

## **Energy for adaptation: connecting the Paris Agreement with the Sustainable Development Goals**

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The landmark climate deal adopted in 2015 at the end of the 21th UNFCCC Conference of the Parties (COP 21) confirms the need for increased efforts to cope with the impacts of climate change (UNFCCC, 2015). For the first time in the history of climate negotiations, the Paris Agreement establishes a long-term adaptation goal, elevating adaptation to the same level as mitigation, and reiterating the urgency of an integrated approach to climate resilience and inclusive low-carbon development. Even if the rise in global average temperature is restricted within 2°C, impacts of climate change are inevitable (De Cian et al. 2016, Park et al. 2018). Climate change is projected to negatively impact primarily low-income countries located near the Equator (Burke et al. 2015) that have limited capacity to adapt (Field et al. 2014).

In identifying what adaptation looks like on the ground, the research community shares a broad consensus on socio-economic development being the foremost strategy to reduce vulnerability (Schelling 1992, Smit et al. 2001, McGray et al. 2007, Tol 2018). Being a key enabling component of development, energy can also facilitate adaptation. Recent reviews defining how energy services have appeared in the literature (Fell, 2017) highlight the linkages between energy use and adaptation. Several energy services are noticeably climate sensitive and contribute to reduce adverse effects of weather shocks or uncomfortable climate conditions. A classic example is that of space heating and cooling. Climate-sensitive energy services also include water heating, energy use in transportation, water pumping, and refrigeration (Fell 2017). On closer inspection, many of the energy services that are climate sensitive largely overlap with the basic energy requirements necessary to ensure minimum standards for decent living (Rao and Baer, 2012) related for example to adequate water supply or safe and comfortable space (Rao and Min, 2017), reinforcing the mutual synergies between universal energy access objectives and adaptation. While the literature has mostly emphasized the role of energy as key to sustainable development (McCollum et al. 2018) and for decent living conditions (Rao and Pachauri, 2017), stressing the urgency to decarbonize the sources used to provide those services, the question of how climate adaptation will further influence the demand for energy services remains understudied (Ebinger and Vergara, 2011).

Here we offer a novel perspective on energy use and services in the context of climate change adaptation policy. Starting from the definition of energy for adaptation as those functions and actions that reduce climate vulnerability and influence energy use, we scrutinize the Nationally Determined Contributions (NDCs) submitted to the UNFCCC in the context of the Paris Agreement to identify high-priority adaptation options most directly connected to energy

demand. After validating the results of the analysis within the adaptation literature, we approach the development-adaptation relationship (Denton et al. 2014) from the perspective of the latter element in the relationship. Finally, we investigate how energy for adaptation could contribute to achieve the 17 Sustainable Development Goals (SDGs).

### **Adaptation needs energy**

The energy sector is the primary target of present efforts to reduce greenhouse gas emissions (Clarke et al. 2014), but energy services also provide a critical margin of adaptation across all sectors of the economy. Space heating and cooling allow households to maintain the desired levels of thermal comfort in their living environment, alleviating climate-related damages to health (Deschenes and Greenstone, 2013, Dell et al. 2014). Cooling systems make commercial and industrial activities possible in places where already difficult climatic conditions can negatively influence production levels and labour productivity (Hsiang, 2010, Park and Behrer, 2017). Industrial demand is sensitive to outdoor temperature as some activities, such as cooling for food production, take place within a narrow stable temperature window (Hekkenberg et al., 2009). Transport is also likely to be affected, as air conditioning affects vehicle efficiency and fuel consumption (Scott and Huang, 2007). Increased demand for water to deal with extreme droughts implies greater dependency on energy in both the agricultural and residential sectors. Not only water requirements for agriculture will need more energy, cooling demand for livestock will also see an increase in demand (Scott and Huang, 2007). As a result, adaptation will become an increasingly important driver of energy demand. Recent evidence suggests that by 2050 the world population could need up to 17% more energy in order to cope with a warmer climate across all sectors of the economy (De Cian and Sue Wing, 2017).

