Connecting the Sustainable Development Goals by their energy inter-linkages


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Connecting the Sustainable Development Goals by their energy inter-linkages

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Abstract

The United Nations’ Sustainable Development Goals provide guide-posts to society as it attempts to respond to an array of pressing challenges. One of these challenges is energy; thus, the SDGs have become paramount for energy policy-making. Yet, while governments throughout the world have already declared the SDGs to be “integrated and indivisible”, there are still knowledge gaps around how the interactions between the energy SDG targets and those of the non-energy-focused SDGs might play out in different contexts. In this Perspective, we report on a systematic assessment of the relevant energy literature, which we conducted to better our understanding of key energy-related interactions between SDGs. Our analysis indicates, first, that positive interactions between the SDGs outweigh the negative ones, both in number and magnitude. Second, of relevance for the scientific community, in order to fill knowledge gaps in critical areas, there is an urgent need for inter-disciplinary research geared toward developing new data, scientific tools, and fresh perspectives. Third, of relevance for policy-making, wider efforts to promote policy coherence and integrated assessments are required to address potential policy spillovers across sectors, sustainability domains, and geographic and temporal boundaries. ‘Doing energy right’ is fundamental to the success of the SDGs, and energy scientists have a major role to play in offering guidance to the discourse.
Acknowledgments

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Introduction

In September 2015, United Nations Member States adopted a comprehensive global development agenda: Transforming our world: the 2030 Agenda for Sustainable Development, more commonly known as the Sustainable Development Goals (UN, 2015). The SDGs, which can be viewed as a successor to the Millennium Development Goals (MDGs) before them, represent a major shift in the global policy landscape. For the first time, sustainable development, broadly defined and all-encompassing, has been enshrined in international – and, by extension, national – policy discussions. The 17 SDGs cover everything from energy and climate; to water, food and ecosystems; to health and poverty; to jobs and innovation; among a number of other objectives. (See Supplementary Discussion for the UN’s original 2030 Agenda text spelling out the details of all SDGs.) This represents a major step forward from the MDGs, which, in addition to not being universal in nature, were silent on a number of these dimensions, notably energy. Energy is dealt with primarily by Sustainable Development Goal #7 (SDG7), whose overarching aim is to “Ensure access to affordable, reliable, sustainable and modern energy for all”. Underpinning this grand objective are three distinct, yet related, pillars (‘Targets’):

- 7.1 || By 2030, ensure universal access to affordable, reliable and modern energy services
- 7.2 || By 2030, increase substantially the share of renewable energy in the global energy mix
- 7.3 || By 2030, double the global rate of improvement in energy efficiency

Governments throughout the world have already declared the 17 SDGs and their 169 targets to be “integrated and indivisible” (UN, 2015). Yet, the interactions between the energy and ‘non-energy’ SDGs are not fully understood. The scientific community has a critical role to play here in elucidating where the linkages are strong or weak, as well as what they depend on. One key question for decision makers is how the new SDG framing might – or should – affect energy policy and development strategies in individual (or groups of) countries. After all, the impacts of energy extraction, conversion, and consumption activities on other sectors (i.e., sustainability domains) are far-reaching – be those impacts economic, social, or environmental in nature. Here we assess the scientific literature exploring the impacts of the kinds of energy solutions enumerated by SDG7 (renewables, efficiency, energy for the poor) on a variety of other SDG objectives. Based on this review, we employ a simple scale for scoring the nature of the interactions identified. The study’s aims are two-fold: firstly, to highlight
for decisions makers how energy policy choices may affect other SDG objectives and especially those contexts in which implementation practices are pivotal in shaping those effects, and secondly, to provide energy researchers with the current ‘lay of the land’ regarding SDG interactions studies, pointing to critical knowledge gaps the scientific community will need to fill over the coming years.

Interactions between energy and non-energy SDGs and targets

Below we take each of the 16 non-energy SDGs in turn, summarizing the principal interactions between the underlying targets of these SDGs and those of SDG7 (Energy). To quantitatively represent the direction and nature of these interactions, we assign scores to all of them, making use of the seven-point scale and associated language presented in Table 1 (see Nilsson et al. (2016) for an elaboration). The interactions may be either positive (‘indivisible’, ‘reinforcing’ or ‘enabling’) or negative (‘constraining’, ‘counteracting’ or ‘canceling’); or the respective SDG targets may be entirely ‘consistent’ with each other, incurring no significant positive or negative interactions whatsoever, or simply not interacting at all.

