

1 **MAPPING SYNERGIES AND TRADE-OFFS BETWEEN ENERGY AND THE**  
2 **SUSTAINABLE DEVELOPMENT GOALS**

3  
4 *Francesco Fuso Nerini*<sup>1,2\*</sup>; *Julia Tomei*<sup>3\*\*</sup>; *Long Seng To*<sup>4,5</sup>; *Iwona Bisaga*<sup>6</sup>; *Priti Parikh*<sup>6</sup>; *Mairi*  
5 *Black*<sup>4</sup>; *Aiduan Borrion*<sup>6</sup>; *Catalina Spataru*<sup>1</sup>; *Vanesa Castan-Broto*<sup>7,8</sup>; *Gabrial Anandarajah*<sup>1</sup>; *Ben*  
6 *Milligan*<sup>9\*\*\*</sup>; *Yacob Mulugetta*<sup>4</sup>  
7

8 <sup>1</sup> UCL Energy Institute, University College London, 14 Upper Woburn Place, WC1H 0NN, London,  
9 UK

10 <sup>2</sup> Unit of Energy Systems Analysis (dESA), KTH Royal Institute of Technology, Brinellvägen 68  
11 SE-100 44 Stockholm, Sweden

12 <sup>3</sup> Institute for Sustainable Resources (ISR), University College London, 14 Upper Woburn Place,  
13 WC1H 0NN, London, UK

14 <sup>4</sup> Department of Science, Technology, Engineering and Public Policy (UCL STEaPP), University  
15 College London, 2nd Floor, Boston House, 36-38 Fitzroy Square, London W1T 6EY, UK

16 <sup>5</sup> Department of Geography, Loughborough University, Leicestershire LE11 3TU, UK

17 <sup>6</sup> Department of Civil, Environmental and Geomatic Engineering (CEGE), Chadwick Building,  
18 University College London, WC1E6BT London, UK

19 <sup>7</sup> Development Planning Unit (DPU), University College London, 34 Tavistock Square, London  
20 WC1H 9EZ, UK

21 <sup>8</sup> Faculty of Social Sciences, ICOSS, University of Sheffield, 219 Portobello, S1 4DP, Sheffield, UK

22 <sup>9</sup> Faculty of Laws, University College London, Bidborough House, London WC1H 9BT, UK  
23

24 \* francesco.fusonerini@energy.kth.se, \*\* j.tomei@ucl.ac.uk, \*\*\* b.milligan@ucl.ac.uk  
25

26 **ABSTRACT**  
27

28 *The 2030 Agenda for Sustainable Development—including 17 interconnected Sustainable*  
29 *Development Goals (SDGs) and 169 Targets—is a global plan of action for people, planet and*  
30 *prosperity. SDG7 calls for action to ensure access to affordable, reliable, sustainable and modern*  
31 *energy for all. Here we characterise synergies and trade-offs between efforts to achieve SDG7, and*  
32 *delivery of the 2030 Agenda as a whole. We identify 113 Targets requiring actions to change energy*  
33 *systems, and published evidence of relationships between 143 Targets and efforts to achieve SDG7.*  
34 *Synergies and trade-offs exist in three key domains, where decisions about SDG7 affect humanity’s*  
35 *ability to: (1) realise aspirations of greater welfare and wellbeing; (2) build physical and social*  
36 *infrastructures for sustainable development; and (3) achieve sustainable management of the natural*  
37 *environment. There is an urgent need to better organise, connect and extend this evidence, to help all*  
38 *actors work together to achieve sustainable development.*

