ADAPTATION AND MITIGATION STRATEGIES FOR CLIMATE CHANGE: A REVIEW OF THE ATTRIBUTES OF TRANSFORMATIONAL CHANGE IN THE ENERGY AND PUBLIC HEALTH SECTORS

PROTOCOL

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ABBREVIATIONS

3ie	International Initiative for Impact Evaluation
AMSTAR	A Measurement Tool to Assess Systematic Reviews
ATT	Average treatment effect on treated
C4ED	Center for Evaluation and Development
CAIT	Climate Access Indicators Tool
CBA	Controlled Before and After Study
CIF	Climate Investment Fund
CO₂	Carbon dioxide
COP21	Conference of the Parties
CRT	Cluster Randomized Trial
DID	Difference-in-differences approach
EGM	Evidence gap map
EPPI-Centre	Evidence for Policy and Practice Information and Co-ordination Center
F-gases	Fluorinated gases
GCF	Green Climate Fund
GHG	Greenhouse gas
GRADE	Grading of Recommendation, Assessment, Development and Evaluation
HIV	Human immunodeficiency viruses
ICTs	Internet and information and communications technologies
ITS	Interrupted time series study design
IPCC	Intergovernmental Panel on Climate Change
IV	Instrumental variable
LATE	Local average treatment effect
LMICs	Low- and middle-income countries
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
NAPA	National Adaptation Program of Action
ORS	Oral rehydration solution
PICOS	Population, intervention, comparison, outcome and study design model
PPP	Public-Private-Partnership or Private-Private-Partnership
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PSM	Propensity score matching
RCT	Randomized controlled trial
RDD	Regression discontinuity design
SURE	Supporting the Use of Research Evidence
ToC	Theory of Change
ToT	Treatment effect on the treated

TWh	Terawatt hour
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
W	Watts
WASH	Water, sanitation and hygiene
WHO	World Health Organization
WRI	World Recourses Institute

OPERATIONAL DEFINITIONS

Energy resource types[1]

Non-renewable energy: Also known as 'dirty energy'. Energy resources that cannot be readily replaced by natural means at a quick enough pace to keep up with human consumption. These are fossil fuels: coal, petroleum and natural gas. Carbon is the main element in fossil fuels.

Renewable energy: Also known as 'clean energy'. These are naturally produced from sources that do not deplete or can be replenished within a human's lifetime. The most common examples include solar, wind, geothermal, biomass and hydroelectricity sources of energy.

Transformational change[2]

Large depth of change: Effect sizes for Cohen's d = 0.8 is large, very large if d=1.2 and huge for a d=2 or a relative risk of at least 2 is large and greater than 5 is very large.

Large scale of change: There are at least 1,000 individual beneficiaries receiving the intervention, or if intervention target is an administrative area larger than a village e.g. district, region or state.

Sustained change: The effect persists for at least one year after first full implementation of the intervention.

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[1] International Renewable Energy Agency (IRENA): *https://www.irena.org/climatechange* & the United States Natural Resources Defense Council *https://www.nrdc.org/*

[2] Large depth of change: Cohen. 1988. Statistical power analysis for the behavioral sciences. L. Erlbaum Associates, Hillsdale, N.J; and Guyatt et al. 2011. GRADE guidelines: 9. Rating up the quality of evidence. Journal of Clinical Epidemiology 64, 1311–1316. *https://doi.org/10.1016/j.jclinepi.2011.06.004*

ABSTRACT

Climate change is a global problem, and disproportionately so in low- and middle-income countries. We aim to identify interventions that have contributed to transformational change in the energy sector and in behavioural change in public health. These interventions can highlight lessons for precipitating transformational change in climate mitigation and/or adaptation interventions. We focus on large impacts on a large scale, and sustained over at least a year. We will conduct a systematic review and evidence gap map for each sector and triangulate the findings in the final synthesis report. All steps in this evidence synthesis will follow pre-set standards in the PRISMA consensus statement, the Campbell Collaboration guidelines.

A. BACKGROUND AND RATIONALE[3]

1. CLIMATE CHANGE IN LOW- AND MIDDLE-INCOME COUNTRIES

The Intergovernmental Panel on Climate Change (IPCC) estimates that if greenhouse gas (GHG) emissions maintain their rise at the current rate ("business-as-usual"), then by the end of the 21st century, the average temperature will increase by 2.6 to 4.8 degrees Celsius and sea levels will rise by 0.45 to 0.82 meters [1].

The international community is responding to climate change adaptation and mitigation through the Paris Agreement and national adaptation efforts. Mitigation measures cover efforts to reduce GHG emissions, such as through a transition to clean energy sources, and the absorption of gases already emitted. Adaptation, on the other hand, refers to actions needed to better cope with the impact of climate change [2, 3].

Ongoing global efforts are, however, not sufficient to meet the goals of the Paris Agreement. Although climate finance has risen considerably over the past years, it is still deemed too low compared to the level required to achieve a 1.5 degrees Celsius global-warming scenario [4]. As one example, investments into low-carbon technologies fall short of what is required to meet the mitigation target, according to a report by the International Energy Agency (2019). The same applies to insufficient adaptation finance [5], which does not meet the needs expressed by developing countries [6].

2. ENERGY SECTOR AND CLIMATE CHANGE IN LOW- AND MIDDLE-INCOME COUNTRIES

Global warming is a consequence of the lagged, cumulative effect of greenhouse gas emissions. Such gases stay in the atmosphere for up to a century, such that on a per capita, historical basis, industrialized countries (that is, Annex 1 countries who are party to the UNFCCC) bear the majority of the responsibility for such pollutants.

That said, nearly all of the growth in energy demand, and consequently fossil-fuel use and GHG emissions, is predicted to come from LMICs [7]. Part of this increase may in itself be driven by climate change. With rising temperatures, LMICs, for example, are expected to increasingly use air conditioners, with the demand for residential air conditioning projected to rise from 500 TWh in 2000 to around 4000 TWh in 2050 [8]. The reliance of LMICs on fossil fuels for energy production means the projected increase in energy demand will, without strong counter-measures, results in even higher greenhouse gas emissions [9]. For the period 1994 -2014, Falconí et al. [10] already found considerably higher growth rates of per capita CO2 emissions in middle-income compared to high-income countries (HICs), with -0.2% for the latter compared to 2.8% for upper and 1.4% for lower middle income countries. Similarly, upper and lower middle-income countries have nearly 24 times (for upper) and 9 times (for lower) the per-capita energy-use growth rate of HICs. The contrast between the responsibility of Annex 1 countries for historical emissions and the responsibility of non-Annex 1 countries for future emissions is why climate change is such an intractable problem. It also shows why the energy sector in LMICs plays such a key role for climate change mitigation measures.