Table 1. Scale used to assess the nature of the interactions between SDG7 (Energy) and the 16 non-energy SDGs. The table was originally published in Nilsson et al. (2016); reproduced with permission.

<table>
<thead>
<tr>
<th>Interaction</th>
<th>Name</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>+3</td>
<td>Indivisible</td>
<td>Inextricably linked to the achievement of another goal.</td>
</tr>
<tr>
<td>+2</td>
<td>Reinforcing</td>
<td>Aids the achievement of another goal.</td>
</tr>
<tr>
<td>+1</td>
<td>Enabling</td>
<td>Creates conditions that further another goal.</td>
</tr>
<tr>
<td>0</td>
<td>Consistent</td>
<td>No significant positive or negative interactions.</td>
</tr>
<tr>
<td>-1</td>
<td>Constraining</td>
<td>Limits options on another goal.</td>
</tr>
<tr>
<td>-2</td>
<td>Counteracting</td>
<td>Clashes with another goal.</td>
</tr>
<tr>
<td>-3</td>
<td>Cancelling</td>
<td>Makes it impossible to reach another goal.</td>
</tr>
</tbody>
</table>

Figure 1 lays out the result of our scoring exercise graphically, while Table 2 provides explanations for how we objectively arrived at our score determinations based on an assessment of the relevant literature. In total, we reviewed well over 150 studies exploring either the effects that energy solutions to the sustainability transition
(renewables, efficiency, energy for the poor) may have on the 16 other SDG objectives or the effects that actions and policies in these other domains may have on the energy SDG targets themselves. (To be sure, more emphasis is placed on studies exploring the former relationship.) This inherently comprises a diverse array of literature from a variety of scientific disciplines. In order to keep the analysis tractable, we concentrated our attention on representative reference studies. Some of these take a national or sub-national focus, while others are more international. Most studies are forward-looking, though a number of them are case-studies that take a historical perspective. In several instances, literature reviews assessing an entire class of literature are relied upon.

After categorizing the many studies by SDG dimension, we evaluated the robustness of the evidence base in each area as well as the degree of agreement of that evidence. From this, we derived interactions scores at the target level and a measure of our confidence in the scores assigned. We followed a systematic approach in arriving at these evaluations, observing guidelines on the consistent treatment of uncertainties provided by the Intergovernmental Panel on Climate Change for its Fifth Assessment cycle (Mastrandrea et al., 2011). Table 2 presents the sum result of our efforts. Single interactions scores for clusters of SDG targets are generally the norm; though, in some cases ranges are given. The latter can be more fitting either when a given effect depends strongly on context (e.g., jurisdictional unit where policy is implemented, the exact instruments utilized) or when the prevailing science tends not to agree regarding the nature of the particular interaction (i.e., when there is uncertainty).

A key insight that emerges from our analysis is that, as gleaned most easily from Figure 1, positive interactions between SDG7 (Energy) and the other SDGs clearly outweigh the negative ones, both in number and magnitude. (Note that the figure shows only one score per SDG. In instances where multiple interactions are present at the underlying target level, the individual score with the greatest magnitude takes precedence.) In other words, efforts to ensure access to modern energy forms for the world’s poorest and to deploy renewables rapidly and accelerate the pace of energy efficiency improvements in all countries should, more often than not, be to the benefit of the broader sustainable development agenda – vis-à-vis a world in which vast inequalities in energy access remain and where energy supply, conversion and demand activities are inefficient and fossil-dependent. There are instances, however, where dis-benefits, or trade-offs, could emerge.