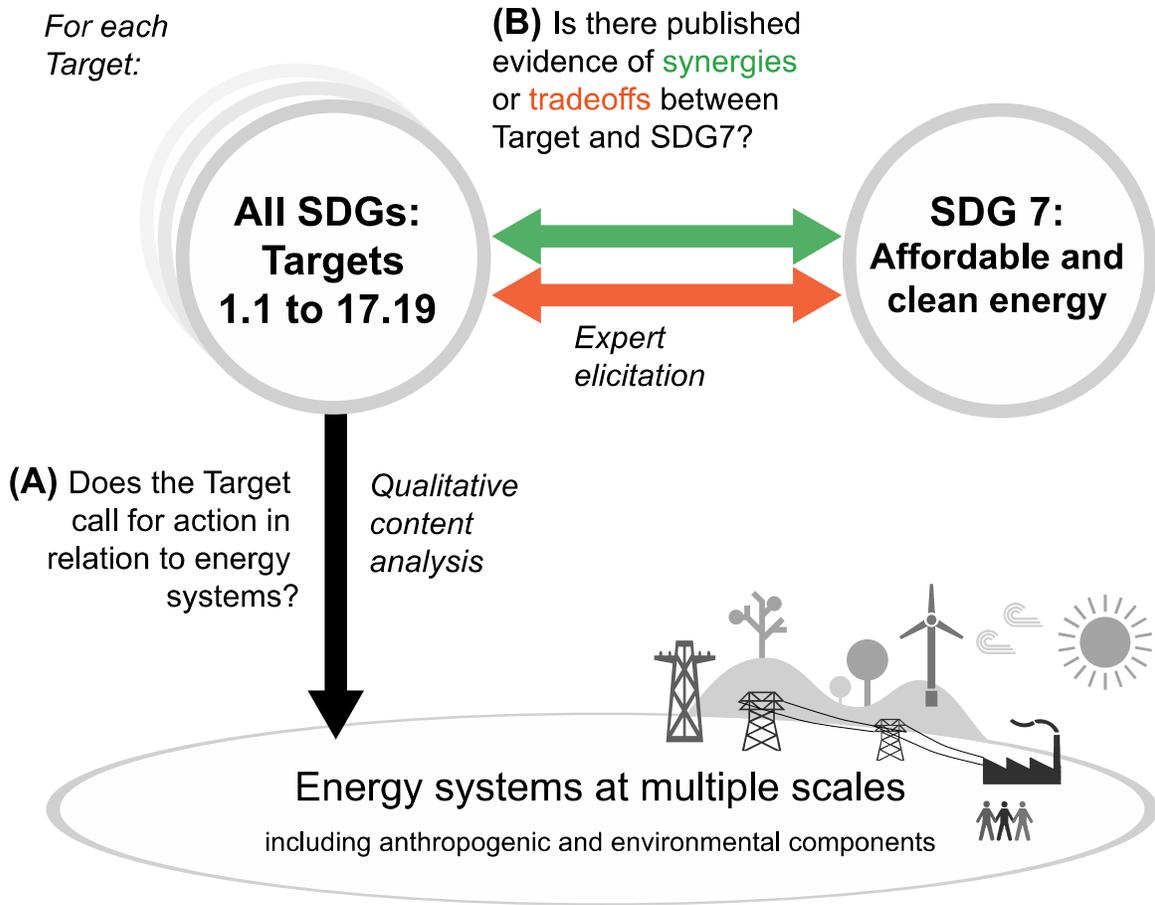
39  
40

41 On 5 September 2015, the 193 member states of the United Nations (UN) adopted a new Agenda for  
42 Sustainable Development<sup>1</sup>. The 2030 Agenda succeeds the UN's Millennium Development Goals  
43 (MDGs), and features 17 Sustainable Development Goals (SDGs) with 169 Targets, which UN  
44 member states have committed to implement by 2030. Energy was not explicitly referred to in the  
45 MDGs, and came to be referred to as the 'missing' MDG<sup>2</sup>. During the operational period of the  
46 MDGs and negotiation of the 2030 Agenda, it was increasingly recognised that energy underpins  
47 economic and social development, without which it would not be possible to eliminate poverty. This  
48 change in status<sup>3</sup> made sustainable energy provision and access one of the central themes of the 2030  
49 Agenda, whose preamble calls for 'universal access to affordable, reliable and sustainable energy' and  
50 recognises that 'social and economic development depends of the sustainable management of our  
51 planet's natural resources'<sup>1</sup>. SDG7 is accompanied by five Targets to be achieved by 2030: ensure  
52 universal access to affordable, reliable and modern energy services (7.1); increase the share of  
53 renewable energy in the global energy mix (7.2); double the global rate of improvement in energy  
54 efficiency (7.3); enhance international cooperation to facilitate access to clean energy research and  
55 technology (7.a), and promote investment in energy infrastructure and clean energy technology (7.b).

56 By understanding the complex links between the SDGs and their constituent Targets, researchers can  
57 better support policymakers to think systematically about interactions between the different SDGs;  
58 including how actions to achieve each Goal affect each other within and between sectors<sup>3,4</sup>. Studies to  
59 date<sup>4,5</sup> have lacked a Target-level approach or have focused on only a few of the SDGs<sup>6</sup>. Here we  
60 present a formative attempt by an interdisciplinary group of researchers to identify the full range of  
61 Goals and Targets in the 2030 Agenda that call for changes in energy systems, and characterise  
62 evidence of synergies or trade-offs between delivery of each of the 169 Targets and efforts focused on  
63 pursuit of SDG7 and each of its constituent Targets. The purpose of this Perspective is not to provide  
64 definitive answers. Instead we aim to lay a foundation for systematic (and context specific)  
65 exploration of the interlinkages between each of the SDG Targets, in the context of decision-making  
66 about development and the transformation of energy systems<sup>1</sup>.

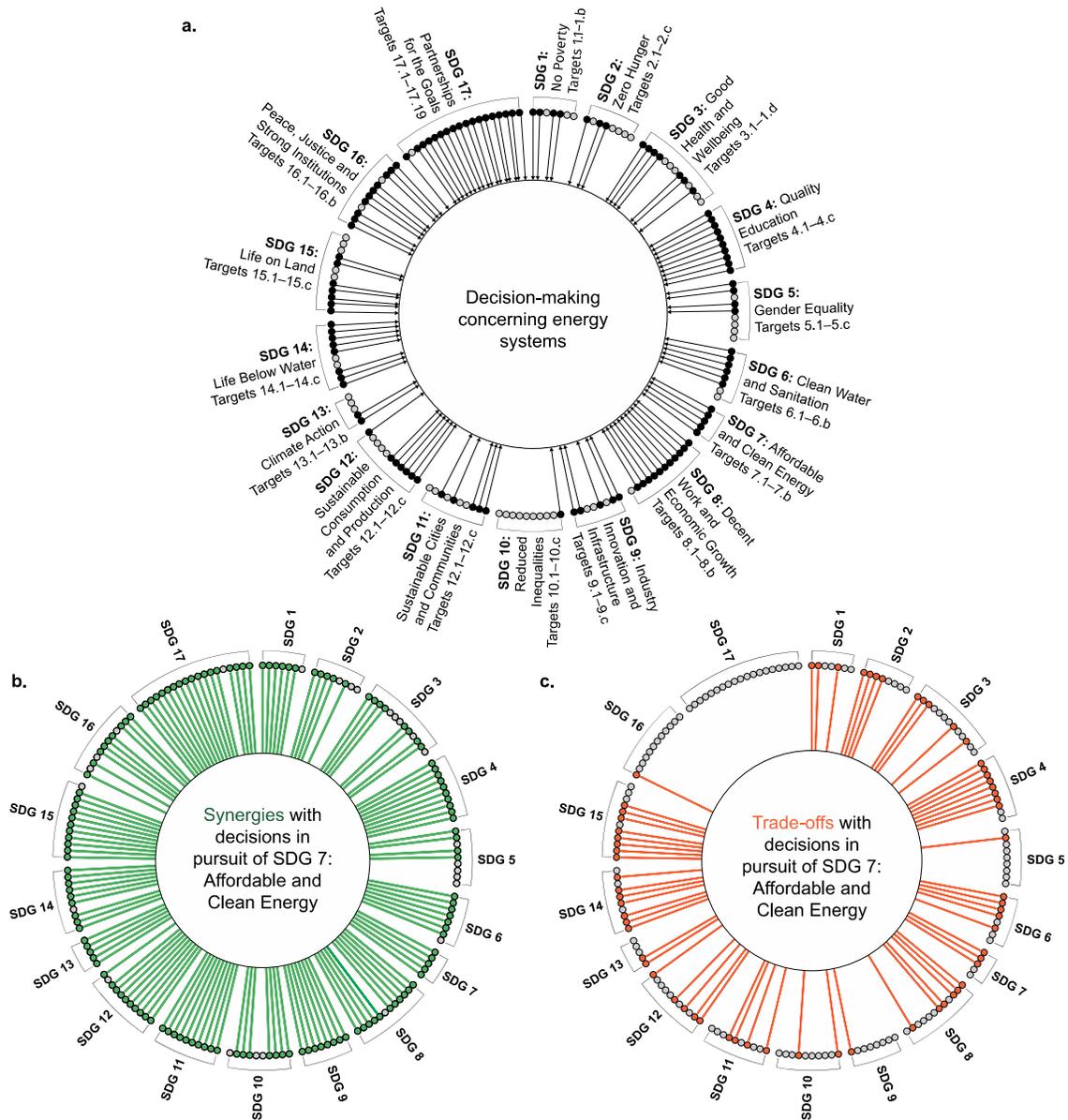
## 67 **Interlinkages between energy systems and the 2030 Agenda**

