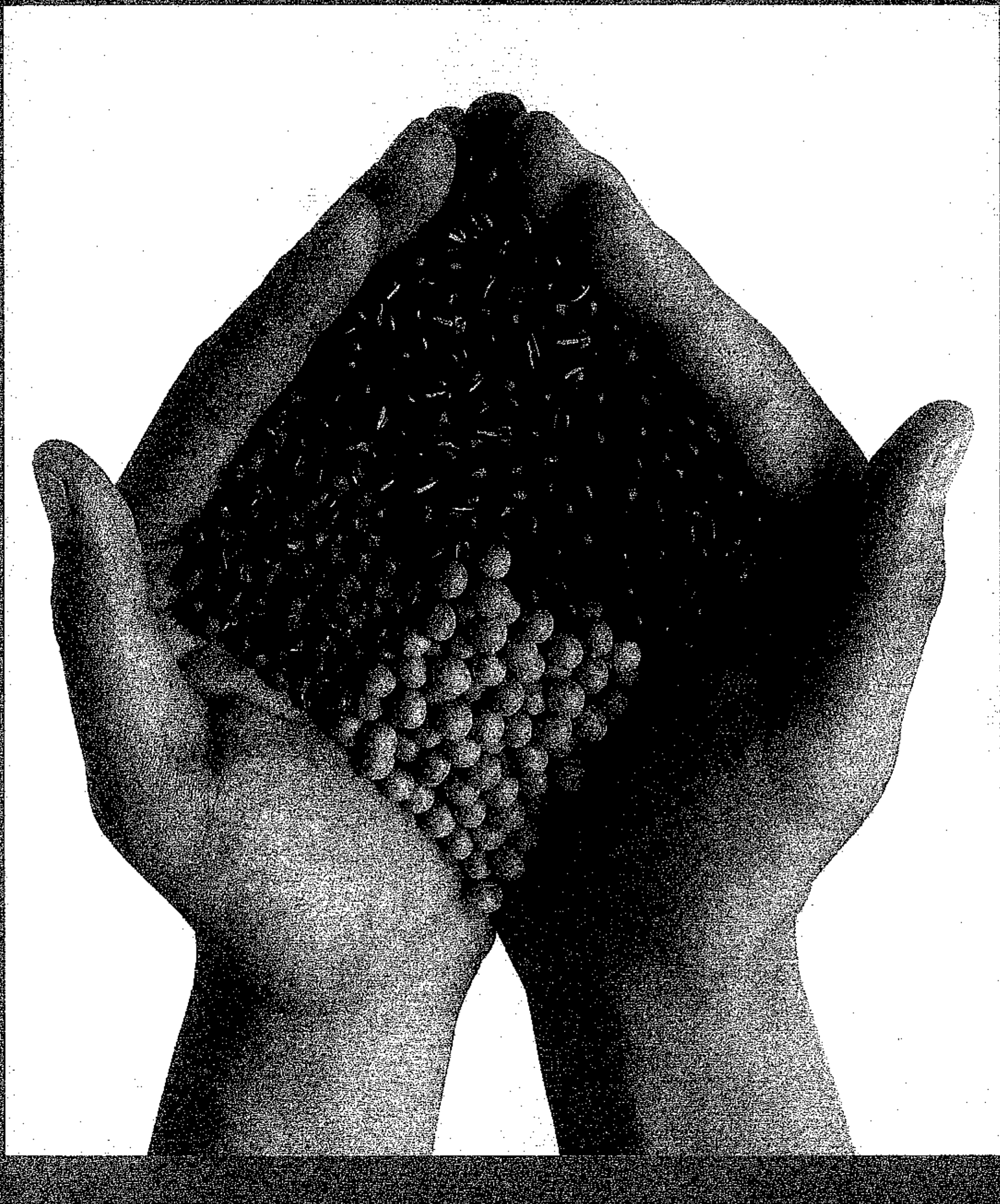
Fondazione Giangiacomo Feltrinelli

LABORATORIO EXPO

THE MANY FACES OF SUSTAINABILITY

Edited by Salvatore Veca



Direzione:
Carlo F. Feltrinelli

Comitato scientifico:
Maurice Aymard, Giuseppe Berta, Enrica Chiappero-Martinetti,
Alessandro Colombo, Maria Guercio, Mauro Magatti,
Donatella della Porta, Michele Salvati, Nadia Urbinati, Danilo Zolo