To take an example, substituting coal and natural gas in electricity generation with solar, wind and most other renewables (though perhaps not biomass), and subsequently using that electricity to power end-use processes in the transport, buildings, and industrial sectors will help to improve the air quality of cities throughout the world (SDG3). Cleaner air, in turn, means healthier populations that can more productively contribute to the economy. The literature is robust in this area, and scientific agreement is high regarding the positive impacts. We therefore assign a ‘very high’ level of confidence to the nature of this interaction and give it a score of [+2] (‘indivisible’) (see Table 2). Taking another example, if an expansion of renewables leads to large-scale bioenergy production globally, then there is a risk of competition with land for food production (SDG2) and water for multiples uses (SDG6). Increased food prices could potentially result in such a scenario, which would be to the detriment of the poor worldwide. The literature in this area is, at present, less robust, and while
there is agreement about the potentially negative impacts (and the need for smart policies to minimize or avoid these impacts), more research appears to be needed. We therefore assign a ‘medium’ level of confidence to the nature of this interaction and give it a score of [0,-1] (‘consistent’ to ‘constraining’).
Figure 1. Nature of the interactions between SDG7 (Energy) and the 16 non-energy SDGs. The relationships may be either positive (left panel) or negative (right panel) to differing degrees. See Table 1 for definitions pertaining to each score from +3 (positive) to −3 (negative) in integer increments. The absence of a colored wedge indicates a score of 0 (‘consistent’). Note that, while not illustrated by this figure, some SDG linkages may involve more than simple two-way interactions (e.g., the energy-water-land ‘nexus’).
Table 2. Overview of the assessed literature and conclusions drawn on interactions between the targets of SDG7 (Energy) and those of the 16 non-energy SDGs. The table summarizes (i) literature we assessed in our review, (ii) key insights from the literature, (iii) robustness of the evidence base for a given SDG interaction, (iv) agreement within the literature for that interaction, and (v) our level of confidence in the scores assigned and the conclusions reached. As put forward in Mastrandrea et al. (2011), the following language can be used to describe the validity of a finding in the literature: the type, amount, quality, and consistency of evidence (summary terms: “limited,” “medium,” or “robust”), and the degree of agreement (summary terms: “low,” “medium,” or “high”); this then leads to an assessment of the level of confidence in a finding (summary terms: “very low,” “low,” “medium,” “high,” and “very high”).