As the scale of adaptation needs increases, more energy could lead to more emissions and higher energy prices, with potentially negative consequences for poor households and economic competitiveness. Whether those implications could ultimately hinder progress towards sustainability and decarbonization, and whether the rapid need to adapt will lead to maladaptation (Barnett and O'Neill, 2010) locking our societies in energy-intensive infrastructure, remains unexplored. Indeed, we still do not have projections that integrate energy needs for adaptation into emission reduction scenarios. A few examples can illustrate the importance of omitted interactions. Water and energy are closely linked, and the production or consumption of one resource requires the use of the other. Desalination, water treatment, and distribution are all highly energy-intensive processes, and the energy-intensity of the entire water chain is likely to increase over time as water resources become less accessible while treatment standards and demand rise (Sanders and Webber 2012). Failure to integrate impacts and adaptation needs into the planning process could lead to unsustainable scenarios (Hallegatte et al 2014). Adaptation through the use of energy bear a high risk of being maladaptive as it can lead to higher emissions, cause a disproportionate burden on the most vulnerable, entail high opportunity costs, lead to path dependency, and reduce the incentive to carry out more sustainable forms of adaptation (Barnett and O'Neill 2010).

### **NDCs reveal countries' priorities with respect to adaptation**

While explicitly asking countries about their needs in terms of energy for adaptation could be plagued by the fact that governments often avoid making their preferences clear, the NDCs offer a unique opportunity that reveals national interests and preferences regarding climate

action (Kehoane and Victor 2016). Through their bottom up approach, the contributions submitted under the Paris Agreement make it possible to understand countries' adaptation priorities and the extent to which planned actions could involve a significant use of energy. Among the 190+ national governments that submitted an INDC or a NDC, henceforth (I)NDC, to the UNFCCC, 139 of them include adaptation plans, especially those proposed by emerging and developing countries where the priority of protecting their people from dangerous climate impacts is more urgent. We thoroughly analyze the 139 (I)NDC documents and identify the adaptation objectives, plans, actions that most directly affect energy demand while reducing vulnerability. When NDCs were missing, the INDC documents have been considered. We examined both unconditional and conditional actions described in the (I)NDCs, paying particular attention to the context, and considering all the other sections (e.g. capacity buildings, technology transfer, fairness and ambition). We keep track of whether a specific option is mentioned as adaptation, mitigation, or both. We define energy for adaptation as those adaptation strategies that most directly affect energy use according to the following four criteria:

- 1) Are energy-intensive
- 2) Relate to energy-intensive sectors
- 3) Require access to energy in order to spread their benefits and reach targeted population
- 4) Can save energy directly or indirectly, by reducing the use of other resources that would require energy

The final list of options includes only those that i) are mentioned as adaptation by at least one country and ii) are supported by the adaptation literature (e.g. IPCC Fifth Assessment Report, 2014, Bertule et al. 2018, Bower et al. 2018, Ebinger and Vergara 2011, UNFCCC 2017, EUEI PDF 2017). For example, decentralized renewable energy or energy efficiency are mostly mentioned in relation to mitigation, but several countries propose those strategies in the adaptation section, and their importance in coping with climate impacts is acknowledged within the adaptation literature (Table 1).

The second step of the analysis establishes a linkage between the resulting energy for adaptation options and the 17 Sustainable Development Goals (SDGs). We associate each of the energy for adaptation options identified in the first step to the SDG targets or indicators it contributes to on the basis of an extended review of the existent literature. We focus on synergies (i.e. positive linkages) as the objective of the analysis is to bring evidence on how specific adaptation options to climate change contribute to sustainable development. To avoid double counting, within each SDG we uniquely map each adaptation option to the most strongly related indicator or target. Goal 13 on climate change is the exception, as all options contribute to the goal by definition. Indicators and targets are not always consistent with one another. We therefore use alternatively SDG indicators or targets on a case-by-case basis, based on the strength of the linkage. Because of the great variety of targets proposed in the SDG framework, in this phase we distinguish the identified options in case countries clearly specify they will be implemented using renewable energy sources.