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[3] This protocol is based on the approach paper „A Review of the Attributes of Transformational Change in the Energy and Public Health Sectors to Inform Climate Mitigation and Adaptation" by Aitmambet et al. (2020).

3. PUBLIC HEALTH SECTOR AND CLIMATE CHANGE IN LOW- AND MIDDLE-INCOME COUNTRIES

We also approach this exercise by reviewing the evidence on behavioral change in the sector of public health. The public health literature has the longest tradition of long-term causal studies on behavioral change and thereby how to overcome the "last-mile problem", which so often stands in the way of realizing changes at scale, with depth and through time [*11*]. For the public health sector, we include interventions targeting behavioral change in five broad areas – nutritional (dietary) habits, physical activity, substance abuse, hygiene practices and utilization of health care services. The goal is to assess how lessons in energy and behavioral change in public health (in terms of interventions that led to large and sustained change at scale) may inform broader mitigation and adaptation investment. This review therefore combines, in a novel way, two different reviews into one learning exercise.

4. RATIONALE: WHY REVIEW THE EVIDENCE ON CLIMATE CHANGE IN ENERGY AND PUBLIC HEALTH SECTORS IN LOW- AND MIDDLE-INCOME COUNTRIES?

The rationale for this review is three-fold as follows [*12*, *13*]:

1) <u>New evidence</u>: To our knowledge, there appears to be an absence of systematic evidence on the causal drivers of transformational change in general, and in particular in relation to climate change mitigation and adaptation.

2) <u>Robust evidence</u>: We propose to provide high-quality evidence based on the inclusion of experimental studies, studies that demonstrate transformational change, complete with quality assessments of the included studies (risk of bias).

3) <u>Evidence gaps</u>: We will produce evidence gap maps for each sector to highlight where the evidence is and where more evidence in needed in terms of interventions and outcomes in energy and public health sectors. We will also aggregate these to produce transformational change maps.

B. OBJECTIVES OF THE REVIEW

<u>Objective 1</u>. To examine the attributes, determinants and contributors of transformational change in the energy sector and;

<u>Objective 2</u>. To learn from transformational change related to behavioral change in the public health sector.

C. RESEARCH QUESTIONS

Specifically, there are three research questions of focus:

1) In two sectors including (i) energy and power, in particular production and use of energy, energy efficiency, renewable energy, and transitions from GHG-emitting energy sources to clean energy, and (ii) behavioral change in public health; what are we learning about what is transformational? What are the drivers and inhibitors of transformational change as defined by the three attributes that we recognize as necessary, depth, scale and sustained change? What is rigorous causal evidence telling us about what causes these, what are contextual factors, and what are mediating factors? What does a statistical meta-analysis of these results show us?

2) Do scale effects differ by sector, intervention, context or other variables? How much and why? What sorts of interventions are those where scale effects are witnessed? What are the drivers of transformational change as measured by effect sizes of immediate and intermediate outcomes, distal outcomes and overall/ultimate impacts?

3) What is the (statistical) 'range' of transformation that we are witnessing in different sectors and sub-sectors, as measured by their effect sizes, and is there an emerging pattern? Can we define a specific threshold, or a variety of thresholds, in these two sectors that helps us understand 'large' change? What are these thresholds and what are the cut-offs in (standardized) effect sizes that can be identified to distinguish 'large' change? What are the characteristics and attributes of the causes of 'large sized' change?

D. SYSTEMATIC REVIEW METHODS

1. PROTOCOL DEVELOPMENT AND REGISTRATION

This systematic review protocol will be registered in the International Prospective Register of Systematic Reviews PROSPERO which is an open access online registry managed by the University of York, York, United Kingdom, *http://www.crd.york.ac.uk/PROSPERO/* [14] and then published in a peer-reviewed journal, agreed upon by both the international team and the group of consultants in Uganda. Briefly, we will use standard systematic methods that limit bias through a duplicate search, identification and selection of studies, as well as abstracting the data [15]. We will refer to the following consensus recommendations for systematic reviews conduct: the PRISMA-P statement (Preferred reporting items for systematic review and meta-analysis protocols) to develop this protocol [16]. Finally, we will report our results in line with the PRISMA guidelines (Preferred Reporting Items for Systematic Reviews and Meta-analyses) [17]. For the Evidence Gap Maps, we will follow the approach documented by the Campbell Collaboration [18].

E. REVIEW QUESTIONS

1. COMMON ELIGIBILITY CRITERIA FOR STUDIES IN BOTH ENERGY AND PUBLIC HEALTH SECTORS

The review questions will consider studies for eligibility according to the "PICOS" model. The criteria cutting across both sectors include:

1) **Population under study:** Studies about adolescents or adults in the general population groups, irrespective of gender, income levels or other socioeconomic or health related vulnerabilities for both energy and public health sectors.

2) **Comparator:** Studies with a comparison group, which may be an active alternative intervention or passive or inert intervention.

3) **Scale of the outcome of interest:** Studies on interventions with at least 1,000 individual beneficiaries (treatment effect on the treated) or the intervention targets an entire administrative area larger than a village. Note that the actual study sample size can be smaller than those who are beneficiaries of the intervention.

4) **Timing of the outcome assessment:** Studies where the outcome is measured at least one year after first full implementation of the causally identified intervention component of interest.

5) **Study design:** Studies are included if they are:

a) Experimental designs: Cluster or individual randomized controlled trials (CRTs, RCTs);

b) Quasi-experimental designs: These may take various nomenclatures in energy or public health realms such as case-control, controlled before and after studies; interrupted time series designs; difference-in-difference, instrumental variables and regression-discontinuity-designs; and propensity score matching;

c) Syntheses: Systematic reviews and meta-analyses.