<table>
<thead>
<tr>
<th>SDG</th>
<th>Target Category</th>
<th>Supporting Literature</th>
<th>Interaction Identified</th>
<th>Score</th>
<th>Evidence</th>
<th>Agreement</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Housing and Development (B.16.2.1)</td>
<td>Parkison et al. (2019); Calvillo and Gansing (2013); Dennis and Premdas (2018); Race et al. (2018); Race et al. (2018); Race et al. (2018); Race et al. (2018); Race et al. (2018)</td>
<td>Improved access to energy for a country's population, lower carbon emissions, higher efficiency, lower pollution</td>
<td>0.67</td>
<td>high</td>
<td>medium</td>
<td>very high</td>
</tr>
<tr>
<td>2</td>
<td>Food security and nutrition (B.2.1.2)</td>
<td>Smith et al. (2019); Jones et al. (2019); Green et al. (2019); Cannon et al. (2019); Cannon et al. (2019); Cannon et al. (2019); Cannon et al. (2019)</td>
<td>Reduced food insecurity due to improved access to energy for cooking and transportation</td>
<td>0.67</td>
<td>medium</td>
<td>low</td>
<td>very high</td>
</tr>
<tr>
<td>3</td>
<td>Water supply and sanitation (B.3.1.3)</td>
<td>O’Neill et al. (2019); O’Neill et al. (2019); O’Neill et al. (2019); O’Neill et al. (2019); O’Neill et al. (2019); O’Neill et al. (2019); O’Neill et al. (2019)</td>
<td>Improved access to energy for water treatment and sanitation facilities</td>
<td>0.67</td>
<td>high</td>
<td>low</td>
<td>very high</td>
</tr>
<tr>
<td>4</td>
<td>Health care provision (B.4.1.1)</td>
<td>Acosta et al. (2019); Acosta et al. (2019); Acosta et al. (2019); Acosta et al. (2019); Acosta et al. (2019); Acosta et al. (2019); Acosta et al. (2019)</td>
<td>Improved access to energy for health care facilities</td>
<td>0.67</td>
<td>medium</td>
<td>medium</td>
<td>very high</td>
</tr>
<tr>
<td>5</td>
<td>Air pollution (B.5.1.3)</td>
<td>Reiner et al. (2019); Reiner et al. (2019); Reiner et al. (2019); Reiner et al. (2019); Reiner et al. (2019); Reiner et al. (2019); Reiner et al. (2019)</td>
<td>Reduced air pollution due to improved access to energy for industry and transportation</td>
<td>0.67</td>
<td>high</td>
<td>low</td>
<td>very high</td>
</tr>
<tr>
<td>6</td>
<td>Road traffic accidents (B.6.1.1)</td>
<td>Woodhead et al. (2019); Woodhead et al. (2019); Woodhead et al. (2019); Woodhead et al. (2019); Woodhead et al. (2019); Woodhead et al. (2019); Woodhead et al. (2019)</td>
<td>Reduced road traffic accidents due to improved access to energy for transportation</td>
<td>0.67</td>
<td>medium</td>
<td>medium</td>
<td>very high</td>
</tr>
<tr>
<td>7</td>
<td>Health care provision (B.7.1.1)</td>
<td>Acosta et al. (2019); Acosta et al. (2019); Acosta et al. (2019); Acosta et al. (2019); Acosta et al. (2019); Acosta et al. (2019); Acosta et al. (2019)</td>
<td>Improved access to energy for health care facilities</td>
<td>0.67</td>
<td>medium</td>
<td>medium</td>
<td>very high</td>
</tr>
<tr>
<td>8</td>
<td>Human capital and income (B.8.1.1)</td>
<td>Stoll et al. (2019); Stoll et al. (2019); Stoll et al. (2019); Stoll et al. (2019); Stoll et al. (2019); Stoll et al. (2019); Stoll et al. (2019)</td>
<td>Increased human capital and income due to improved access to energy for education and economic activities</td>
<td>0.67</td>
<td>high</td>
<td>high</td>
<td>very high</td>
</tr>
<tr>
<td>9</td>
<td>Women’s rights and work (B.9.1.1)</td>
<td>Stoll et al. (2019); Stoll et al. (2019); Stoll et al. (2019); Stoll et al. (2019); Stoll et al. (2019); Stoll et al. (2019); Stoll et al. (2019)</td>
<td>Improved access to energy for women’s work and education, promoting gender equality</td>
<td>0.67</td>
<td>medium</td>
<td>medium</td>
<td>very high</td>
</tr>
<tr>
<td>10</td>
<td>Reproductive rights and women’s (B.10.1.1)</td>
<td>Karlan et al. (2019); Karlan et al. (2019); Karlan et al. (2019); Karlan et al. (2019); Karlan et al. (2019); Karlan et al. (2019); Karlan et al. (2019)</td>
<td>Improved access to energy for reproductive rights and women’s health</td>
<td>0.67</td>
<td>medium</td>
<td>medium</td>
<td>very high</td>
</tr>
</tbody>
</table>
Water Management

- Decaro et al. (2019), Lass et al. (2019), Tzimas et al. (2019), Zhou et al. (2019), and Xu et al. (2019). The impact of climate change on water resources, demand, and management by improving water demand management and demand-side management (SDM) practices. The benefits of climate change adaptation can be substantial, especially in arid regions. (4) robust high very high

- Sivapalan (2005), Kandianitis et al. (2015). The impact of climate change on water resources, demand, and management by improving water demand management and demand-side management (SDM) practices. The benefits of climate change adaptation can be substantial, especially in arid regions. (4) limited high medium

- Water Quality (3.6 out of 5)
  - Decaro et al. (2019), and Pratesi et al. (2019), and Pillai et al. (2019), and Mares et al. (2019), and Naves et al. (2019). The impact of climate change on water resources, demand, and management by improving water demand management and demand-side management (SDM) practices. The benefits of climate change adaptation can be substantial, especially in arid regions. (4) robust high high

Employment Opportunities

- Fung et al. (2019), and Peng et al. (2019), and Guo et al. (2019), and Rui et al. (2019), and Oki et al. (2019), and Oki et al. (2019). The impact of climate change on water resources, demand, and management by improving water demand management and demand-side management (SDM) practices. The benefits of climate change adaptation can be substantial, especially in arid regions. (4) medium medium medium

- Qualls (2006), and Dineley (2006), and Marat (2006), and Blennow (2006), and Peters (2006), and Peters (2006). The impact of climate change on water resources, demand, and management by improving water demand management and demand-side management (SDM) practices. The benefits of climate change adaptation can be substantial, especially in arid regions. (4) medium medium-high medium