Redazione:
Carlotta Petacco

Direttore responsabile:
Adolfo Scalpelli

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LABORATORIO EXPO

The Many Faces of Sustainability

Edited by

Salvatore Veca

Access to Energy and Sustainable Development*

Stefano Pareglio and Jacopo Bonan

1. Stylized facts

Energy is a key condition to guarantee access to clean water, sanitation, schooling and business in developing countries and represents a key factor for growth and development. From a general point of view, it is still debatable whether access to affordable, reliable, safe and clean energy should be considered a human right or an instrumental right, as fundamental needs may be guaranteed through energy. However, not only the clear correlation patterns between modern energy and economic and human development, but also the strong evidence on the causal relationship of access to modern energy on welfare and quality of life are sufficient elements to clearly underline the crucial role of access to modern energy in sustainable development.

Access to modern energy services is intended as access to electricity and to modern and clean cooking facilities. Access to modern energy may allow reallocation of household time (especially by women and children) from energy provision to improved education and income generation. People can benefit, through better lighting, from greater flexibility in time allocation through the day and evening. It also allows access to IT and media. When combined with other infrastructures,

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access to modern energy services lowers transportation and communication costs, favors better access to markets and information. Access to electricity may also improve rural productivity, due to the introduction of technology and therefore may directly contribute to household income and push labor supply in non-agricultural activities. It is also a key element for safer food processing and storage, for example through refrigeration.

Energy poverty is defined as lack, scarcity or difficulty in accessing modern energy services by households; in particular it refers to access to electricity and to modern and clean cooking facilities. The International Energy Agency estimates that currently 1.26 billion people (18% of worldwide population) lack access to electricity and 2.64 billion (38% of global population) rely on traditional cooking methods based on the use of biomass with severe consequences on health due to indoor air pollution (IEA, 2013). This is "only" 300 million people less than in 2000, the first year in which the International Energy Agency has started tracking electricity access data. The global trend hides very stark differences among regions (IEA, 2014b).

The geographical distribution of such phenomena is uneven across the world: 84% of people lacking access to modern energy services live in rural areas; people without electricity are mostly in developing Asia (51%) and Africa (44%), similarly those still relying on traditional cookstoves and fuels are concentrated in developing Asia (72%) and Africa (25%). Today the largest populations without electricity are in India, Nigeria, Ethiopia, Bangladesh, Democratic Republic of Congo and Indonesia, even though some of those countries have electrification programs in place. Progress has been registered in some countries in Africa, but overall in most Sub-Saharan African countries the extension of electricity access struggles to keep pace with a fast growing population that outpaces the efforts in place. This feature is confirmed by the distribution of energy use in which results are stubbornly unequal among human beings living in different parts of the planet: in 2010 world per capita energy use was 1.9 ton of oil equivalent (henceforth toe) with a minimum in Eritrea (0.13 toe) and a maximum in Iceland (16.9 toe), a range that is 9 times the average.

Energy poverty is becoming more and more important even in developed countries. Although there is not a consensus on the definition, fuel poverty in developed countries describes the situation whereby households struggle to afford adequate energy services (Thomson and in EU27 and 15.8% of households in the 12 new Member States could not afford to heat their home adequately in 2011 (Thomson and Snell, 2013).