6) **Setting of the intervention:** Studies in low- and middle-income countries as defined by the World Bank criteria for the fiscal year 2020.

7) **Language of publication:** Only studies written in English will be included.

2. SPECIFIC CRITERIA FOR INCLUSION OF STUDIES IN THE ENERGY SECTOR: INTERVENTION AND OUTCOMES

a) Interventions

The energy sector includes studies of four broad interventions. These are institution and market systems; incentives and standards; 'soft interventions' and investments into energy infrastructure, equipment and technology.

i) *Institutions and market systems*: Interventions that change the institutional structure of energy systems or markets. These are:

- Governance arrangements: public-administration reforms, industry coordination and industry self-regulation. Specific examples include technical assistance, restructuring of government units, and changes in management practices; business associations and industry bodies.

- Marketplace reforms: privatization, liberalization and introduction of market-based mechanisms. Specific examples are energy and emissions trading platforms, and frameworks for private sector involvement (Public-Private-Partnership).

- Reversal of marketplace reforms: de-privatization (nationalization or state-owned enterprises) and de-liberalization (market control).

ii) *Incentives and standards*: These interventions provide inducements or motivations to elicit behavioral change towards a specific desired energy sector outcome.

- Incentives: are interventions meant to create reward expectations for following a particular behavior or abstaining from it. Monetary or in-kind incentives. Specific examples include distribution of more energy efficient consumer appliances, subsidies, block tariffs, tax rebates and feed-in tariffs.

- Coercion: These create the expectation of punishment. Examples are disincentives such as taxes and fees, permits, green quotas.

- Restrictions: are interventions prohibiting engagement in target behavior with the use of rules such as bans or regulated uses. These are command and control, damage control or prohibitive measures. Specific examples are in form of bans, limits or caps and energy standards.

iii) *Soft interventions*: Are those that do not change the "choice-set" of actors. These are:

- Education: awareness and knowledge campaigns (behavior change communication) to promote progressive energy practices for climate change mitigation and

adaptation. This may not only to inspire a particular behavior but also provide knowledge about competing behaviors.

- <u>Persuasion</u>: using various methods of communication, say reminders or warnings via phone or other devices, positive or negative feelings to stimulate behavior change action regarding energy choices and use.

- <u>Training</u>: individuals are imparted skills to encourage behavior of activity being trained. For example, community skills building workshops on efficient energy use.

- <u>Social environmental restructuring</u>: This entails changing social environment in terms of social norms, peer pressure and feedback for more efficient energy use.

- <u>Modeling</u>: this is where depicting what the model behavior should be stimulates behavioral change. This is the method of leading by example, by showcasing the model behavior. For example, model behavior advertisements, TV shows or posters.

- <u>Enablement</u>: This involves setting defaults. These are supportive interventions that increase the means or reduce the barriers, or increase the capability to act on targeted behavior.

iv) ***Investments into energy infrastructure, equipment and technology***: Would typically be done by state-actors and without transfer of ownership to private parties. The three example sub-categories are:

- <u>Energy transmission, distribution and storage of electric energy systems</u>: This captures batteries for storage, pumped-storage hydroelectricity.

- <u>Renewable energy</u>: Dams for hydropower or windmills for wind energy.

- <u>Other physical environmental restructuring</u>: Changes to the physical environment other than investments into infrastructure and distribution of appliances, such as changing traffic signals.

b) **Outcomes:** There are seven broad outcomes of interest in the energy sector. These are around energy access, supply, demand and consumption; energy markets and efficiency gains (adaptation), resilience, emissions (pollution) and labor markets.

i) ***Supply of and access to energy***: These are four sub-categories:

- <u>Energy equity and affordability</u>: energy inclusiveness, energy affordability hence further expanding access and energy cost reductions.

- <u>Supply of renewable energy</u>[4]: generation and supply of traditional renewable energy or next generation renewable energy. This includes biofuels.

- <u>Supply of non-renewable energy</u>[1]: generation and supply of energy from coal, oil, gas, Liquefied Petroleum Gas (LPG), Liquefied Natural Gas (LNG), kerosene, petrol, diesel and nuclear.

- <u>On-grid and off-grid electricity access</u>: generation and supply of electricity, electricity coverage and adoption of grid access.

ii) ***Energy market development***: These are:

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[4]Measured in units of energy

- Investments[5]: typically private and in energy generation particularly renewable energy be it traditional or next generation; fossil fuels, nuclear energy and electricity.

- Competitiveness of energy markets: This entails market power of energy suppliers, composition. Specifically, the number of suppliers of energy products and services, concentration indices, service quality standards, power outages, variation in voltage and use of technological innovations.

- Price responses and integration of electricity systems: These include liquidity, pricing regulation and instruments, price adjustments, spatial connectivity of electricity systems and linkages within the power supply chain.

iii) ***Energy demand and consumption[6]***

- Renewable energy: consumption of and demand for traditional renewable energy or next generation renewable energy.

- Non-renewable energy: consumption of and demand for energy from coal, oil, gas, LPG, LNG, kerosene, petrol, diesel, nuclear; diesel-generators (off-grid).

- On-grid electricity: consumption of and demand for electricity produced by a mix of energy sources; otherwise, it is categorized under renewable or non-renewable.

iv) ***Adoption of more energy efficient technologies[7]***

- Transmission, distribution, storage and conservation technologies: adoption of energy efficient generation technologies.

- Generation technologies: adoption of energy efficient transmission, distribution, storage and conservation technologies.

- Productive-use equipment: adoption of energy efficient technologies and equipment in manufacturing, construction/infrastructure and services sectors.

- Consumer appliances: adoption of more energy efficient consumer appliances for lighting, transportation and cooking.

v) ***Resilience of energy systems (adaptation)***

- Adaptive capacity: e.g. security of energy supply through diversification of energy sources and lower energy imports. Energy security, reliance on energy imports, excess generating capacity, oil, gas, and LNG storage reservoirs.

- Anticipatory capacity: Implies reducing impact of known specific types of disruptions through preparedness and planning. Energy use planning, peak energy use, smoothing of energy consumption, decentralization of energy systems, integrating energy resilience into systems planning (heat, power, transportation systems).