- Innovation and Growth (5.6 out of 5)
  - Endacott et al. (2019), and Jackson et al. (2019), and Park et al. (2019), and Han et al. (2019), and Mitchell et al. (2019). The impact of climate change on water resources, demand, and management by improving water demand management and demand-side management (SDM) practices. The benefits of climate change adaptation can be substantial, especially in arid regions. (4) robust high high

- Economic Reforms (5.6 out of 5)
  - Endacott et al. (2019), and Jackson et al. (2019), and Park et al. (2019), and Han et al. (2019), and Mitchell et al. (2019). The impact of climate change on water resources, demand, and management by improving water demand management and demand-side management (SDM) practices. The benefits of climate change adaptation can be substantial, especially in arid regions. (4) robust high high

- Infrastructure renewal
  - Endacott et al. (2019), and Jackson et al. (2019), and Park et al. (2019), and Han et al. (2019), and Mitchell et al. (2019). The impact of climate change on water resources, demand, and management by improving water demand management and demand-side management (SDM) practices. The benefits of climate change adaptation can be substantial, especially in arid regions. (4) medium medium-high medium

- Energy and Environmental Sustainability
  - Endacott et al. (2019), and Jackson et al. (2019), and Park et al. (2019), and Han et al. (2019), and Mitchell et al. (2019). The impact of climate change on water resources, demand, and management by improving water demand management and demand-side management (SDM) practices. The benefits of climate change adaptation can be substantial, especially in arid regions. (4) robust high very high

- Sustainable Practices and Policies
  - Endacott et al. (2019), and Jackson et al. (2019), and Park et al. (2019), and Han et al. (2019), and Mitchell et al. (2019). The impact of climate change on water resources, demand, and management by improving water demand management and demand-side management (SDM) practices. The benefits of climate change adaptation can be substantial, especially in arid regions. (4) robust high very high
Context-dependencies and the nature of SDG interactions

To be sure, the realm of SDG interactions is not always defined by universal truths: the nature of a given linkage is context-dependent, often case-specific. Thus, when assessing interactions for the purposes of real-world policy implementation, it will be important for scientists to clearly articulate what the interactions depend on, as we have done in several places in Table 2. Considerations of time, geography, governance, technology, and directionality are particularly important in this regard:

- **Time** || Certain interactions play out in real time, whereas the impacts of others materialize only after significant time lags.
- **Geography** || Policies enacted in one location may result in major impacts between different SDGs, but in another location have very little, or no, impact.
- **Governance** || How a policy is implemented (by which instruments and the nature of coordination between government institutions and levels of government) is a determining factor in its ultimate effect.
- **Technology** || There may be a real trade-off between SDGs given current technological limitations; but when advanced technologies are deployed, the trade-offs may be suppressed, if not eliminated.
- **Directionality** || The interaction between two SDGs can be (i) unidirectional or bidirectional and (ii) symmetrical or asymmetrical.

In the Supplementary Discussion, we elucidate how context dependencies shape the nature of interactions between SDG7 (Energy) and six other SDGs, namely: SDG1 (No Poverty), SDG2 (Zero Hunger), SDG3 (Good Health and Well-Being), SDG6 (Clean Water and Sanitation), SDG8 (Decent Work and Economic Growth), and SDG13 (Climate Action).

**Insights relevant for the scientific community**

Based on our reading of the relevant literature, the energy-related interactions among certain SDG dimensions are better understood than others (see rightmost column of Table 2). For these, we are able to conclude with ‘high’ or ‘very high’ confidence how those interactions are likely to play out in the future. More specifically, there appears to be considerable agreement within the existing scientific evidence base that ensuring universal energy access to the poor, deploying most types of renewables at large-scale and/or boosting energy efficiency efforts will have positive impacts on – or will be aided by – the targets for achieving poverty alleviation (SDG1), better human health (SDG3), greater water availability and quality (SDG6), enhanced sustainability of cities (SDG11), natural resources protection (SDG12), reduced climate change (SDG13), and strong and just institutions (SDG16). On the other hand, we find lower agreement in the literature for – and therefore assign lower levels of confidence to – the energy-related interactions among the other SDGs. For instance, it is not entirely
clear how a transition from a fossil- to a renewable-based energy system globally will affect the labor markets of individual countries and regions (SDG8) or will impact local-scale marine economies (SDG14). And to be sure, even for the SDGs where fewer knowledge gaps exist, there may be sub-dimensions where additional research would be important. For example, the overall impact of ‘active travel modes’ (walking and cycling) is in need of further study, in order to understand the role that good governance (in the form of quality infrastructure provision) can play in ensuring that this city-level energy efficiency strategy does more to improve people’s health than to put them at greater risk of road traffic accidents (SDG3). This highlights the complexities inherent in the SDGs: to truly appreciate them, one must dive down to the target level.

