.

- **Technology assessments:** technology options can affect multiple resources at once. Appraising them across policy domains will be an important next step. An example is how nuclear power in the UAE could reduce GHG emissions, increase exports of domestic fuels such as oil, as there is lower domestic demand by the power sector and provide bulk electricity required for desalinating water. As with policies, an aim of the CLEWs framework is to provide a more inclusive assessment of technological options.
- **Scenario development:** in a sense distinct from the aims above, another goal is to take consistent scenarios development further, to understand future development opportunities. This is important to help understand, for example, whether current development really is sustainable? Are there other development scenarios to consider? And, what kinds of technology improvement might significantly change a development trajectory?

How is the CLEWs framework applied?

The CLEWs framework¹² has been used in a plethora of projects and in different ways; two are particularly notable. The most comprehensive process for its application has been with the United Nations Economic Commission for Europe (UNECE) in its **nexus approach**¹³. The other, a similar approach, focuses on **national governments**¹⁴. It is applied by the United Nations Division of Economic and Social Affairs (UNDESA) and the United Nations Development Program (UNDP) and recently by the **United Nations Economic Commission for Africa (UNECA)**¹⁵.

The approach includes three main tracks: A) stakeholder driven assessment of the interlinkages of key delivery chains and identification of resulting CLEWs linkage or 'nexus' challenges; B) development of a quantified CLEWs model or set of CLEWs modelling tools; C) Dissemination and capacity building.

The tracks have varying levels of overlap, depending on the setting. **Track A** focuses on supporting a group of stakeholders and decision makers by reconstructing¹⁶ CLEWs delivery chains and identifying critical interactions between them. (Thereafter unearthed key challenges are used to guide the analysis and model development). In **track B** the model(s) are developed in order to understand the importance of the interlinkages and the implications of inter-sector policy harmonisation. A useful starting point is a simple reconstruction of sector-specific models. The reconstruction can also be particularly helpful in building trust by showing that the results of in-house assessments can be accurately replicated without the interlinkages. After which the impact of the linkages is demonstrated by running the model(s) in a fully integrated mode with consistent scenario parameterisation. **Track C** focuses on capacity building. This happens during A and B (with the building of chains and their replication) but added to this (and notable in the UNDP/UNDESA approach) is training on the use of the software developed as well as the co-creation (i.e. writing together) of the policy outputs.

These are some concrete examples of applications of the CLEWs framework, spanning local and global application:

CLEWs has been applied at municipal level in a **prize-winning**¹⁷ work in **New York City**¹⁸ and Oskarshamn (Sweden)¹⁹. Interesting findings here were that being water efficient resulted in large energy and GHG emissions savings. An example of water efficiency measure is a low-flow shower head. Using them reduces water pumping and treatment needs, both of which require energy.

At the global level, the **GLUCOSE toolkit**²⁰ explored climate change and mitigation strategies by examining the interactions between three modules: the energy sector, land and food production, and material production.

In World Bank Group (WBG)²¹ work, agricultural expansion, irrigation, growing population and hydro-power needs were concurrently evaluated within a modelling framework that used an ensemble of models. The objective was to understand the risk posed by climate change to the multi-billion Euro

12 Climate, Land (Food), Energy, Water Strategies – CLEWs Framework, n.d.

13 This was co-created with KTH-dESA to understand complexities that arise between countries as a result of shared rivers and basins. de Strasser, L., Lipponen, A., Howells, M., Stec, S., Bréthaut, C., de Strasser, L., Lipponen, A., Howells, M., Stec, S., Bréthaut, C., 2016. A Methodology to Assess the Water Energy Food Ecosystems Nexus in Transboundary River Basins. *Water* 8, 59.

14 UN Modelling Tools, n.d.

15 Climate, Land, Energy and Water Strategies (CLEWs) to Support the Implementation of Nationally Determined Contributions (NDCs) to Climate Action

16 The re-construction helps ensure that the all parties are 'bought in' to the reality of the linkages – and missing or additional phenomena are properly captured

17 <https://www.kth.se/en/itm/inst/energiteknik/forskning/desa/desa-news/best-paper-award-at-the-4th-international-conference-on-sustainable-development-1.678487>

18 Engström, R.E., Howells, M., Destouni, G., Bhatt, V., Bazilian, M., Rogner, H.-H., 2017. Connecting the resource nexus to basic urban service provision – with a focus on water-energy interactions in New York City. *Sustain. Cities Soc.* 31, 83–94.