- Absorptive capacity: This is with respect to realized risks of disruption. Ability of households to cope with energy production side blackouts, power quality, reliability of energy systems.

vi) ***GHG emissions and pollution***: as result of energy generation, transmission, storage and consumption.

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[5]Measured in monetary terms
[6]Measured in energy units
[7]Measured in uptake, not in monetary units or through demand for energy

- CO2 emissions: for example, carbon capture at power plants.
- Indoor air pollution: for example, from cook stoves.

vii) ***Labor market co-benefits*:** This entails employment, unemployment, number of new jobs and local-level multiplier effects on labor market.

- Employment status: jobs created in formal sector.
- Employment mobility: shift from part-time to full-time working hours.

3. SPECIFIC CRITERIA FOR EXCLUSION OF STUDIES IN THE ENERGY SECTOR

Studies are excluded from the energy sector for:

a) **Irrelevance:** Does not fit the general objective of the energy sector of this review, climate change mitigation.

b) **Population:** Reporting about children below 12 years.

c) **Intervention**: With the following intervention characteristics:

   i) Not directly related to climate change mitigation: For example, labor market reforms, labor-market trainings, agronomic trials, engineering, geological, geographical, new business models and investments into infrastructure other than energy infrastructure.

   ii) Investment and distribution of small energy appliances: less than 200W, such as solar lanterns and solar household appliances.

   iii) Investments into non-renewable energy: that is fossil fuels: coal, petroleum, and natural gas; and nuclear plants.

   iv) Disaster risk reduction: general measures that only indirectly affect energy system resilience.

d) **Outcome:** With the following outcome characteristics:

   i) Irrelevance: Not directly related to climate change mitigation or adaptation in the energy sector. Implementation of a new business model in the energy sector; engineering or technological innovations other than related to energy-efficiency, economic growth, biomass production or agricultural yields.

   ii) Carbon and forestry: Carbon sequestration and (de) forestation.

   iii) Labor market outcomes: that is not measured in response to an intervention targeting climate-change mitigation or adaptation or energy access.

   iv) Time use: other than for formal employment.

4. SPECIFIC CRITERIA FOR INCLUSION OF STUDIES IN THE PUBLIC HEALTH SECTOR: PRIORITY AREAS, INTERVENTION AND OUTCOMES

There are five priority public health areas of relevance to this review: substance abuse, utilization of health services, hygiene, nutrition and physical activity. These are areas where behavior change interventions may have transformational impact and lessons can be drawn for climate change mitigation and adaptation. Below are notes from the World Health Organization definitions:

1) Substance abuse: the harmful or hazardous use of psychoactive substances, including alcohol and illicit drugs. Included studies report the use of tobacco, alcohol, narcotics or stimulant drugs. These may be used variously through drinking, smoking, sniffing or patches [*19*].

2) Utilization of health services: Is the use of services by persons for the purpose of preventing and curing health problems, promoting maintenance of health and well-being, or obtaining information about one's health status and prognosis. Included are uptake of primary healthcare whether preventive, primitive and curative: immunization or vaccination against infectious diseases, antenatal or post-natal care, facility deliveries, testing or check-ups for prevalent diseases (HIV, malaria), or adherence to services offered e.g. oral rehydration salts [20].

3) Hygiene practices: Are conditions and practices that help to maintain health and prevent the spread of diseases. Included are studies about hand washing, use of sanitary facilities (open defecation), drinking water treatment (solar, chlorine, boiling) [21, 22].

4) Nutrition and dietary habits: Are food preferences by persons in their daily life. Included aspects are about food fortification, diet diversification, nutritional/food equity, dieting and nutritional supplementation [23, 24].

5) Physical activity: Is any bodily movement produced by skeletal muscles that requires energy expenditure; including activities undertaken while working, playing, carrying out household chores, travelling and engaging in recreational pursuits. In this review included activities are exercise: walking, cycling, going to the gym and such related choices [25].

There are nine intervention areas of interest in this review for which studies will be included. These are education, persuasion, incentives, coercion, training, restriction, modeling, environmental modification and modeling.

a) **Interventions:** The specific interventions are nine (9) and follow the behavioral framework defined by Michie and colleagues[8] [26].

    i) Education: awareness and knowledge campaigns (behavior change communication) to promote health such as frequent hand washing or mass immunization. This may not only to inspire a particular behavior but also provide knowledge about competing behaviors.

    ii) Persuasion: using various methods of communication, say reminders or warnings via phone or other devices, positive or negative feelings to stimulate behavior change action. Communicating reminders or warnings through mobile devices (e.g. phone) to not drink and drive or harms of smoking are good examples.

    iii) Incentivization: are interventions meant to create reward expectations for following a particular behavior or abstaining from it. Monetary and in-kind rewards such as free or subsidized medication, consultation or vaccines.

    iv) Coercion: These create the expectation of punishment such as price increases for alcohol or tobacco or related spot-checks and spot fines for drink driving.

    v) Training: individuals are imparted skills to encourage behavior of activity being trained. Community skills building workshops for hygiene practices.

    vi) Restriction: are interventions prohibiting engagement in target behavior with the use of rules such as bans or regulated uses. These can alternatively also be used to encourage a particular behavior by discouraging competing behaviors. For example, prohibiting sales of alcohol to younger than 18 years old, only at particular times, smoking only in particular areas in a bar.

    vii) Social environmental restructuring: where by modifying the physical context around an individual, such as improving infrastructure or technologies related to the targeted

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[8] Michie et al 2011. The behavior change wheel: A new method for characterizing and designing behavior change interventions. Implementation Sci 6, 42. *https://doi.org/10.1186/1748-5908-6-42*

behavior, these can be encouraged or discouraged. Physical improvements or creation of infrastructure to facilitate access to health services or use of health facilities or reduce unhealthy practices. Another subset of intervention under this capture the modification of the social context around the targeted behavior, such as prompts that provide guidelines are also considered under this category.

viii) <u>Physical environmental restructuring</u>: improvements or creation of infrastructure to facilitate access to health services or use of health facilities or reduce unhealthy practices.

ix) <u>Modeling</u>: this is where depicting what the model behavior should be stimulates behavioral change. This is the method of leading by example, by showcasing the model behavior. Role-play with model behavior advertisements, TV shows or posters.

x) <u>Enablement</u>: These are supportive interventions that increase the means or reduce the barriers, or increase the capability to act on targeted behavior. Such as behavioral support for smoking cessation by mobile-based applications and services, or those that encourage health check-ups.

b) **Outcome:** Are related to behavior change with a causal link to the intervention of interest.

i) *Action behavior:* These are actions taken by individual to improve health.