### **Evidence of energy use for adaptation in the (I)NDCs**

Energy use for adaptation emerges as a pervasive set of strategies used to reduce vulnerability across all sectors of the economy. Table 1 lists the 20 adaptation strategies proposed in the (I)NDCs that meet the four criteria outlined in the previous section and that

most directly relate to energy. Examples of how those options are described in the national documents illustrate the degree of uncertainty related to actual implementation. It also explains why methodologies based on textual analysis would not have been able to identify all the options listed in Table 1, which have been gathered through the detailed screening of each document. Examples include countries with quantitative objectives, such as Antigua and Barbuda, a country planning to increase seawater desalination capacity by 50% above 2015 levels and raise to 100% the share of electricity demand in the water sector and other essential services (including health, food storage and emergency services) met through off-grid renewable sources. Singapore plans to use advanced membrane technologies to treat high-grade, reclaimed water and make it safe to drink. Seychelles plans to promote solar water heating among households and services, with a target of 80% by 2035. Co-generation in hotels is planned to cover 20% of hot water needs by 2035. Other examples are characterized by a higher degree of uncertainty. For example, Togo mentions the reuse of wastewater without any further details. Several countries mention broad programmes such as Solar Homes (Bangladesh) or Sustainable Energy for all (Saint Lucia), which can reasonably be expected to bring benefits in terms of cleaner energy for living conditions. Swaziland and Burkina Faso explicitly consider energy efficiency for their co-benefits in terms of adaptation.

**Table 1.** Overview of the energy use for adaptation options from the (I)NDCs. The table describes the options, summarizes the supporting adaptation literature, and illustrates examples of how those options are mentioned in the (I)NDCs.

<i>Sector</i>	<i>Adaptation Option</i>	<i>Description and Supporting Literature</i>	<i>Examples from (I)NDCs</i>
Water	Desalination	Removing salt from sea or brackish water can increase water supply (Bertule et al. 2018, Barnett and O'Neill, 2010). Renewable-based technologies have a growing potential for this type of energy-intensive water treatment (IRENA, 2012).	SINGAPORE: Singapore plans to expand desalination capacity to meet up to 80% of its water demand in 2060. ANTIGUA&BARBUDA: By 2025, increase seawater desalination capacity by 50% above 2015 levels. TUNISIA: Installation of mini seawater desalination plants using renewable energies in the tourist sector.
	Irrigation	Expanding equipped but not irrigated land as well as developing new irrigation projects (Ebinger and Vergara 2011, Bouwer et al. 2018) can reduce crop vulnerability. Large-scale deployment of solar pumps can support renewable-based irrigation (IRENA, 2016).	ZAMBIA: Introduce water technologies for irrigation. MALAWI: Increase irrigation at smallholder level and increase the land area under irrigation. UGANDA: Expanding the use of off-grid solar systems to support value addition and irrigation.
	Renewable-based water distribution	Expanding or improving water supply and distribution, including water pumping can increase water supply and reduce losses. Given the high energy-intensity of this option, the use of renewable energy reduces the risk of maladaptation (Bouwer et al. 2018, Sanders and Webber, 2012).	ANTIGUA&BARBUDA: 100% of electricity demand in the water sector through off-grid renewable sources. UGANDA: Extending electricity or expanding use of off-grid solar system to support water supply. GAMBIA: Use of renewable energy for lifting water from wells and boreholes.
	Water conservation & improved efficiency	Implementing i) agricultural practices that reduce water requirements; ii) institutional changes that favor water-saving behaviors (e.g. water metering, changes in water charging and trade); improved water resource management and efficiency in industry and distribution (Bouwer et al. 2018, Bertule et al. 2018) can reduce water needs, while keeping the same services.	JORDAN: Introducing water metering. IRAQ: Water use efficiency in distribution network and water consumption meters. SWAZILAND: Reduce vulnerability to the impacts of climate change through integrated water resource management.
	Water recycling and reuse	Implementing technologies to collect, reuse, and treat wastewater can increase water supply for non-drinkable uses, such as irrigation and industrial usages, as well as for domestic use (Bouwer et al. 2018, Bertule et al. 2018).	TOGO: Reuse of wastewater. SINGAPORE: Use advanced membrane technologies to purify reclaimed, treated water, making the water ultra-clean and safe to drink. SWAZILAND: Water recycling and reuse.