Regarding access to modern cooking stoves, the World Health Organization estimates that the use of traditional methods of cooking, through wood and biomass combustion, has severe consequences on the health of households, due to indoor air pollution. The recent Global Burden Disease study estimates that almost four million people die every year from indoor air pollution due to the use of traditional cooking fuels and stoves (Lim *et al.*, 2012; Martin *et al.*, 2011). Moreover, the extensive use of wood as main energy fuel impacts the local environment, due to deforestation, soil degradation and erosion. At global level, inefficient biomass combustion is a major determinant of black carbon, a contributor to global climate change. Emissions from cooking stoves continue to be a major component of global anthropogenic particulate matter (UNEP/WMO, 2011) particularly in developing countries, for example in Africa and South Asia where emissions from cooking stoves are well over 50% of anthropogenic sources (Bond *et al.*, 2013).

According to IEA's scenarios, global energy poverty will not change significantly by 2030: about 1 billion people will still lack electricity, with strong improvements in Latin America, Middle East and developing Asia but no progress in Sub-Saharan Africa. 2.5 billion people will still rely on biomass for cooking, basically with no progress in absolute terms with respect to the current situation.

The achievement of universal access to modern energy, one of the international targets to reach by 2030, is also complicated by the urgent need to reduce the role of fossil fuels in the world energy mix in order to curb greenhouse gas (GHG) emissions. The risks of climate change have been underlined by the last Intergovernmental Panel on Climate Change (IPCC) report: global temperatures are projected to rise over the 21st century under all scenarios and called for action to boost mitigation efforts to reduce GHG emissions, which continue to grow driven by economic and population dynamics (IPCC, 2014).

Universal access to modern energy services, environmental sustainability and economic development may be seen as a trilemma: it seems impossible to reach all targets at the same time under budget constraints which have become even tighter after the recent crises. Solutions which could reconcile these three elements are possible, but dedicated strategies and policies need to be developed by several actors at different levels of decision-making, from individuals to international organizations, including governments, private sector and civil society. The present paper analyzes the different components of the trilemma and their inter-connections, then it provides a short description of current most important international initiatives, finally we propose some policy suggestions which could contribute to the ongoing debate.

2. Analyzing the trilemma

2.1. Access to energy and economic development

There is a clear correlation between energy, development and household welfare: clean water, food, sanitation, health, schooling, lighting, communication, information are all aspects strictly dependent on the use of energy. Access to electricity is a key factor for business development, innovation and technology diffusion. Productive use of energy refers to agricultural, commercial and industrial activities involving energy services as a direct input to the production of goods or provision of services. It has the potential to create additional revenues for end users who can then afford to consume energy and pay for it or refinance the investment in an off-grid system; increases in productive energy use would also ensure sufficient demand for energy from providers and hence contribute to the economic viability of the energy system. Nevertheless, the evidence shows that a) the level of productive use in newly electrified areas is often disappointing and b) electricity connection as well as usage by small and microenterprises do not necessarily lead to the expected economic effects such as higher profits (Mayer-Tasch *et al.*, 2013).

Several rigorous studies have sought to measure the impact of access to electricity and adoption of improved cookstoves on a set of outcomes pertaining to human and economic development. By "rigorous" we define a minimum standard in terms of identification strategies and microeconometric estimation techniques in impact evaluation exercises, *i.e.* studies which assess the causal relationship between access to electricity and different outcome variables trying to solve the issues of reverse causality, endogeneity and selection bias through rigorous estimation design such as instrumental variables estimation, difference in differences, by exploiting natural experiments, panel data analysis, fixed effects estimations, randomized controlled trials and propensity score matching. It turns out that access to electricity is a strong causal determinant of changes in labour market outcomes: employment and revenues rise in connected areas. Interestingly, such changes concern women and activities not related to agriculture. Access to electricity also seems to have strong impacts on schooling and household welfare. Conversely, the evidence of the impacts of the adoption of improved cookstoves on health and household welfare outcomes is still quite scarce and inconclusive. More research is needed to enrich the debate, possibly coming from different contexts and products, given the high variability in technologies across the world (Bonan, Pareglio and Tavoni, 2014). The following sections review the relevant evidence in the literature regarding the impacts of access to modern energy on different sets of outcomes pertaining to households and individuals and the improvement of quality of life.