- <u>Social</u>: HIV testing, open defecation, drunk driving, passive smoking.

- <u>Private</u>: ANC, PNC, institutional delivery, hand washing.

ii) *Consumption/purchasing:* purchasing drugs or alcohol, nutritious food.

- <u>Social</u>: toilet construction.

- <u>Private</u>: expenditure on drugs, alcohol bought, spending on tobacco/cigarettes.

5. SPECIFIC CRITERIA FOR EXCLUSION OF STUDIES IN THE PUBLIC HEALTH SECTOR

Studies are excluded from the public health sector for:

a) **Irrelevance:** Does not fit the objective of the public health sector in the five priority areas as follows:

i) <u>Nutrition & dietary habits</u>: Agriculture and related food fortification

ii) <u>Physical activity</u>: Exercise among athletes

iii) <u>Substance abuse</u>: Violence due to substance abuse

iv) <u>Hygiene</u>: Food storage, waste disposal and menstrual hygiene

v) <u>Healthcare utilization</u>: hospital/ health care quality improvement, insurance uptake, pay for performance, contraceptive use, malaria prophylaxis or Insecticide Nets

Each intervention within each of these 5 priority sub-sectors will be allocated to one of 6 nested sources of behavior following the COM-B behavioral change wheel from Michie and colleagues [26] as defined below:

i) *Physical capability* can be achieved through physical skill development, which is the focus of training or enablement.

ii) *Psychological capability* can be achieved through imparting knowledge or understanding via education, training emotional, cognitive and/or behavioral skills or enablement.

iii) ***Reflective motivation*** can be achieved through increasing knowledge and understanding, eliciting positive (or negative) feelings about the behavioral target through education, persuasion, incentives and coercion.

iv) ***Automatic motivation*** can be achieved through associative learning that elicit positive (or negative) feelings and impulses and counter-impulses relating to the behavioral target, imitative learning, habit formation or direct influences on automatic motivational processes. It can be achieved through persuasion, incentivisation, coercion, environmental restructuring, modeling or enablement.

v) ***Physical opportunity*** can be achieved through environmental change via restriction, environmental restructuring and enablement.

vi) ***Social opportunity*** can be achieved through environmental change via restriction, environmental restructuring and enablement.

b) **Population:** Reporting about children below 18 years.

c) **Intervention**: With the following intervention characteristics:

   i) <u>Natural interventions</u>: These are not in the control of humans, such as sudden climate related shocks or natural disasters or migration.

   ii) <u>Laboratory or clinical trial or field interventions</u>: targeting a hospital, clinic or laboratory. For example quality of care, Performance Based Financing, health professional training or education.

   iii) <u>Policy changes from governmental authorities</u>: These are liberalization of health sector. (De) regulation or decentralization or privatization or simplification of procedures. Policy changes may be governmental change/laws or regulation: legislature, bills or policies, coordination of government at different levels nationally or sub-nationally.

d) **Outcome:** With the following outcome characteristics:

   i) <u>Irrelevance</u>: Not relevant to the five sectors and not falling under action behaviors or consumption or purchasing. These are outcomes that are not related to health and health related practices of individuals, villages or communities. Examples include: penetration of new medical technology, implementation success of particular, health related legal policy, administrative changes in hospitals, health facility and service quality and access.

   ii) <u>Secondary outcomes</u>: Secondary health outcomes without direct behavioral change channel. These are disease/illness prevalence rate, cure, morbidity, mortality and accidents.

6. COMMON CRITERIA FOR EXCLUSION FOR BOTH ENERGY AND PUBLIC HEALTH SECTORS

a) Study design

   i) Quantitative designs are generally other methods that are not based on control groups:

   - Granger causality
   - Correlation analysis
   - Cross sectional studies
   - Cohort designs
   - Random effects, input-output models

- General-equilibrium models
- Theoretical, modeling and simulation studies

ii) Qualitative studies:

- Ethnography
- Grounded theory
- Phenomenology
- Qualitative case study

iii) Traditional narrative reviews (non-systematic)

iv) Opinion pieces, perspectives, editorials

b) **Population/Setting:** Studies including high income countries only or include low- and middle-income countries without disaggregated data which can be abstracted independent of high-income countries.

F. INFORMATION SOURCES

1. SEARCH STRATEGY AND PRELIMINARY RESULTS

Our comprehensive search strategy consists of the following:

1) **Electronic search**: The electronic search strategy will follow the PICOS approach. Search terms will include various combinations of technical terms. Key words will be combined using Boolean logic: "OR" for similar terms in the same element and "AND" for terms across the elements.

2) **Information sources**

a) **Energy sector**

i) Databases

(1) Academic Search Complete (via EBSCO)

(2) CAB Abstracts (via EBSCO)

(3) EconLit (via EBSCO)

(4) GreenFILE (via EBSCO)

(5) Web of Science (Social Sciences Citation Index, Science Citation Index Expanded, Emerging Sources Citation Index)

(6) World Bank eLibrary (via EBSCO) [9]

ii) Websites of agencies and research institutes

(1) African Development Bank (AfDB) *https://www.afdb.org/en*

(2) Asian Development Bank *https://www.adb.org/*

(3) Campbell Collaboration *https://campbellcollaboration.org/*

(4) Collaboration for Environmental Evidence *https://www.environmentalevidence.org/*

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[9] We will conduct the search in Ideas RePEc and World Bank eLibrary databases assuming that the technical problem on the EBSCO database will be solved by EBSCO. We are in contact with the EBSCO technical support service on this matter.