	Water harvesting and groundwater recharge	Collecting and storing rainwater, artificially recharging groundwater aquifers, as well as implementing large-scale or small-scale water reservoirs on farmland can increase water supply and storage (Bertule et al. 2018, Bouwer et al. 2018).	JORDAN: Maintenance of old Roman wells for water harvesting purposes and establishment of new wells in the rural area. MOROCCO: Artificial replenishment of groundwater tables. LEBANON: Artificial recharge of groundwater aquifers and increasing surface storage.
	Efficiency in irrigation	Implementing water saving irrigation techniques (e.g. modern pressurized irrigation systems, micro-irrigation, wetting and drying practice) can reduce water and energy demand while keeping agricultural productivity (Bertule et al. 2018, Bouwer et al. 2018).	CHINA: Develop water-saving agricultural irrigation. JORDAN: Introduce water saving technologies such as drip, micro-spray, and night irrigation. TOGO: Build and/or improve reservoirs for micro-irrigation and livestock watering in rural areas throughout all regions.
<b>Living Conditions</b>	Heating/cooling	Expanding space heating and cooling can increase resilience of the built environment (Revi et al. 2014, Ebinger and Vergara 2011, Hallegatte et al. 2014). Renewable-based heating and cooling have a large potential in several countries (IRENA, 2015).	JORDAN: Expand the use of solar cooling in commercial and industrial facilities. MOLDOVA: Research on technologies and practices that save cooling energy and reduce electrical peak load. LESOTHO: Diffuse the use of efficient biomass space heating stoves.
	Water heating	Expanding water heating can increase resilience of the built environment (Scott and Huang, 2007). Solar water heating has a large potential in many countries (Ebinger and Vergara 2011, IRENA, 2015).	BANGLADESH: Expand Solar Homes Programme. URUGUAY: Use of solar collectors for domestic hot water in large users, industrial and residential users. SEYCHELLES: Promote the use of solar water heating and cogeneration for hot water in hotels.
<b>Food</b>	Livestock	Expanding heating and cooling services can increase the resilience of livestock and mitigate their vulnerability to water scarcity, drought, and extreme events (Scott and Huang, 2007).	MEXICO: Strengthen [...] thermal comfort for livestock. JORDAN: Promote renewable energy in agricultural and food production for cooling and heating purposes, e.g. in poultry production. MOLDOVA: Improve ventilation and air conditioning systems in livestock farms.
	Food storage	Building and upgrading storage facilities and processes can reduce post-harvest losses happening during the storage phase (Abass et al. 2014, Kumar and Kalita, 2017).	ETHIOPIA: Implement methods that prevent deterioration of food and feed in storage facilities. UGANDA: Expand post-harvest handling and storage. GAMBIA: Post harvest and food processing and preservation techniques.
<b>Health</b>	Medical services	Improving hospital and infrastructure for medical services, expanding network of health centers can increase the supply of the essential health services needed to reduce vulnerability of the health sector (Noble et al. 2014).	MALAWI: Construct more health centers in order to improve access to health facilities within a walking distance. SUDAN: Improve community sanitation and medical services, including capacities for diagnosis and treatment. SUDAN: Public health systems strengthened by building hospitals [...].
	Early warning systems	Developing early warning systems can prevent human and economic losses in case of extreme events. Benefits can significantly exceed the costs, resulting in potentially large health benefits at low cost (Bouwer et al. 2018, Denton et al. 2014).	JORDAN: EWS to protect health from the potential impacts of climate change. MALDIVES: Develop appropriate early warning systems. BAHAMAS: Ensure that national emergency management plans also include heat stress
<b>Infrastructure</b>	Multi-purpose dams	Implementing dams that include more than one function can accommodate multiple adaptation needs, such as energy, water storage, and flood control (Bertule et al. 2018, Bouwer et al. 2018).	MALAWI: Construct storage dams for hydropower generation. CENTRAL AFRICAN REPUBLIC: Develop hydroelectric installations (including micro-dams). JORDAN: Dams for storing floodwaters during the wet winter seasons and releasing water during the summer seasons.
	Rural electrification	Extending rural electrification can enable adaptation and mitigate climate vulnerability (EUEI PDF, 2017, Murphy and Corbyn 2013). If based on a diversified network of energy sources, it can reduce the vulnerability of energy supply (Ebinger and Vergara, 2011).	BANGLADESH: Key areas to address adverse impacts of climate change include Increased Rural Electrification. SAINT LUCIA: Sustainable energy for all initiative. UGANDA: Extend electricity to the rural areas.
	Transport	Improving the resilience of public transportation systems can reduce the vulnerability of urban centers, which are highly dependent on transport for daily functioning (Revi et al. 2014). Improvements in vehicles and transport efficiency can compensate for the increased use of air	SINGAPORE: Constant review and revision of design codes, regulations and policies to account for new information and the latest climate projections. BAHRAIN: Improve public transport efficiency, reduce personal vehicle use. MOLDOVA: Promote the use of