2.1.1. Impacts of access to electricity

Labour market

Some studies look at the causal nexus between electrification and different economic and social outcomes. The impact of electrification on labour market outcomes seems to be one of the most robust, although still not definitive.

Regarding employment, Dinkelman (2011) shows a significant rise in female occupation (9 to 9.5% increase) and number of worked hours for females in rural areas of South Africa which can be attributed to access to electricity. The underlying mechanism consists of the conversion of time from firewood collection to income generating activities (*e.g.* small business and cottage industry). Lipscomb *et al.* (2013) also find strong effects on activity rates and formal employment both in rural and urban areas of Brazil.

Regarding labour supply, the evidence seems to indicate an increase in the medium and long run in several studies across different regions. Grogan and Sadanand (2013) consider a sample of rural households in Nicaragua: rural electrification increases the probability that women are employed in non-agriculture activities outside the household. Similarly, Dasso and Fernandez (2013) find increases in hours of work fo men and higher earnings derived from more intensive non-agricultur activities for women in rural Peru. Dinkelman (2011) finds significan increases in labour supply for both women and men in South Africa Van de Walle *et al.* (2013) detect significant substitution effects from irregular and casual work to the formal sector for men in India. Highe quality electricity provision by private providers compared to publi ones seems to lead to a reduction of hours worked in agriculture (Tore ro *et al.*, 2007). However, Bernard and Torero (2014) find no short-ru effect of rural electrification on time spent on income generating acti ities at household level.

The evidence of the effects of electricity on wages does not seem t be conclusive, though. For example, Dinkelman (2011) finds highe earnings for men (not for women) but no average effects on wage Similarly Khandker *et al.* (2013) show significant increases in househol incomes, via improvements in non-agricultural activities, and no effe on wages. Increases in non-agriculture income are also supported i studies by Dinkelman (2011) and Lipscomb *et al.* (2013). Reductions i electricity outages and increases in hours per day generate relevai improvements in non-agricultural incomes in rural India (Chakravor *et al.*, 2013).

Household welfare

Recent works find that access to electricity has positive effects c household welfare, in terms of income, consumption, cooking and ligh ing decisions, time allocation, schooling and health.

Only a few studies assess the influence of electricity on levels consumption and expenditure: Khandker *et al.* (2013) find that rur access to electricity in Vietnam leads to a 23% increase in consumptic expenditure. Similarly Van de Walle *et al.* (2013) show that access electricity in India leads to a significant increase in total expenditu particularly for food, fuel and kerosene stoves. Changes in the use sources of light and cooking are found in other contexts: Bensch *et* (2011) find significant increases in lighting hours and energy expen ture in Rwanda; similarly Dinkelman (2011) shows that access to ele tricity leads to a large increase in the use of electricity for lighting a to the substitution of cooking habits: from wood to electricity.

Several works lead to the conclusion that access to electricity h an impact on the way people allocate their time, as a consequence, for example, of the decrease in time spent collecting biofuels for adults in India (Khandker *et al.* 2012), but it also influences important changes in children's lives, particularly on the time dedicated to study and schooling. Positive effects of household electrification are shown on enrollment and years of schooling for Indian girls (Van de Walle, 2013). In other studies by Khandker *et al.* (2012, 2013) and Lipscomb *et al.* (2013) such results are confirmed for both boys and girls in India, Vietnam and Brazil. Children's study time outside school seems to increase in some studies (Khandker *et al.* 2012, Bensch *et al.* 2011), however no short run effects on children's time spent on studying or collecting wood are found by Bernard and Torero (2014) in a randomized study on rural electrification in Ethiopia.