    (5)   International Initiative for Impact Evaluation: 3ie Development Evidence Portal *https://developmentevidence.3ieimpact.org/*

    (6)   National Bureau of Economic Research *https://www.nber.org/*

    (7)   Swedish International Development Cooperation Agency (SIDA)[10] *https://www.sida.se/English/*

  iii)   Key journals

    (1)   Energy Economics

    (2)   Energy Journal

    (3)   Energy Policy

Given the scope of the review in terms of the range of topics as well as the time period covered, we will not perform hand search of key journals. Instead, we will run a database search in the Web of Science platform with the simplified set of search terms in the three relevant energy journals with the highest impact factors.[11]

  b)   **Public health sector**

  i)   Databases

    (1)   EconLit (via EBSCO)

    (2)   Global Health (CAB- Ovid)

    (3)   Medline (Ovid)

    (4)   Web of Science (Social Sciences Citation Index)

  ii)   Websites of agencies and research institutes

    (1)   Campbell Collaboration *https://campbellcollaboration.org/*

    (2)   Cochrane Database of Systematic Reviews *https://www.cochranelibrary.com/cdsr/*

    (3)   Collaboration for Environmental Evidence *https://www.environmentalevidence.org/*

    (4)   International Initiative for Impact Evaluation: 3ie Development Evidence Portal *https://developmentevidence.3ieimpact.org/*

3)   **Limitations of the search terms**: The search will be limited by time period and language. Only studies in the English language and published from 1990 onwards for energy sector and 2000 onwards for public health will be searched for.

Table 1.   Yield of literature on the energy sector

DATABASE	NUMBER OF HITS
Academic Search Complete (via EBSCO)	1,459
CAB Abstracts (via EBSCO)	2,064

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[10] We included SIDA as a bilateral agency website because during preliminary searches we identified it as having potentially relevant impact evaluation studies. We excluded websites of other shortlisted bilateral agencies due to a lack of relevant studies.

[11] The highest impact journals relevant for this review were selected from the list available at Scimago Journal & Country Rank for energy. These more relaxed restrictions (in terms of outcomes, and long-term or large-scale) will ensure that only three of the six categories below (countries, methodology and interventions) are combined using the AND operator with the following Publication Name terms string:

SO=("energy economics" OR "energy journal" OR "energy policy").

DATABASE	NUMBER OF HITS
GreenFILE + EconLit (via EBSCO)	1,941
Web of Science (Social Sciences Citation Index, Science Citation Index Expanded, Emerging Sources Citation Index)	2,046
World Bank eLibrary (via EBSCO)	594
African Development Bank (AfDB)	35
Asian Development Bank	152
Campbell Collaboration	2
Collaboration for Environmental Evidence	3
International Initiative for Impact Evaluation	90
National Bureau of Economic Research	43
Swedish International Development Cooperation Agency	21
Energy Economics, Energy Journal, Energy Policy	260
TOTAL before de-duplication	**8,710**

G. DATA MANAGEMENT

1. DATA MANAGEMENT: SCREENING, CODING AND ABSTRACTION

Data will be managed in four stages. Generally, literature search results will be uploaded into EPPI Reviewer 4 software: *http://eppi.ioe.ac.uk/eppireviewer4/* that facilitates collaborative work among reviewers. After removal of duplicates the team (two pairs of reviewers) will commence the screening, eventual coding and data extraction from the included papers. Any disagreements in screening, coding and data abstraction will be resolved by consensus. In order to maintain quality, only two fixed pairs of reviewers are proposed. Screening quality will be assessed to check that at least 80% of the example papers are captured by the full text coding stage.

Based on previous experience, we estimate about 22,000 titles and abstracts to be screened. In the pilot phase, a team pair of reviewers will screen 200 titles and abstracts for each sector (total 400) to achieve inter-rater agreement of at least 80% after consensus. This will optimally prime the machine learning function of EPPI Reviewer 4 software. This machine learning will be employed to sift through this bulk of literature and reprioritize them according to relevance.

Stage 1: Pilot stage. In the pilot phase, 200 titles and abstracts from each sector will (total 400) will be uploaded into Zotero: *https://www.zotero.org/* and coded in Excel: *https://www.microsoft.com/en-us/microsoft-365/excel* for initial title and abstract screening to test the utility of and refine the proposed screening codes before entering them into EPPI Reviewer 4. The same process will be followed for the full text screening to refine and finalize the codes and data to be abstracted.

Stage 2: Title and abstract screening stage. After the full pilot, all identified articles will be screened for eligibility by title and abstracts. Duplicate screening will be done for the first 50% of the articles after which single screening will be done until saturation. Saturation will be reached when 1 in every 100–screened titles and abstracts are included. At this point the rest of the titles and

abstracts will be discarded. Full texts of those articles that are eligible will be retrieved and pushed to the next stage of screening.

Stage 3: Full text screening. Pairs of review teams will review the full texts for eligibility applying the PICOS model. Those full texts found eligible will be pushed to the next level of full text coding and data extraction. Differences in full text screening will be resolved by consensus between the review team pair.

Stage 4: Full text coding and data extraction stage. Any two reviewers will extract data into EPPI Reviewer 4 in duplicate and independently. The data items to be coded for the Evidence Gap Map are for interventions and outcomes, as pre-specified in the section for review question. In the energy sector, we will also apply the Behavior Change Wheel of Michie and colleagues [26] and code interventions according to whether they are structural or behavioral. For the systematic reviews, the following data will be extracted, beyond the coding at the EGM stage: intervention level (individual or cluster), intervention size, sample size or number of beneficiaries, estimate of effect (outcome) and duration of follow up (time of outcome assessment). Differences in full text coding and review data extraction will be resolved by consensus between the review team pair.

2. RISK OF BIAS ASSESSMENT

The methodological quality (internal validity) of the individual studies included in the systematic reviews will be independently assessed for each of the outcomes using a domain approach [15]: selection, outcome detection or measurement, attrition biases are some of the key domains. The following domains will be considered specific for study designs, experimental and non-experimental [27]. Differences in risk of bias assessments will be resolved by consensus between the review team pair.

3. ASSESSMENT OF OVERALL QUALITY OF EVIDENCE

We will employ a modified GRADE criteria to assess for confidence in the evidence for a particular outcome in this review, separately for each sector (Grading, Recommendations, Assessment, Development and Evaluation)[28]. Differences in GRADE assessments will be resolved by consensus within the review team pair.