68 Figure 1 explains the methods used to assess each of the 169 Targets in the 2030 Agenda, and their  
69 respective interlinkages with energy systems. These were designed to answer two questions: (A) Does  
70 the Target call for action in relation to energy systems? and (B) Is there published evidence of  
71 synergies or trade-offs between the Target, and decisions about energy systems in pursuit of SDG7.  
72 'Energy systems' were defined broadly to include all components of anthropogenic and  
73 environmental systems related to the production, conversation, delivery and use of energy<sup>5</sup>. A systems  
74 perspective is crucial to understanding the practical complexity of energy provision and use, and  
75 facilitates effective intervention strategies<sup>6</sup>. Results of the assessment for each Target are reported in  
76 full in the supplementary material, and summarised in Figure 2.



77  
78  
79  
80  
81  
82  
83  
84  
85  
86  
87  
88  
89  
90  
91  
92  
93  
94  
95  
96

**Figure 1 | Methods used to assess interlinkages between energy systems and the 2030 Agenda.** Methods (A) and (B) were conducted for each of the 169 Targets in the 2030 Agenda for Sustainable Development. Method (A) focused on identifying the normative implications of each Target for energy systems. A consensus-based qualitative content analysis was undertaken to identify each Target's explicit (i.e. written in the text) normative content. The analysis was informed by Hall and Wright (2008)<sup>7</sup>. Method (B) focused on identifying evidence of empirical relationships (synergies or trade-offs) between the achievement of each Target, and decisions about energy systems in pursuit of SDG7 (defined by its Targets 7.1, 7.2, 7.3, 7.a, 7.b). Synergies and trade-offs were identified and characterised using a consensus-based expert elicitation process, undertaken by the authors as a body of experts from diverse disciplines spanning engineering, natural and social sciences. Design of the expert elicitation process was informed by Butler et al. (2015) and Morgan (2014)<sup>8,9</sup>. The process involved the search for published studies in academic and peer-reviewed grey literature (e.g. UN reports). Group members did not undertake a systematic review of evidence relevant to each Target. Instead a single item of relevant published evidence was deemed sufficient to indicate the presence of a synergy or trade-off between a Target and SDG7. During regular group meetings over a period of approximately twelve months, results of methods A and B for all 169 Targets were presented and refined through facilitated discussion until a consensus was reached. All results were reviewed iteratively by all experts. The experts (the authors of this paper) consisted of academics from diverse disciplines spanning engineering, natural and social sciences.



97

98 **Figure 2 | Interlinkages between energy systems the SDGs and Targets.** In **a.**, **b.** and **c.** specific Targets  
 99 recognised in the 2030 Agenda for Sustainable Development are grouped together under each associated SDG.  
 100 Targets are ordered clockwise—e.g. Target 1.1 in each diagram is represented by the leftmost circle in the group  
 101 associated with SDG1. **a.** Targets highlighted black (and indicated with black arrows) call for action in relation to  
 102 energy systems. **b.** For Targets highlighted green (and indicated with green lines), we identified published  
 103 evidence of synergies with decisions in pursuit of SDG7. **c.** For Targets highlighted orange (and indicated with  
 104 orange lines), we identified published evidence of trade-offs with decisions in pursuit of SDG7. In **b.** and **c.**,  
 105 the absence of highlighting indicates the absence of identified evidence. This does not necessarily indicate the  
 106 absence of a synergy or trade-off between the relevant Target and SDG7.

107

108 We found that 113 Targets (~65%) require actions to be taken concerning energy systems (A). Given  
 109 the broad definition of energy systems mentioned above, these actions are diverse and include efforts  
 110 to: address climate change (e.g. Target 13.2), reduce deaths from pollution (e.g. Target 3.9), and end  
 111 certain human rights abuses (e.g. Target 8.7). This gives a strong indication of the substantial changes  
 112 needed in global energy systems in order to deliver the SDGs.

113

114 We also identified evidence of synergies or trade-offs between at least 143 Targets (~85%, spanning  
115 all of the SDGs) and actions in pursuit of SDG7 (B). There are more than twice as many synergies  
116 between SDG7 and other Targets, than trade-offs (143 synergies and 65 trade-offs). Nearly all trade-  
117 offs relate to the tension between the need for rapid action to address key issues for human wellbeing  
118 (e.g. poverty eradication, access to clean water, food and modern energy, etc.), and the careful  
119 planning needed to achieve efficient energy systems with a high integration of renewable energy. We  
120 did not attempt to map these comprehensively, and indicate only whether or not there was evidence of  
121 synergies or trade-offs. Our review of evidence suggested that there are likely to be multiple synergies  
122 and trade-offs within each Target, and that identification of these relationships is highly context  
123 specific. The coarse-grained synergies and trade-offs that we identified can be categorised into three  
124 broad domains, where decisions about energy systems affect humanity's ability to: first, realise  
125 individual and collective aspirations of greater welfare and wellbeing; second, build physical and  
126 social infrastructures for sustainable development; and finally, achieve sustainable management of the  
127 environment and natural resources. This is consistent with Goal-level analyses done in other  
128 contexts<sup>10,11</sup>. The identified evidence concerning synergies and trade-offs (B) is summarised below,  
129 together with limited selected examples, and reported in full in the supplementary material.