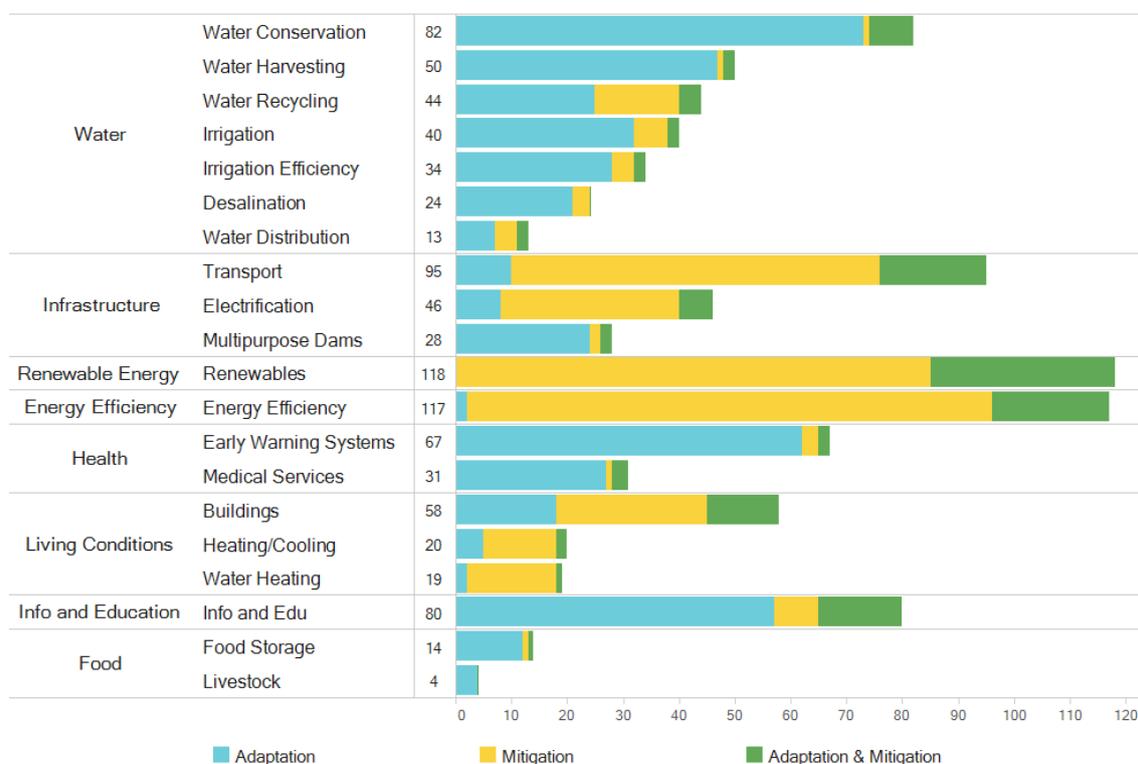
conditioning (Scott and Huang, 2007, Ebinger and Vergara 2011).

heat-tolerant streets and highways  
landscape protection.

	Building standards	Implementing building codes, upgrading informal settlements, and retrofitting existing housing stock can reduce vulnerability of settlements and support mitigation (Ebinger and Vergara 2011, Hallegatte et al. 2014, Revi et al. 2014).	MALAWI: Develop and implement climate related building codes to account for climate change. ANTIGUA&BARBUDA: By 2020, update the Building Code to meet projected impacts of climate change. URUGUAY: Green Seal Certification to achieve a more resilient performance of buildings, through appropriate design and materials to be better prepared for extreme weather events, in the tourist sector.
<b>Energy Efficiency</b>	Energy efficiency	Implementing energy efficiency programs can reduce the vulnerability of the energy system, with mitigation co-benefits. If less energy is required for an identical service, power outages will cause less damage and thus encourage climate resilience (Scott and Huang, 2007, Ebinger and Vergara 2011).	MALAWI: Promote the use of energy efficient light bulbs. SWAZILAND: Reduced vulnerability to climate change through energy efficiency. BURKINA FASO: Promote energy efficiency in urban and rural households.
<b>Renewable Energy</b>	Renewable energy	Differentiating the sources of energy supply by relying on a wider range of renewable sources can reduce the vulnerability of the energy sector (Ebinger & Vergara 2011, Denton et al. 2014). For example, micro grids and decentralized energy solutions are low-carbon and create a more resilient power system (EUEI PDF, 2017).	ETHIOPIA: Expand electric power generation from geothermal, wind and solar sources to minimize the adverse effects of droughts on hydroelectricity. EGYPT: Renewable energy may provide a number of opportunities, e.g. sustainable and equitable economic development, energy access, secure energy supply, reduced local environmental and health impacts. BURKINA FASO: Diversification of energy sources (solar, wind, biogas).
<b>Information &amp; Education</b>	Information and education	Awareness and capacity building can enhance adaptive capacity and support development (Denton et al. 2014). Climate services are an important component of the adaptation agenda (Tall et al. 2018).	KENYA: Enhance education, training, public awareness, public participation, public access to information on climate change adaptation across public and private sectors. Enhance climate information services. MALDIVES: Improve climate data collection, management and forecasting remains a critical gap area. Education, training and public awareness remain a key priority.