H. DATA ANALYSIS

1. DATA SYNTHESIS

The data synthesis will be done at multiple stages: EGM, systematic review and or meta-analysis depending on availability of information, data quality and statistical viability. The meta-analysis will depend on having at least 10 individual studies.

Briefly, the analysis of the data will be done separately for each sector. The unit of analysis will be a study. Several articles of the same study will be amalgamated into one dataset where feasible or the article reporting with the largest sample size of the study will be considered.

Evidence Gap Maps: Our approach to Evidence Gap Maps (EGM) will be informed by Campbell Collaboration approach [18]. Briefly, we will apply the data already identified, screened and coded from this review to develop one EGM per sector. Using the EPPI mapper adds-on for EPPIR4 we will produce the EGMs in visual presentation of the evidence matrix. The intervention categories lie on the y-axis whilst outcome domains will run in the x-axis. Additional dimensions of the study or

intervention characteristics, such as study design, geographical region and country income subgroup status or population sub-group will be applied as filters. The specific actual variables for the EGM axes will be determined after study coding.

Systematic review: This will employ descriptive statistics and if appropriate Forest plots. A funnel plot, Begg's and Egger's test will be employed to explore publication bias [*15*].

Meta-analysis: Estimates of captured in various forms will be transformed and standardized using appropriate statistical methods to facilitate meta-analysis. Biological, methodological and statistical heterogeneity will be assessed using the Cochran's Q and the I-squared statistics. In the absence of statistically significant heterogeneity, we will use RevMan v.5.2 [*29*] and Stata v.14.2 [*30*], to pool and analyze the data using the random effects model. Only the sufficiently populated cells (at least 10 individual studies) will be employed to run meta-analyses on the available evidence and estimate average effect sizes. The degree of heterogeneity will be assessed using Higgins I-squared into low (<50%), moderate (>51% to <75%) or high (>75%) [11]. In order to explore the robustness of the results, sensitivity analyses and meta-regression will be considered. Potential factors to be explored in this sensitivity analyses are: study quality and intervention related heterogeneity.

I. TRANSFORMATIONAL CHANGE MAPS

We will then map only those combinations of interventions and outcomes where evidence of transformational change is found. That is to say, we will only show those combinations of interventions and outcomes where there is a large effect size at least one year after the intervention, following the thresholds defined before. It is this step where the results of the studies, i.e., depth of change and sustained change, are used as selection criteria. However, selection is not done at the level of the individual study but rather at the level of intervention-outcome combinations (cells in the EGM).

J. REPORTING AND DISCUSSION RESULTS

Standard reporting format: Findings from this review will be reported according to the PRISMA statement [*31*], and PRISMA extension for equity considerations [*32*]. The discussion section will draw on findings from the synthesis. Policy relevant aspects of applicability, relevance, equity, costs and monitoring and evaluation will be addressed here.

Triangulation of findings: Findings from the public health sector will be employed to interrogate the results from the energy sector. The overarching theme will be to draw lessons from behavior change interventions in the public health realm and from the energy sector to apply to climate mitigation and adaptation interventions.

K. POTENTIAL LIMITATIONS OF REVIEW METHODS

This review may be limited by:

Time bias: We envisage two potential areas of selection bias. First, we exclude studies published earlier than 1990 (energy sector) and 2000 (public health sector). This however, does not account for data collected before this time cut off and published much later. Secondly, the World Bank country ranking by income status by 2020 may not take into consideration the transitional nature of previous income status when the literature was published or data collected.

Publication bias due to limitations by language: Excluding study literature in French, Spanish, German and Mandarin may limit the generalise-ability of our findings particularly in francophone

Africa. We intend to assess for publication bias and report the findings in lieu of this limitation. In so doing we will employ both statistical approaches: Begg's and Egger's tests and a funnel plot [15].

Evidence types: It is possible to identify poorly designed quasi-experimental designs that provide lower quality evidence of effects, for quantitative outcomes. Rather than exclude quasi-experimental designs (non-randomised), we will employ the Risk of Bias criteria for different study designs, elaborated in the protocol and recommended by the Cochrane EPOC group in assessing the quality of included primary studies and employing these quality features in sensitivity analyses; followed by the Grading of Recommendations, Assessment, Development and Evaluation (GRADE) framework in assessing the overall quality of evidence for specific quantitative outcomes. Here, we will develop summary of findings tables, and assess the confidence in the effect estimates, and strength of recommendations based on the quality of evidence. Indeed, with low quality or absence of evidence, we will identify areas for further research in the systematic review and evidence and gap map.

Synthesis & reporting: (a) Due to the different study designs, interventions and varying contexts, synthesis will be a challenge. In order to overcome this, we will employ random effects meta-analysis. In the multi-stage structured synthesis [15] we will use both narrative synthesis (stage 1) and descriptive quantitative analysis including forest plots (stage 2), even without meta-analysis. In the event of substantial homogeneity among included studies we will conduct a random-effects meta-analysis for each critical outcome.

Reporting will follow a triangulation approach between both sectors: energy and public health. The lessons learned from the public health sector will interrogate findings from the energy sector [33].

L.   PRELIMINARY FINDINGS: PILOTING ENERGY SECTOR

The review team screened two hundred titles and abstracts for the energy sector. The C4ED team submitted these. Briefly, out of the 200 articles, 117 (58.5%) were included for full text screening. Of these 95 (81%) were retrieved and 30 of them (31.5%) included for coding. The following are the detailed results.

Table 2.   Summary of outputs from piloting the energy sector

REVIEW STEP	RESULT
Data bases searched	NR
Number of articles got from each data base	NR
Total articles collated	200
Number of TiAb screened	200
Number of TiAb duplicates excluded	1
Number of TiAb screened in duplicate and excluded (see reasons in table 4)	83 (41.5%)
Number of TiAb included for full text screening: (After [§]reconciliation/consensus)	117 (58.5%)
Full texts retrieved for screening (Google Scholar)	95 (81%)
Full texts NOT YET retrieved due to pay wall access	22 (19%)
Full texts not yet screened in duplicate	0
Full texts screened in duplicate and disagreed/pending ([§]reconciliation ongoing)	4
Full texts screened in duplicate and excluded (reasons in table 5)	61
Full texts screened in duplicate and included	30 (31.5%)

Note: [§]Results are reconciled by consensus.