### 130 **Aspirations of greater welfare and wellbeing**

131 The provision of affordable, reliable, sustainable and modern energy for all is vital for ensuring  
132 wellbeing. The contribution of energy to this domain is illustrated by this analysis, which identified 58  
133 and 34 Targets with synergies and trade-offs respectively with SDG7 across all Goals.

134 Energy has a fundamental role to play in efforts to end poverty<sup>12</sup> (SDG1). Provision of modern energy  
135 services (Target 7.1) will support the achievement of other Goals. For example, raising living  
136 standards through provision of basic services, including healthcare, education, water and sanitation  
137 (SDG2–4, 6–7, 9); improved household incomes (SDG8); and resilient rural and urban livelihoods  
138 (SDG1, 11). For instance, a focus on SDG4 (education) reveals the multiple synergies between  
139 wellbeing, energy and education at local, national and global levels. Target 4.2 requires that all girls  
140 and boys complete free, equitable and quality primary and secondary education. Achieving this Target  
141 depends on supply of electricity to schools, as well as to homes<sup>13</sup>. There is evidence that electricity  
142 access affects educational attainment<sup>14</sup>. Electricity is also vital for provision of information and  
143 communication technologies, which underpin adult education and global citizenship (Target 4.6,  
144 4.7)<sup>15</sup>. This will be critical to eliminate local and global inequalities by providing access to  
145 information and technology, and empowering the social, economic and political inclusion of all  
146 (Target 10.2)<sup>16</sup>.

147 Realising greater welfare and wellbeing cannot be achieved without peaceful societies and equal  
148 access to justice (SDG16). There is great potential for justice-based approaches to aid energy  
149 decisions<sup>17,18</sup>. Rather than just being an analytical concept, framing energy decisions in justice terms  
150 can help to elicit the relationship between individual and public values, map and resolve disputes, and  
151 give directional input to make better choices<sup>19</sup>. This is strongly recognised in the SDGs, for example,  
152 in terms of delivering improvements in governance of energy systems, including just institutions,  
153 strengthened rule of law, greater participation, transparency and accountability, access to information,  
154 and the reduction of corruption (Targets 9.c, 16.1, 16.3, 16.5, 16.7, 16.8, 16.10, 16.a, 16.b). For  
155 instance, development of many large-scale hydropower plants has been mired in social and political  
156 conflicts as a result of poor consultation with, and consideration of, livelihood conditions of affected  
157 local communities<sup>20</sup>. Similar impacts have been documented concerning the land used to produce

158 biofuels<sup>21,22</sup>, and extraction of coal, gas and oil<sup>23</sup>. These examples highlight the vital role of natural  
159 resources in securing wellbeing (see below).

## 160 **Physical and social infrastructures**

161 Physical and social infrastructures link aspirations for wellbeing and welfare with the underpinning  
162 natural resources<sup>10,24</sup>. There is published evidence of 109 Targets with synergies and 47 with trade-  
163 offs between SDG7 and infrastructures. Energy is a core component of the physical and social  
164 infrastructures needed to end poverty and support economic growth (SDG1, 8).

165  
166 Existing energy infrastructures will need to be significantly upgraded to achieve SDG7<sup>25,26</sup>. Nearly 1.2  
167 billion people in the world lack access to electricity and ~3 billion people lack access to clean cooking  
168 facilities<sup>26,27</sup>. A mix of locally appropriate centralised and decentralised energy infrastructures will be  
169 needed to achieve universal energy access (Target 7.1)<sup>28</sup>. Infrastructures required for energy access  
170 depend on access to financial services and markets (Target 9.3), knowledge (Target 9.5, 9.a), and  
171 strong institutions and international cooperation (SDG17). Many Targets are underpinned by energy  
172 access (Target 7.1) – energy is needed to power food systems<sup>29</sup> (Target 2.1–2.4), medical facilities<sup>30</sup>  
173 (Target 3.1–3.4, 5.6), and water treatment and distributions systems (Target 6.1–6.3). Efficient water  
174 infrastructure can also reduce energy usage<sup>26,31</sup> (Target 6.4, 6.5). More broadly, energy in its various  
175 forms is needed in cities (SDG11) where the spatial patterns influence the way we use energy, and  
176 vice-versa<sup>32</sup>.

177  
178 Energy contributes to the resilience of infrastructure, sustainable industrialisation (SDG9) and  
179 sustainable production and consumption (SDG12). For example, resilient and sustainable  
180 infrastructures (Target 9.1) require reliable energy systems with limited environmental impacts that  
181 mitigate adverse effects of climate change<sup>33</sup>. Climate change can affect the production of electricity  
182 from hydropower and thermal power plants in several regions of the world<sup>34</sup>. Achieving sustainable  
183 management and efficient use of natural resources (Target 12.2) will require changes to how energy  
184 systems use natural resources to minimise adverse impacts<sup>31</sup>.

185

## 186 **The environment and natural resources**

187 Natural environments are the foundation of human wellbeing and development – they are comprised  
188 of biotic and abiotic stocks of natural resources, which provide flows of valuable, and in some cases  
189 irreplaceable, goods in addition to ecosystem services<sup>35,36</sup>. Energy systems are underpinned by, and  
190 profoundly impact upon, these environmental stocks and flows<sup>37</sup>. There are 46 environment-related  
191 Targets with synergies, and 31 with trade-offs, with SDG7.