19 Urban CLEWs work featured at the first Urban Transitions Global Summit, n.d.

20 Glucose is the Global User-friendly CLEWs model. See: Global CLEWS, n.d.

21 Cervigni, R., Liden, R., Neumann, J.E., Strzepek, K.M., 2015. Enhancing the climate resilience of Africa's infrastructure: the power and water sectors. *The World Bank*.

future of planned African hydropower investments. That work was undertaken by the WBG, Stockholm Environment Institute (SEI), the RAND Corporation, Massachusetts Institute of Technology (MIT) and the Royals Institute of Technology (KTH).

Integrated national CLEWs models are used (or to be used) for national planning efforts with support from UNDESA and UNDP in Bolivia, Costa Rica, Ghana, Mexico, Kyrgyz Republic, Paraguay, Mongolia, Vietnam, Uganda and elsewhere. Similar models have been developed with the UNECA for Sierra Leone and Ethiopia. In each case, detailed representation of resources and interactions were made and then optimised in order to inform policy development. Key findings include the identification of *'hotspots'* where future conflict might arise due to external constraints (such as, for example, climate change) or siloed policy making (for example biofuel production reducing domestic food production security).

The UNECE trans-boundary river basin nexus approach has been implemented on four river basins and is also currently being implemented on a groundwater aquifer

in North Africa. An example is the Sava River Basin, which extends over 97,700 km², is about 3000 km long and is shared between five countries. The study concluded that the development of hydropower should be done sustainably and be developed for power generation as well as so called *'balancing'*. This allows the integration of other renewable energies such as solar and wind. Given the traction, a deep dive study followed into the Drina River Basin (DRB), which is one of the main tributaries of the Sava River. This DRB study underlined the importance of coordinating the operation of the hydropower plants. By coordinating their scheduling, dams could be used as flood control during risky high-rainfall times, with increasing revenue to be had from regional power sales²².

In summary, the challenges are real, and the CLEWs toolkit is being developed to help address them. There is a growing body of analysis. A regular [summer school](#)²³ is open for academics (to support them setting up graduate programs) as well as government analysts. A key model-generator and CLEWs process is free and open source with a growing community. Please do join in and contribute!



²² UNECE, 2017

²³ www.sdsummerschool.com



ARTICLE

How RES-BASED DESALINATION MAY HELP TO MEET WATER NEEDS IN THE EU

Life on earth depends on water. Europe is relatively 'prosperous' in water resources, but the supply is unevenly balanced, with shortages largely affecting the southern member countries. Three quarters of the planet's surface is covered with water, but 97% of this huge quantity is contained in the oceans, and is therefore salty, while only a tiny 3% is made up of fresh water. This small percentage of the earth's water, however, supplies most of the needs of humanity, and is found in lakes, rivers and groundwater. It is thus obvious that the only practically inexhaustible source of water is the oceans, though their very high salinity is much above the safe consumption limit. It would therefore be possible to address the water shortage problem faced by many countries and many millions of people with seawater desalination. However, the separation of salts from seawater requires large amounts of energy which, when produced from fossil fuels, can increase environmental pollution and exacerbate the earth's climate-related problems. There is therefore a need to employ environmentally-friendly energy sources such as renewables to desalinate seawater. Fortunately, Europe's southern region, which is dry and thus in more need of desalinated water, enjoys high levels of renewables: mainly solar and wind energy.

Desalination processes require substantial quantities of energy to achieve the removal of salts from seawater. This is a very important parameter as

energy is an expensive commodity and a permanent running cost, which varies with fuel prices and which few water-starved regions can afford. A variety of systems used to convert seawater into fresh water suitable for human use exists as well as a variety of systems which can be used to convert renewable energy sources into useful forms of energy. These can be used to power desalination systems and include a variety of solar collectors, photovoltaics and wind turbines. There are two main categories of desalination system: direct and indirect collection systems. Table 1 presents the most important technologies in use today. The motive power in the phase-change or thermal processes is a thermal energy source, whereas in the membrane or single-phase processes, electricity is used. An exception is membrane distillation (MD) which is classified as a phase change process but needs membranes to operate. All processes presented in Table 1 require the chemical pre-treatment of seawater to avoid foaming, fouling, scaling and corrosion as well as chemical post-treatment, mainly for disinfection.