Overall, the energy-related adaptation options emerging from the (I)NDC plans can be grouped into 8 major sectors: water, infrastructure, renewable energy, energy efficiency, health, information and education, living conditions, and food (Figure 1).

**Figure 1.** Frequency of energy for adaptation options in the (I)NDCs. Colour scale shows whether options are mentioned as adaptation (blue), mitigation (yellow), or both (green). Numbers indicate the frequency of each of the 20 options shown in the bar chart.

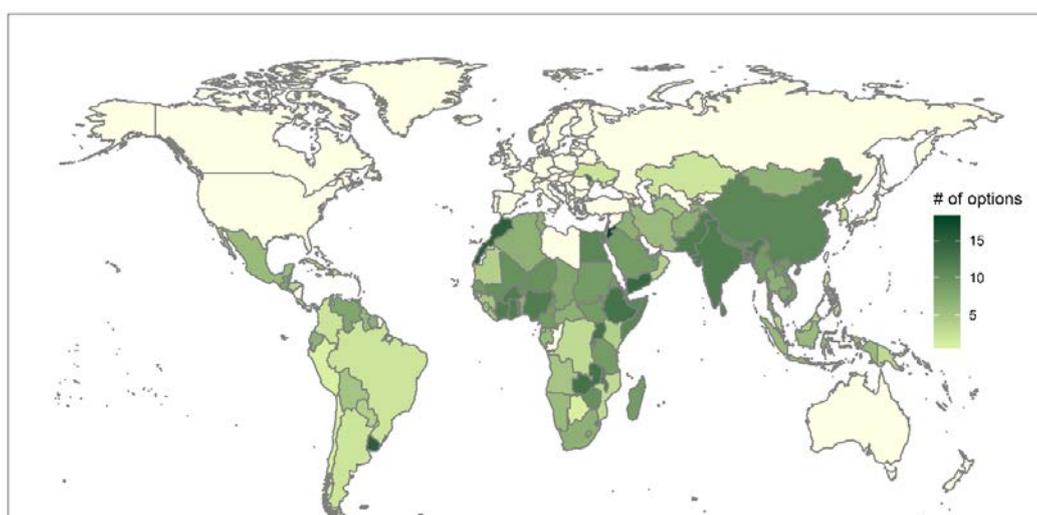


About one third of total energy for adaptation measures identified are related to the water supply sector, followed by infrastructure, which includes the provision of basic public services like electricity, buildings and transport. Renewable energy sources and energy efficiency measures, each accounting for 12% of all options, play a critical role as key solutions bridging mitigation and adaptation needs. Health services are often mentioned (10% of total number of options) as a sector that urgently needs to be extended and improved to adequately respond to extreme weather events and potential climate change implications for human wellbeing. A similar share (10%) of adaptation actions contributes to ensure adequate life and working conditions (space heating and cooling, water heating, building codes). Enhanced information and education, which requires energy access to reach the most vulnerable communities, represent 8% of total identified measures. A smaller share (4%) of adaptation actions requires energy services that contribute to the protection of vulnerable livestock (e.g. thermal comfort for livestock) and food supply (food storage). As expected, options related to infrastructure, renewables and energy efficiency are mostly mentioned in relation to mitigation (yellow color in Figure 1), but they are sometimes perceived as having the potential to bring about several co-benefits in terms of reduced vulnerability and improved resilience (Table 1). For example, decentralized energy systems based on diverse sources of energy - which are being accounted for in the renewable energy category - might be more flexible and less prone to large power outages. To the extent that renewables help to enrich the portfolio of energy sources, they contribute to adaptation (Ebinger and Vergara 2011). Win-win options are often

prioritized. Measures such as water conservation, water harvesting, irrigation efficiency, energy efficiency, building and transport standards account for 44% of all options mentioned.