192 At a global scale, energy systems produce ~60% of total anthropogenic emissions of greenhouse  
193 gases<sup>38</sup>, and is consequently a core focus of urgent action to combat climate change and its impacts  
194 (SDG 13). Investment in low-carbon energy systems (Target 7.2, 7.a) will be fundamental to  
195 achieving the 2°C/1.5°C mitigation goals of the 2015 Paris Agreement on Climate Change<sup>33</sup>. Reliable  
196 energy services underpinned by research, technology and infrastructure (Target 7.1, 7.a, 7.b) can  
197 contribute to climate change adaptation, natural hazard reduction and resilience (SDG3, 9, 13). Use of  
198 natural resources by globalised energy systems (e.g. for fuel, raw materials) has impacted on  
199 ecosystem services that underpin food and water security (SDG2,6), and human health<sup>36</sup> (SDG3). The  
200 need to increase energy supply responding to growing demand, must be reconciled with the need to  
201 protect and restore critical ecosystems that support development in other sectors. This will depend on  
202 technology, behaviour and policy changes that dramatically decrease the natural resource-intensity of

203 energy systems (Target 7.3, SDG 12) as part of broader efforts to decouple adverse environmental  
204 impacts from economic growth<sup>39</sup> (Target 8.4).

205 There are complex trade-offs between the natural resource dependencies of energy, food and water  
206 systems, and environmental threats including biodiversity loss, climate change and localised air/ water  
207 pollution<sup>40,31,41</sup>. Water quality and sanitation (SDG6, 14–15) are fundamental to social vulnerability  
208 (SDG1) and healthy lives (SDG3). Energy is needed to restore water-related ecosystems (Target 6.6,  
209 Goal 14–15), sustainably manage irrigation in food systems (Target 2.4), increase water efficiency  
210 (Target 6.4, 9.4, 11.b)<sup>26,42</sup>, access and mobilise natural resources to end poverty (Target 1.4), and  
211 increase food production (Target 2.3, 2.4)<sup>43,44</sup>. Lack of access to modern energy services can drive  
212 ecosystem loss and degradation (Target 15.2) – for example any deforestation and forest degradation  
213 associated with use of fuelwood<sup>45,46</sup>.

214 Energy systems can have direct (e.g. local pollution, competition for space with energy infrastructure)  
215 and indirect (e.g. ocean acidification, climate change<sup>47</sup>) impacts on conservation, restoration and  
216 enhancement of marine and terrestrial ecosystems and other natural resources (SDG9, 14–15)<sup>48,49</sup>.  
217 SDG15 is intertwined with the nature of energy transitions, especially where livelihoods are  
218 dependent on ecosystem goods and services<sup>50</sup>. Energy systems that fully account for these  
219 interdependencies including the multiple benefits and values of the environment (Target 15.9, 17.9)  
220 can minimise adverse impacts of energy use on ecosystems and biodiversity<sup>51</sup> (Target 12.2).

221

## 222 **Empowering action to deliver the 2030 Agenda**

223

224 Our analysis highlights how energy systems are a foundation of social and economic development,  
225 and affect delivery of outcomes across all SDGs. It is also not possible to deliver SDG7 – ensuring  
226 access to affordable, reliable, sustainable and modern energy for all – without understanding how  
227 energy systems affect and depend on wellbeing, infrastructure and the environment. The SDGs  
228 represent a new framework for examining these linkages and making decisions that balance them  
229 effectively. Our analysis represents a first step towards mapping relationships between energy  
230 systems, SDG7, and other Goals in the 2030 Agenda. It reveals the tremendous complexity of links  
231 between energy systems and wellbeing, infrastructure and the environment, which means that SDG7  
232 cannot be achieved in sectoral isolation. We have shown that all SDGs and ~65% of Targets require  
233 action to change energy systems.

234 We found evidence of synergies between 143 Targets and efforts to achieve SDG7, meaning that  
235 ~85% of 2030 Agenda Targets are mutually reinforcing with SDG7. We also found evidence of trade-  
236 offs between SDG7 and ~35% of the 2030 Agenda Targets. Many of these trade-offs relate to tensions  
237 between the need to rapidly expand access to basic services, and the need for efficient energy systems  
238 underpinned by renewable resources. These synergies and trade-offs will manifest differently in  
239 different settings, and the impacts for different social groups will need to be understood and  
240 accommodated. Considerations of rights, justice and equity must be integrated into the exploration of  
241 solutions for these complex energy dilemmas,<sup>19</sup> to ensure we leave no one behind. Every Target  
242 counts, and no single Target should be overlooked in efforts to achieve SDG7. This will be a  
243 challenging task which will require collaboration between diverse actors across every domain.

## 244 **Implications for researchers**

245 For the research community, this task depends on transdisciplinary collaboration. This includes  
246 understanding the interactions between disciplines and diverse actors, and will require generation of,  
247 and access to, data and knowledge on energy and other sectors. Current knowledge concerning energy  
248 and sustainable development is isolated in many different institutions, locations and disciplines. The

249 isolation is compounded by the fact that many people, in all countries, cannot or have not been  
250 empowered with skills needed to access this knowledge. To address this, the evidence on the linkages  
251 between energy systems, SDG7 and other Goals need to be organised and connected in a manner that  
252 informs and enables efforts to achieve the 2030 Agenda. Our analysis provides a useful framework for  
253 researchers and decision-makers to design and evaluate specific interventions in energy systems to  
254 achieve sustainable development. However, this needs to be done as an inclusive, collaborative and  
255 open initiative to link energy research back to specific Targets and Goals. Such collaboration is  
256 already taking place in other contexts, for example the Future Earth Knowledge Action Networks<sup>52</sup>.

### 257 **Implications for decision-makers**

258 For decision makers in public and private sectors, the 2030 Agenda highlights that wellbeing for all  
259 can only be realised by transforming vertical silos and current modes of resource use, and by paying  
260 proper attention to supporting infrastructures and the natural environment. To this end the complexity  
261 of interrelationships between SDG7 and other Goals challenges conventional structures and processes  
262 of decision-making in government and private entities. Decision makers can no longer think in silos,  
263 and will need to find ways of widening participation, creating collective ownership and building  
264 consensus. In practice, this will require a transformation in the structure of decision-making, including  
265 the integration of vertical and horizontal planning and a long-term perspective. This requires strong  
266 local and national visions that are sensitive to the need for global collaboration. Given that energy cuts  
267 across all SDGs, structured analyses such as the one presented here can help to ensure that actions to  
268 achieve SDG7 are compatible with local and national development priorities. In so doing, this type of  
269 analysis can help the design of policies that balance synergies and trade-offs across wellbeing,  
270 infrastructure and environment in specific settings.