Table 3.   Summary of inter-rater agreement from piloting the energy sector

SCREENED	R1	R2	AGREED (ROUND 1)	RECONCILED (ROUND 2)	PENDING CLARIFICATION
Excluded	55	66	43	61	04
Included	40	29	18	30	
Total	**95**	**95**	**61**	**91**	
Inter-Rater Agreement			**64.2%**	**95.8%**	**0%**
Target Inter-Rater Agreement			**80%**	**80%**	**0%**

Note: R1- Reviewer 1; R2- Reviewer 2; Round 1 – initial independent assessments; Round 2 – assessments after discussion for consensus; Pending clarification – disagreed even after reconciliation

Reasons for titles and abstracts exclusion

Out for the 200 articles, one duplicate paper (1.2%) was excluded. Most of the 83 (41.5%) excluded articles were due to irrelevance (38.5%), mainly being from the health sector such as solid waste disposal, alcohol imports, indoor air pollution, dietary and physical activity interventions. This was followed by inappropriate intervention (36.1%), intervention, study design and population of interest. It is important to highlight that detailed exclusions beyond estimations of relevance are less likely with only title and abstract information hence the high inclusion rate at this stage. These pilot 200 titles and abstracts included benchmark studies that could explain the relatively high eligibility. Further training on the inclusion criteria would bring this share down.

Table 4.   Summary of title & abstracts exclusions piloting the energy sector

REASON FOR EXCLUSION	§ N=83 (%)
Duplicate paper	1 (1.2%)
Irrelevant	32 (38.5%)
Intervention	30 (36.1%)
Not CC mitigation	*22*
Small energy appliance	*7*
Non-renewable/nuclear energy	*2*
Outcome	9 (10.8%)
Irrelevant outcome	*8*
Deforestation	*1*
Study design	6 (7.2%)
Qualitative or theory based	*3*
Correlation	*2*
Time series macro-level	*1*
Population	5 (6%)
High income country	*4*
Children <12 years	*1*

Note: These details will not be aggregated in the full review report; §Captures pending papers.

Reasons for full text exclusion

Most articles were excluded for study design issues (67.2%), followed by inappropriate intervention (14%). The reasons for excluding based on outcome of interest tied with high-income country population (9.4%). Further details are captured in Table 5, below.

Table 5.   Summary of full text exclusions from piloting the energy sector

REASON FOR EXCLUSION	[§]N=64 (%)
Study design	43 (67.2%)
No control group	*14*
Modelling or simulation or forecasting	*10*
Descriptive or formative or process evaluation	*6*
Time series macro-level	*2*
Correlation	*1*
Qualitative or theory based	*1*
Non-systematic reviews	*9*
Outcome	6 (9.4%)
Irrelevant outcome	*5*
Deforestation	*1*
Population	6 (9.4%)
High-income and low-income countries aggregated	*4*
High income country	*2*
Intervention	9 (14%)
Irrelevant intervention	*2*
Non-renewable/nuclear energy	*2*
Scale <1000 beneficiaries	*2*
Not CC mitigation	*1*
Economic growth	*1*
Targeting firms	*1*

Note: These details will not be aggregated in the full review report; [§]Captures pending papers.

M. PRELIMINARY FINDINGS: PILOTING PUBLIC HEALTH SECTOR

The review team screened two hundred titles and abstracts for the public health sector pilot. Among the 200 articles, 67 (33.5%) were included for full text screening. Of these 67 (100%) were retrieved and 13 of them (20%) included for coding. The following are the detailed results.

Table 6.   Summary of outputs from piloting the energy sector

REVIEW STEP	RESULT
Data bases searched	NR
Number of articles got from each data base	NR
Total articles collated	200

Review step	Result
Number of TiAb screened	200
Number of TiAb duplicates excluded	1
Number of TiAb screened in duplicate and excluded (see reasons in Table 4)	133 (66.5%)
Number of TiAb included for full text screening: (After §reconciliation/consensus)	67 (33.5%)
Full texts retrieved for screening (Google Scholar)	67 (100%)
Full texts NOT YET retrieved due to pay wall access	0 (0%)
Full texts not yet screened in duplicate	0
Full texts screened in duplicate and excluded (reasons in Table 5)	52
Full texts screened in duplicate and included	13 (20%)

Note: §Results are reconciled by consensus.

Table 7.   Summary of inter-rater agreement from piloting the energy sector

Screened	R1	R2	Agreed (Round 1)	Reconciled (Round 2)	Pending clarification
Excluded	45	51	43	52	00
Included	20	14	09	13	
Total	**65**	**65**	**65**	**65**	
Inter-Rater Agreement			**80.0%**	**100.0%**	**0%**
Target Inter-Rater Agreement			**80%**	**80%**	**0%**

Note: R1- Reviewer 1; R2- Reviewer 2; Round 1 – initial independent assessments; Round 2 – assessments after discussion for consensus; Pending clarification – disagreed even after reconciliation

Reasons for titles and abstracts exclusion

In Table 8, out for the 200 articles, most of them were due to an irrelevant intervention (26.5%), followed by 30 (15%) due to study design issues and another 09 (4.5%) were protocols. The population was irrelevant in 22 articles (11%), whilst the relevant outcome was missing in 12 (6%) titles and abstracts.

Table 8.   Summary of title & abstracts exclusions piloting the energy sector

Reason for exclusion	§N=133 (%)
Duplicate paper	1 (1.2%)
Population	22 (11%)
Intervention	53 (26.5%)
Outcome	12 (6%)
Study design	39 (7.2%)

Reasons for full text exclusion

Most articles were excluded for intervention design issues (63%), followed by inappropriate population (25%). Further details are captured in Table 9, below.

Table 9.   *Summary of full text exclusions from piloting the energy sector*

REASON FOR EXCLUSION	§N=52 (%)
Study design	04 (7.7%)
No control group	*01*
Protocol	*03*
Outcome	01 (1.9%)
Irrelevant outcome	*01*
Population	13 (25%)
Age <18 years	*10*
High income country	*03*
Intervention	33 (63%)
Scale <1000 beneficiaries	*25*
Scale <12 months f/up	*08*

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