The 139 countries that include adaptation plans are predominantly emerging or developing countries (Figure 2) though no pattern is identified between latitude and number of options. High-latitude countries have very detailed adaptation plans. As an example, the Republic of Moldova is mentioning 14 energy-related adaptation options. A rich list of energy-related adaptation options can be found in countries ranging from North African countries such as Jordan (18 options), Morocco (15 options), to Uruguay (15 options), and Burkina Faso (12 options).

**Figure 2.** Geographic distribution of energy for adaptation options. Countries in light yellow do not include adaptation options in the (I)NDCs.



### Evidence of how adaptation contributes to sustainable development

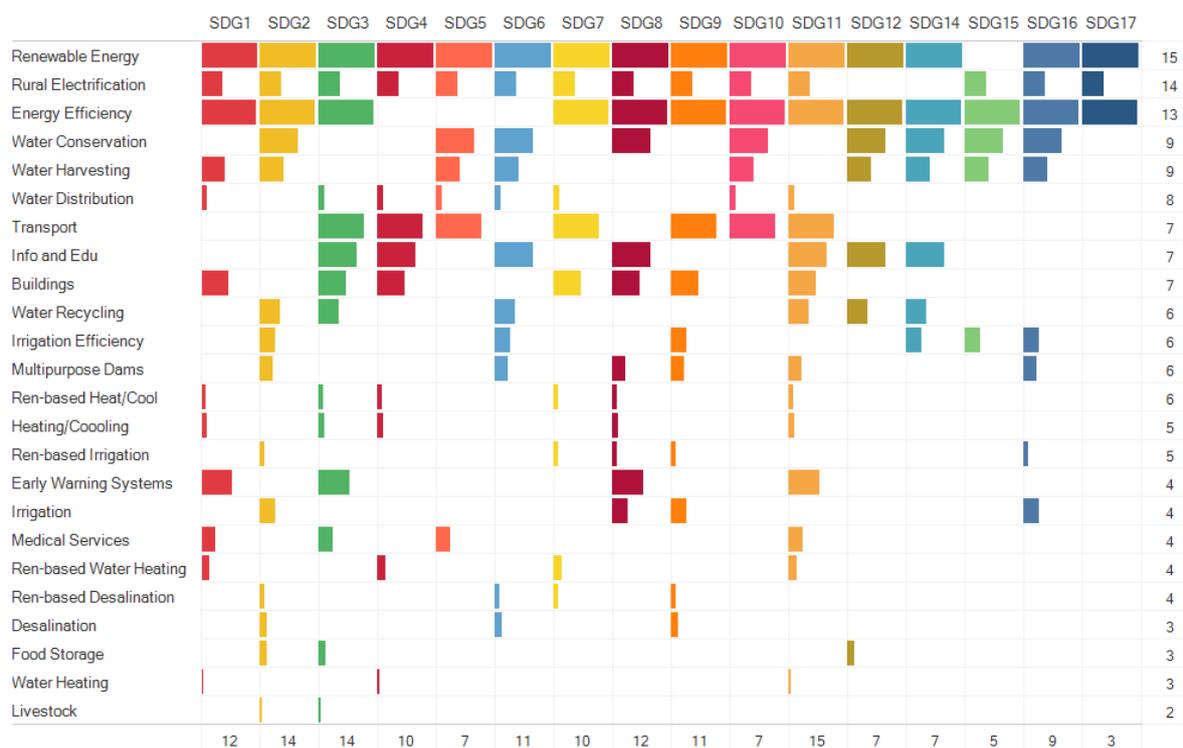
The energy-related adaptation options defined in the previous section are all connected to at least one SDG (Figure 3). Based on the extensive review of the literature summarized in Table S1, the options that support the highest number of goals include renewable energy (contributing to 15 SDGs out of 17), rural electrification (showing potential synergies with 14 SDGs), and energy efficiency (relating to 13 goals). Water conservation and water harvesting follow, with 9 linkages each. As an enabling condition of sustainable development, increased use of modern, efficient and clean energy sources plays a critical role in the realization of most SDGs, especially those most directly related to basic needs (e.g. education, health, food, water, gender equality) or economic growth and productivity (e.g. poverty alleviation, inequality, employment), reinforcing the findings of recent studies linking energy and the SDGs (McCollum et al. 2018).