271 Policy makers responsible for energy matters need to collaborate with colleagues in other portfolios  
272 and vice-versa, and establish governance structures to enable and sustain such coordination. However,  
273 the principle of working across sectors and disciplines does not come naturally as it challenges  
274 entrenched institutional and sectoral behaviours. Cross-sectoral conversations on these institutional  
275 challenges will help advance this integrated agenda. The approach presented here can help policy  
276 makers to review existing institutional architectures and sector-specific policies to determine whether  
277 they are compatible with delivery of the 2030 Agenda. International organisations, including  
278 development banks, have an important role to play by coordinating action, measuring progress,  
279 facilitating dialogue and providing finance<sup>45,53</sup>.

### 280 **A call to action**

281 Finally, each and every actor has a role to play to achieve sustainable development. For SDG7, there  
282 is a tension between the need for action required to rapidly address urgent energy-related issues (e.g.  
283 energy access), and the careful planning of complex energy systems which underpin long-term  
284 development outcomes. Balancing these needs will require new skills and capacity to build country-  
285 specific and regional strategies. A more level playing field across actors and countries is required  
286 recognising that developing countries will need to build further capabilities around production,  
287 transmission, distribution and energy consumption. The research community can help build and  
288 provide the knowledge and capacity needed for other actors to operationalise SDG7 at national and  
289 sub-national levels. This includes developing and sharing flexible and appropriate tools. We envisage  
290 that applications of this approach to specific contexts can help identify key gaps in knowledge—  
291 where collaboration between actors may help to address knowledge gaps and to structure action. A  
292 strategy that brings all actors together to craft appropriate policies that balance synergies and trade-  
293 offs between SDG7 and the other Goals is essential.

294 We encourage all actors to contribute to this discussion—by enriching our analysis with additional  
295 evidence, and applying it to energy policies, programmes and projects so that their design accounts for  
296 the complexity of the 2030 Agenda. Our analysis is intended to serve as a basis for dialogue and  
297 iterative action to deliver SDG7, in a manner that realises wellbeing through provision of key  
298 infrastructures, and conservation, restoration and enhancement of the natural environment and its  
299 resources.

300 **Author Contributions:**

301 F.F.N. coordinated inputs from other authors, designed and contributed to the expert elicitation  
302 process, and wrote the paper. J.T., B.M., L.S.T. and Y.M. designed and contributed to the expert  
303 elicitation process, and wrote the paper. I.B., P.P., M.B., A.B., C.S., V.C.B. and G.A. contributed to  
304 the peer-reviewed expert elicitation process, and writing sections of the paper.  
305

306 **Acknowledgements**

307 The authors would like to thank Xavier Lemaire, Michelle Shipworth, Omotola Adeoye and Carlos  
308 Huggins for their helpful comments. Also thanks to the Energy and Development group at UCL  
309 which provided a platform for this work to be realised.  
310