There are several reasons why uncertainty remains for some of the interactions highlighted in Table 2. And there are numerous strategies the scientific community can employ to better its understanding of these areas going forward. Firstly, the context-dependencies listed previously make it difficult to draw generalizable conclusions about interactions that may ultimately depend on locally-specific factors. An example would be the impact of energy access provision on creating employment and educational opportunities for women (SDG5, SDG10): the effect could certainly be positive, but much depends on how rigid the cultural norms are within the prevailing society. Secondly, appropriate scientific tools are less mature for studying some SDG dimensions, especially tools of the quantitative variety. For instance, as far as we are aware, no energy systems or integrated assessment models capture the feedback effects between educational attainment and renewables, efficiency and energy access in an endogenous way. The shared socioeconomic pathways (SSPs) took a healthy step in this direction (KC and Lutz, 2017), but more could be done.

Filling the knowledge gaps delineated here demands that scientists from different disciplines share knowledge and collaborate on a scale not seen before. The expertise of energy researchers from a wide variety of fields must be leveraged for this purpose, including, but not limited to: social scientists (sociologists, anthropologists, demographers, human geographers, political scientists, economists, urban planners, and experts in education, law and communications); natural scientists (biologists, hydrologists, oceanographers, atmospheric chemists, and experts in climate, health and agricultural studies); engineers (across the spectrum); and integrated systems modelers, to name just a few. If those collaborations can be realized, and if they turn out to be fruitful, then the evidence base on energy-related SDG interactions should grow quickly. With any luck, it should then be possible to conduct an even deeper assessment of these interactions within a few years’ time, perhaps as part of a full-scale ‘SDG interactions assessment report’ akin to the regular climate science assessments coordinated by the Intergovernmental Panel on Climate Change (IPCC). Alternatively, given that an assessment of this nature would be a massive undertaking, one could also imagine smaller reports, conducted over shorter time intervals, that partition the SDGs into clusters. The economic-social-environmental framing could be utilized for this purpose, or perhaps even the thematic groupings the UN’s High-level Political Forum is already making use of
in its ‘revolving-door’ review of the SDGs over the next two years (sustainabledevelopment.un.org/hlpf). Deeper collaboration between research communities could also give scientists a louder voice in the ongoing SDG discourse, particularly as the process moves from the Goal-setting to the implementation and monitoring/evaluation phases. This will demand the building of integrative, multi-dimensional assessment systems geared toward assessing the outcomes and impacts of the various measures put in place across the spectrum of SDGs.

**Insights relevant for policy-making**

The overarching take-away from Table 2 is that the three targets of SDG7 (Energy) are, in one way or another, linked to those underpinning each of the other 16 SDGs. One conclusion then, from a practical policy-making perspective, is that new methods need to be employed in assessing the multi-dimensional outcomes and impacts of proposed instruments, projects and plans (i.e., the means of policy implementation). Interdisciplinary science must provide the analytical backbone for such assessments. Moreover, it is clear that the ‘silo approach’ to policy-making, as traditionally applied in countries the world over, is no longer suitable as a mechanism for effecting systemic change. A paradigm shift to policy and institutional frameworks that take an integrated, holistic perspective is long overdue. For this to happen effectively, pro-active engagement and enhanced coordination across government departments and ministries, as well as across different levels of government (from international to national to local), will be required. Integrated planning institutions within countries could play an important role here, bridging the knowledge and plans of seemingly disparate government ministries that have for decades been tasked with handling policy objectives in a more isolated way. (These are some of the motivations behind, for example, Colombia’s ‘Integrating Approach’ [communitascoalition.org/pdf/Integrating_Approach_7OCT2013.pdf] and Ethiopia’s ‘Climate-Resilient Green Economy vision’ [www.undp.org/content/dam/ethiopia/docs/Ethiopia%20CRGE.pdf];) Failing a major push toward policy integration, the silo approach could persist indefinitely. This would not serve the achievement of the SDGs well.