Looking at the Sustainable Development Goals that would benefit from the implementation of adaptation plans the most, SDG 11 (Inclusive, safe, resilient and sustainable cities and human settlements), SDG2 (Zero hunger), and SDG3 (Healthy lives and well-being for all), show the greatest number of linkages with 15 (62% of all options), 14 and 14 (54% of all options) energy-related adaptation options supporting the achievement of those goals, respectively. SDG11

(Making cities and human settlements more sustainable and resilient) is supported primarily by adaptation solutions related to the infrastructure sector, including renewable energy, low-carbon and climate-proof transport systems and buildings, as explicitly required by most of the targets and indicators included in the goal. SDG2 (Ending hunger and achieving food security) shows strong connections not only with the adaptation actions directly addressing the vulnerability of the food sector but also with a high number of options related to the water and energy sectors. Access to more efficient and cleaner energy technologies as well as practices that increase water supply and efficiency are key to sustain food productivity and reduce post-harvest losses (Karekezi et al. 2012, FAO 2016, Abass et al. 2014, Kumar and Kalita, 2017). A greater heterogeneity characterizes the options that support SDG3 (Promoting healthy lives and well-being for all), highlighting synergies across all the identified sectors. Ensuring universal health will indeed benefit from medical services enhanced to protect vulnerable people from climate risks, increased food security and water quality, improved residential conditions due to building standards, deployment of cleaner and efficient appliances as well as from educational campaigns targeting climate-sensitive diseases.

Clear linkages also emerge with those goals involving key sectors object of our analysis explicitly requiring the implementation or expansion of the energy for adaptation options, such as SDG7 (Affordable and clean energy), supported by 10 options (42%), SDG6 (Clean water and sanitation), supported by 11 options (45%) that increase clean and efficient water supply. Whereas some options that most contribute to sustainable development are widely proposed across (I)NDCs, such as energy efficiency and renewable energy, other options which also have a high potential with respect to contributing to development, namely renewable-based water distribution, water conservation or water harvesting, are less frequently mentioned (Figure 3).

**Figure 3.** Contribution of energy for adaptation options to the SDGs. Coloured bars for each option-SDG combination indicate a positive contribution of the option to the SDG. The size of the bar is proportional to the number of countries mentioning the option in the (I)NDC. Figures at the bottom summarize the numbers of options supporting each Goal. Figures on the right summarize the numbers of Goals supported by each option. All options, by definition, contribute to the climate action Goal 13 (not shown).



## Discussion and conclusions

The climate action plans described in the (I)NDCs reveal that adaptation has the potential to influence future energy demand. The analysis proposed in this Perspective shows that of the 20 energy for adaptation options most frequently mentioned, 6 of them have the potential to save energy, while the remainder 14 options require energy. The majority of countries (65%) plan to rely on renewable sources when mentioning particularly energy-intensive options such as irrigation, desalination, water distribution, space heating and cooling, water heating, but still the risk of maladaptation remains. At the same time, energy for adaptation has a strong potential to support development as articulated in the 17 SDGs. What are the possible leverages that could push the undocumented energy for adaptation options having widespread development benefits (such as renewable-based water distribution), requires further research on policy adoptions and implementation.

Our analyses only elucidates the potential direction adaptation could take should countries actually implement the options described, within the bounds of uncertainty that varies across countries. Future research is warranted to understand policy adoption decisions and how they vary across climatic conditions, institutional, and socio-economic settings. Quantifying the energy requirements of the adaptation options identified in this Perspective, accounting for the

great heterogeneity across space and technology (Sanders and Webber 2012), would provide valuable input for climate policy scenario analyses. Model-based analysis integrating energy for adaptation options and mitigation (van Ruijven et al. 2012, Pachauri 2014, Hasegawa et al. 2014), is needed to substantiate how the global macroeconomic and environmental implications of adaptation could interact with mitigation in the transition towards sustainability.

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