311 **Competing interests**

312 The authors declare no competing financial interests.

313 **REFERENCES**

314

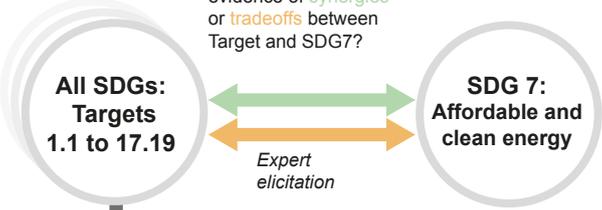
- 315 1. UN General Assembly (UNGA). Transforming our world: the 2030 Agenda for Sustainable  
316 Development. *Resolut. A/RES/70/1*, 25 1–35 (2015).
- 317 2. Brew-Hammond, A. Energy: The Missing Millennium Development Goal. in *Energy for*  
318 *Development* 35–43 (Springer Netherlands, 2012). doi:10.1007/978-94-007-4162-1\_3
- 319 3. Lu, Y., Nakicenovic, N., Visbeck, M. & Stevance, A.-S. Policy: Five priorities for the UN  
320 Sustainable Development Goals. *Nature* **520**, 432–433 (2015).
- 321 4. Nilsson, M., Griggs, D. & Visback, M. Map the interactions between Sustainable  
322 Development Goals. *Nature* **534**, 320–322 (2016).
- 323 5. IRENA. *REthinking Energy 2017: Accelerating the global energy transformation.*  
324 *International. International Renewable Energy Agency* (2017). Available at:  
325 [http://www.irena.org/DocumentDownloads/Publications/IRENA\\_REthinking\\_Energy\\_2017.p](http://www.irena.org/DocumentDownloads/Publications/IRENA_REthinking_Energy_2017.pdf)  
326 [df](http://www.irena.org/DocumentDownloads/Publications/IRENA_REthinking_Energy_2017.pdf)
- 327 6. International Council for Science. *A guide to SDG interactions: from science to*  
328 *implementation.* (2017). Available at: [https://www.icsu.org/publications/a-guide-to-sdg-](https://www.icsu.org/publications/a-guide-to-sdg-interactions-from-science-to-implementation)  
329 [interactions-from-science-to-implementation](https://www.icsu.org/publications/a-guide-to-sdg-interactions-from-science-to-implementation)
- 330 7. Hall, M. A. & Wright, R. F. Systematic content analysis of judicial opinions. *California Law*  
331 *Review* **96**, 63–122 (2008).
- 332 8. Butler, A. J., Thomas, M. K. & Pintar, K. D. M. Systematic Review of Expert Elicitation  
333 Methods as a Tool for Source Attribution of Enteric Illness. *Foodborne Pathog. Dis.* **12**, 367–  
334 382 (2015).
- 335 9. Morgan, M. G. Use (and abuse) of expert elicitation in support of decision making for public  
336 policy. *Proc. Natl. Acad. Sci. U. S. A.* **111**, 7176–84 (2014).
- 337 10. Waage, J. *et al.* Governing the UN sustainable development goals: interactions, infrastructures,  
338 and institutions. *Lancet. Glob. Heal.* **3**, e251-2 (2015).
- 339 11. Africa Progress Panel. *Lights Power Action. Electrifying Africa.* (2017). Available at:  
340 [http://www.africaprogresspanel.org/wp-](http://www.africaprogresspanel.org/wp-content/uploads/2017/03/APP_Lights_Power_Action_Web_PDF.pdf)  
341 [content/uploads/2017/03/APP\\_Lights\\_Power\\_Action\\_Web\\_PDF.pdf](http://www.africaprogresspanel.org/wp-content/uploads/2017/03/APP_Lights_Power_Action_Web_PDF.pdf)
- 342 12. Practical Action. *Poor people’s energy outlook 2014.* (2014). Available at:  
343 [https://infohub.practicalaction.org/oknowledge/bitstream/11283/556929/9/PPEO\\_English\\_201](https://infohub.practicalaction.org/oknowledge/bitstream/11283/556929/9/PPEO_English_2014_LowRes_New.pdf)  
344 [4\\_LowRes\\_New.pdf](https://infohub.practicalaction.org/oknowledge/bitstream/11283/556929/9/PPEO_English_2014_LowRes_New.pdf)
- 345 13. Dornan, M. Access to electricity in Small Island Developing States of the Pacific: Issues and  
346 challenges. *Renew. Sustain. Energy Rev.* **31**, 726–735 (2014).
- 347 14. UNDESA. Electricity and education: The benefits, barriers, and recommendations for  
348 achieving the electrification of primary and secondary schools. (2014). Available at:  
349 [https://sustainabledevelopment.un.org/content/documents/1608Electricity%20and%20Educati](https://sustainabledevelopment.un.org/content/documents/1608Electricity%20and%20Education.pdf)  
350 [on.pdf](https://sustainabledevelopment.un.org/content/documents/1608Electricity%20and%20Education.pdf)
- 351 15. Sovacool, B. K. & Ryan, S. E. The geography of energy and education: Leaders, laggards, and  
352 lessons for achieving primary and secondary school electrification. *Renew. Sustain. Energy*  
353 *Rev.* **58**, 107–123 (2016).
- 354 16. Chaurey, A. & Kandpal, T. C. Assessment and evaluation of PV based decentralized rural  
355 electrification: An overview. *Renewable and Sustainable Energy Reviews* **14**, 2266–2278  
356 (2010).
- 357 17. Jenkins, K., McCauley, D., Heffron, R., Stephan, H. & Rehner, R. Energy justice: A  
358 conceptual review. *Energy Res. Soc. Sci.* **11**, 174–182 (2016).

- 359 18. Sovacool, B. K., Heffron, R. J., McCauley, D. & Goldthau, A. Energy decisions reframed as  
360 justice and ethical concerns. *Nat. Energy* **1**, 16024 (2016).
- 361 19. Sovacool, B. K. & Dworkin, M. H. *Global Energy Justice: Problems, Principles, and*  
362 *Practices*. Cambridge University Press (2014). doi:10.1017/CBO9781107323605
- 363 20. Tilt, B., Braun, Y. & He, D. Social impacts of large dam projects: A comparison of  
364 international case studies and implications for best practice. *J. Environ. Manage.* **90**, S249–  
365 S257 (2009).
- 366 21. Hunsberger, C., Bolwig, S., Corbera, E. & Creutzig, F. Livelihood impacts of biofuel crop  
367 production: Implications for governance. *Geoforum* **54**, 248–260 (2014).
- 368 22. Tomei, J. The sustainability of sugarcane-ethanol systems in Guatemala: Land, labour and law.  
369 *Biomass and Bioenergy* **82**, 94–100 (2015).
- 370 23. Kirshner, J. & Power, M. Mining and extractive urbanism: Postdevelopment in a mozambican  
371 boomtown. *Geoforum* **61**, 67–78 (2015).
- 372 24. Parikh, P., Chaturvedi, S. & George, G. Empowering change: The effects of energy provision  
373 on individual aspirations in slum communities. *Energy Policy* **50**, 477–485 (2012).
- 374 25. Mentis, D. *et al.* Lighting the World: The first global application of an open source, spatial  
375 electrification tool (ONSSET), with a focus on Sub-Saharan Africa. *Environ. Res. Lett.* **12**,  
376 (2017).
- 377 26. IEA. *World Energy Outlook 2016*. (2016).
- 378 27. World Health Organization. *Clean Household Energy for Health, Sustainable Development,*  
379 *and Wellbeing of Women and Children. WHO Guidelines* (2016).  
380 [http://apps.who.int/iris/bitstream/10665/204717/1/9789241565233\\_eng.pdf?ua=1](http://apps.who.int/iris/bitstream/10665/204717/1/9789241565233_eng.pdf?ua=1)
- 381 28. Fuso Nerini, F. *et al.* A cost comparison of technology approaches for improving access to  
382 electricity services. *Energy* **95**, 255–265 (2016).
- 383 29. Ringler, C. *et al.* Global linkages among energy, food and water: an economic assessment. *J.*  
384 *Environ. Stud. Sci.* **6**, 161–171 (2016).
- 385 30. World Health Organisation and World Bank. *Modern Energy Services for Health Facilities in*  
386 *Resource-Constrained Settings*. (2015). Available at:  
387 [http://apps.who.int/iris/bitstream/10665/156847/1/9789241507646\\_eng.pdf](http://apps.who.int/iris/bitstream/10665/156847/1/9789241507646_eng.pdf)
- 388 31. Howells, M. *et al.* Integrated analysis of climate change, land-use, energy and water strategies.  
389 *Nat. Clim. Chang.* **3**, 621–626 (2013).
- 390 32. Broto, V. C. Energy landscapes and urban trajectories towards sustainability. *Energy Policy*  
391 **108**, 755–764 (2017).
- 392 33. IEA & IRENA. *Perspectives for the Energy Transition. Investment Needs for a Low-Carbon*  
393 *Energy System*. (2017). Available at:  
394 [https://www.irena.org/DocumentDownloads/Publications/Perspectives\\_for\\_the\\_Energy\\_Transi](https://www.irena.org/DocumentDownloads/Publications/Perspectives_for_the_Energy_Transition_2017.pdf)  
395 [tion\\_2017.pdf](https://www.irena.org/DocumentDownloads/Publications/Perspectives_for_the_Energy_Transition_2017.pdf)
- 396 34. van Vliet, M. T. H., Wiberg, D., Leduc, S. & Riahi, K. Power-generation system vulnerability  
397 and adaptation to changes in climate and water resources. *Nat. Clim. Chang.* **6**, 375–380  
398 (2016).
- 399 35. Díaz, S. *et al.* The IPBES Conceptual Framework — connecting nature and people. *Curr.*  
400 *Opin. Environ. Sustain.* **14**, 1–16 (2015).
- 401 36. UNEP. *Environment for the future we want. GEO5. Global Environment Outlook*. (2012).  
402 doi:10.2307/2807995. Available at:  
403 [http://www.unep.org/geo/sites/unep.org/geo/files/documents/geo5\\_report\\_full\\_en\\_0.pdf](http://www.unep.org/geo/sites/unep.org/geo/files/documents/geo5_report_full_en_0.pdf)
- 404 37. United Nations Development Programme. *World Energy Assessment. Energy and the*