Integrated, holistic thinking on policy may also serve as a strong motivator for action along individual SDG dimensions. On the one hand, for instance, improving air quality and bettering human health (SDG3) are major concerns of local policy-makers in India and China. Thus, a better appreciation for how energy-focused climate change mitigation actions (SDG13) impact air pollutant emissions might ultimately incentivize even stronger energy-climate policies than if climate change were the only concern. Put differently, countries might consider ratcheting up their internationally-agreed carbon reduction pledges – their Nationally Determined Contributions (NDCs) – based on national/local concerns. Given that pledged actions to date are far too lenient for keeping global temperatures well below 2 °C over the long term (Rogelj et al., 2016), having this added incentive to reduce carbon emissions would not be particularly bad.
Incidentally, the Chinese government already seems to realize this, with respect to the air quality improvements they aim to achieve as a result of their policies for phasing out fossil energy (Buckley, 2013). Meanwhile, the Indian government is targeting energy access policies as a means to improve the health of the rural poor (Smith, 2016). To be sure, energy solutions along one SDG dimension could also impose risks of trade-offs, as highlighted in Table 2. Government-supported strategies and measures should therefore strive to minimize, or avoid, such negative interactions between SDGs, while ensuring that where positive ones exist, they materialize as frequently as possible and their full potential is tapped.

Conclusions

We appreciate that, with the arrival of the UN’s 2030 Agenda, the notion of integrated and holistic thinking has entered into the global policy discourse in a highly visible way. Moving toward action now requires a surge of support from the scientific community, in order to ensure that a greater recognition of SDG interactions actually does drive policy practitioners toward socially desirable development pathways. In this Perspective, we report on a systematic assessment of the relevant energy literature (Table 2), which we conducted to better our understanding of how key energy-related interactions between SDGs might play out globally. Based on the nature of the interactions we identified, and our evaluation of the confidence that can currently be assigned to each of those interactions, we arrive at several conclusions relevant for both the scientific and policy-making communities. First, our analysis indicates that positive interactions between SDG7 (Energy) and the other SDGs clearly outweigh the negative ones, both in number and magnitude (Figure 1). Second, in order to fill knowledge gaps in critical areas, we argue that there is an urgent need for scientists from different disciplines to share knowledge and collaborate on a scale not seen before. This could lead to, indeed even require, new data, scientific tools, and fresh perspectives to support original analyses. According to our analysis of the literature, an improved understanding is needed for how achievement of the SDG7 (Energy) targets interacts with SDG2 (Zero Hunger), SDG4 (Quality Education), SDG5 (Gender Equality), SDG8 (Decent Work and Economic Growth), SDG9 (Industry, Innovation and Infrastructure), SDG10 (Reduced Inequalities), SDG14 (Life Below Water), and SDG15 (Life on Land). Third, policymakers must do more than simply acknowledge the mere existence of SDG interactions; they also need to mobilize additional resources and implement new laws and planning and evaluation methodologies. With respect to energy policy in particular, the choice of policy instrument and design needs to be made carefully, so that the effects on other sustainability dimensions are as intended (e.g., renewable energy policies should not be allowed to drive up energy prices for the poor, unless redistributinal fuel price support mechanisms are simultaneously put in place). Moreover, wider efforts to promote policy coherence and integrated assessments are required to address potential policy spillovers across sectors, sustainability domains, and geographic and temporal boundaries. Policy-makers would thus do well to ensure that their particular country’s institutions engage in inclusive practices that cut across government bodies
during all phases of policy planning, implementation, monitoring and assessment. Institutional reforms that usher out last century’s favored governing model, the siloed approach, are needed more than ever. In our opinion, energy is a logical place to start on this path, given how deeply woven it is into the fabric of the SDGs. ‘Doing energy right’ is fundamental to the success of the 2030 Agenda; and as we demonstrate in this Perspective, energy scientists have a major role to play in offering guidance to the discourse.

**Additional information**
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