Direct collection systems use one piece of equipment, which both collects solar radiation and uses the energy collected to desalinate seawater. Representative of this type of system is the solar still, available in various designs, as shown in Table 1. It is a simple and cheap system but its water production per collector area is relatively small – in the order of 4-5 litres

PHASE-CHANGE PROCESSES	MEMBRANE PROCESSES
<ol style="list-style-type: none"> 1. Multi-stage flash (MSF) 2. Multiple effect distillation (MED) 3. Vapour compression (VC) <ul style="list-style-type: none"> - Thermal vapour compression (TVC) - Mechanical vapour compression (MVC) 4. Membrane distillation (MD) 5. Freezing 6. Humidification/Dehumidification (H/D) 7. Solar distillers (SD) <ul style="list-style-type: none"> - conventional solar stills - special solar stills - cascaded type solar stills - wick-type solar stills - multiple-wick-type solar stills 	<ol style="list-style-type: none"> 1. Reverse osmosis (RO) <ul style="list-style-type: none"> - RO without energy recovery - RO with energy recovery (ER-RO) 2. Electrodialysis (ED)

Table 1 Desalination processes. Source: Cyprus University of Technology

per square meter at best. Indirect collection systems employ two different subsystems; one for collecting renewable energy and another for desalination. These comprise two broad categories; the phase change processes, which include the multistage flash, multiple effect distillation, vapour compression and membrane distillation; and the membrane processes, which include reverse osmosis and electrodialysis. It should be noted that conventional desalination systems are similar to solar systems, since the same type of equipment is used. The main difference is that in conventional systems, a boiler or mains electricity is used, whereas in the renewable ones, solar radiation or wind energy is employed.

Generally speaking, renewable energy systems produce energy from resources that are 'freely' available in nature and do not deplete with consumption. Above all, their collection and use is carried out in a pollution-free way and is friendly to the environment. Therefore, fresh water production using renewable energy-powered desalination technologies is considered to be a viable solution to water scarcity problems. Several renewable energy desalination pilot plants have been installed across

the world. While some were experimental, erected simply to prove their suitability and viability, most have operated successfully for years. They are custom designed for specific application of solar or wind energy to produce fresh water. The energy required for various desalination processes, established by a survey of manufacturers' data, is presented in Table 2. Renewable desalination systems are applicable in areas with abundant renewable energy resources, and are today considered to be economically viable. These viable renewable energy options, available in many southern European countries today, include large PV parks and wind parks to power osmotic-type units and combinations of concentrating solar power plants with thermal desalination units, which can be integrated with the condenser of the thermodynamic cycle employed.

Process	Heat input (kJ/kg of product)	Mechanical power input (kWh/m ³ of product)	Prime energy consumption (kJ/kg of product) ¹
MSF	294	2.5-4 (3.7) ²	338.4
MED	123	2.2	149.4
VC	-	8-16 (16)	192
RO	-	5-13 (10)	120
ER-RO	-	4-6 (5)	60
ED	-	12	144
Solar Still	2330	0.3	2333.6

Notes: 1. Assumed conversion efficiency of electricity generation of 30%
2. Figure used for the prime energy consumption estimation shown in last column

Table 2 Energy consumption of desalination systems. Source: Cyprus University of Technology



SOTERIS KALOGIROU

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The magazines also include a SET Plan news section detailing the last developments to achieve the Integrated SET Plan objectives, and European Commission services and/or relevant organizations/institutions are invited to provide a foreword that highlights the main policy developments on the subject.

The relevance of the water-energy nexus for EU policies

Policy makers are increasingly interested in the water-energy nexus. Significant amounts of water are used for extracting and transforming energy; and energy is used for collecting, pumping, treating and desalinating water. This interdependence implies that the management of energy and water should be addressed simultaneously, in order to increase energy efficiency in the water sector and reduce the water footprint of the energy industries.

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