- 405 *challenge of Sustainability. World Energy Assessment* (2000). Available at:  
 406 <http://www.undp.org/content/undp/en/home/librarypage/environment->  
 407 [energy/sustainable\\_energy/world\\_energy\\_assessmentenergyandthechallengeofsustainability.ht](http://www.undp.org/content/undp/en/home/librarypage/environment-energy/sustainable_energy/world_energy_assessmentenergyandthechallengeofsustainability.html)  
 408 [ml](http://www.undp.org/content/undp/en/home/librarypage/environment-energy/sustainable_energy/world_energy_assessmentenergyandthechallengeofsustainability.html)
- 409 38. IPCC. *IPCC Fifth Assessment Report*. (2014). Available at: <https://www.ipcc.ch/report/ar5/>
- 410 39. UNEP. *Resource Efficiency: Potential and Economic Implications*. (2017). Available at:  
 411 <http://wedocs.unep.org/handle/20.500.11822/7585>
- 412 40. International Energy Agency. *Energy and Air Pollution. World Energy Outlook - Special*  
 413 *Report* (2016). Available at:  
 414 [https://www.iea.org/publications/freepublications/publication/weo-2016-special-report-energy-](https://www.iea.org/publications/freepublications/publication/weo-2016-special-report-energy-and-air-pollution.html)  
 415 [and-air-pollution.html](https://www.iea.org/publications/freepublications/publication/weo-2016-special-report-energy-and-air-pollution.html)
- 416 41. Conway, D. *et al.* Climate and southern Africa's water-energy-food nexus. *Nat. Clim. Chang.*  
 417 **5**, 837–846 (2015).
- 418 42. UN Water. *UN World Water Development Report 2014: Water and Energy*. (2014). Available at:  
 419 <http://unesdoc.unesco.org/images/0022/002257/225741E.pdf>
- 420 43. FAO. *Energy-Smart Food for People and Climate*. (2011). Available at:  
 421 <http://www.fao.org/docrep/014/i2454e/i2454e00.pdf>
- 422 44. Fuso Nerini, F., Andreoni, A., Bauner, D. & Howells, M. Powering production. The case of  
 423 the sisal fibre production in the Tanga region, Tanzania. *Energy Policy* **98**, 544–556 (2016).
- 424 45. The World Bank. *Global Tracking Framework 2017: Progress Towards Sustainable Energy*.  
 425 (World Bank, 2017). Available at:  
 426 <http://www.worldbank.org/en/topic/energy/publication/global-tracking-framework-2017>
- 427 46. Fuso Nerini, F., Ray, C. & Boulkaid, Y. The cost of cooking a meal. The case of Nyeri  
 428 County, Kenya. *Environmental Res. Lett.* **12**, 1–15 (2017).
- 429 47. Wernberg, T. *et al.* An extreme climatic event alters marine ecosystem structure in a global  
 430 biodiversity hotspot. *Nat. Clim. Chang.* **3**, 78–82 (2013).
- 431 48. Hoegh-Guldberg, O. *et al.* Coral Reefs Under Rapid Climate Change and Ocean Acidification.  
 432 *Science* (80-. ). **318**, 1737 LP-1742 (2007).
- 433 49. Sikkema, R. *et al.* Legal harvesting, sustainable sourcing and cascaded use of wood for  
 434 bioenergy: Their coverage through existing certification frameworks for sustainable forest  
 435 management. *Forests* **5**, 2163–2211 (2014).
- 436 50. Daw, T., Brown, K., Rosendo, S. & Pomeroy, R. Applying the ecosystem services concept to  
 437 poverty alleviation: the need to disaggregate human well-being. *Environ. Conserv.* **38**, 370–  
 438 379 (2011).
- 439 51. Terama, E., Milligan, B., Jiménez-Aybar, R., Mace, G. M. & Ekins, P. Accounting for the  
 440 environment as an economic asset: global progress and realizing the 2030 Agenda for  
 441 Sustainable Development. *Sustain. Sci.* **11**, 945–950 (2016).
- 442 52. Future Earth. Knowledge-Action Networks | Future Earth. Available at:  
 443 <http://futureearth.org/knowledge-action-networks>.
- 444 53. IEA and the World Bank. *Progress toward sustainable energy 2015*. (2015). Available at:  
 445 <http://seforall.org/sites/default/files/GTF-2105-Full-Report.pdf>
- 446
- 447

For each Target:

(B) Is there published evidence of synergies or tradeoffs between Target and SDG7?



(A) Does the Target call for action in relation to energy systems?

Qualitative content analysis