The impact of electrification is not limited to rural households which are connected to the grid, but has externality effects on other non-connected villagers. Benefits of rural electrification are shown to spill over to households not connected to the grid, which have higher levels of consumption compared to non-connected households (Van de Walle *et al.*, 2013). The externality effect of electricity operating through the community is also confirmed in Burlando (2014) where villages affected by a long power outage, regardless of their level of electrification, experienced similar significant increases in births.

Health

Electrification can bring indirect benefits to rural communities and households health when it contributes to the improvement of health infrastructure and of health-care quality. However, health effects can also be direct, at the household level. Electrification seems to lead to the substitution of kerosene lighting with electric light, allowing significant and steady reductions over time in overnight $PM_{2.5}$ concentration. This turns out to provide substantial welfare improvements in terms of decreases in acute respiratory infections among children under 6 (Barron and Torero, 2013).

An impact evaluation analysis of electrification on a wider set of outcome indicators and for a larger time span is provided by Lipscomb *et al.* (2013) for Brazil. The authors show the positive impact of electrification on the Human Development Index (HDI), which includes variables referring to income, schooling and health. The improvement in HDI as a consequence of access to electricity is mainly led by the income and schooling component.

Business

Poor electricity infrastructures are considered among the most relevant barriers to economic growth, particularly for the development of industrial activities which rely heavily on the quality supply of electricity. The lack of quality and reliable electric infrastructures lead firms to self-generate energy, often with consequent higher costs. This is the case for several developing countries, particularly in Africa (Alby *et al.*, 2011; Steinbuks and Foster, 2010; Foster and Briceño-Garmendia, 2010). Rud (2012) studies the impact of the expansion of access to electricity on industrial growth in India and finds positive effects on production levels and on the number of industrial activities, at the regional level. An increase in the number of small manufactory activities as a consequence of electrification is also documented in Benin, though no effects on profits are found (Peters *et al.*, 2011). Low quality electricity infrastructures, reflected by frequent shortages, have negative effects on revenues and productivity, due to higher energy costs. The effect is stronger for small firms, which are less likely to own generators to cope with shortages (Allcott *et al.*, 2014, on Indian data). Losses in productivity due to unreliable electricity supply for industrial firms are also observed in China (Fisher-Vanden *et al.*, 2012). Unreliable and inadequate electric power supply also contributes to the reduction of investments in productive capacity by firms (Reinikka and Svensson, 2002 on a survey of Ugandan firms). Ryan (2013) finds that investments in the expansion of electric transmission infrastructures allowing for more capacity and eventually improving the quality of electricity supply would lead to large welfare gains, due to higher competition in the market.

2.1.2. Impacts of access to improved cookstoves

The use of modern and improved cooking stoves may have positive consequences on household welfare and sustainable development, from several points of view such as health and female empowerment. For example, inefficient stoves require more time to cook and gather fuel. This task is mainly undertaken by women and children, who divert time ation and income-generating activities, although these as- strongly related to cultural and behavioural traits which are rom place to place.

ably, the most important channel through which the use of d cookstoves impacts on individuals and households is through ation of indoor air pollution (IAP). Despite the great variety of s which could be defined as improved cookstoves (World Bank, he simple introduction of fireboxes and chimneys allows im- improvements in terms of IAP, compared to traditional stoves r three stone fires). For example, Dutta *et al.* (2007) find reduc- f carbon monoxide concentration by 38% and of $PM_{2.5}$ concen- by 24 to 49% after introducing improved cookstoves.

e reduction in IAP is shown to have beneficial effects on health. al studies seem to indicate that changes in cooking technologies e the incidence of acute respiratory infections and lung capacity. neral, a large strand of the literature in epidemiology and environ- tal science supports the existence of a strong positive association een IAP and negative health outcomes (Zhang and Smith, 2007), ever most evidence relies on observational studies and is unable to tify casual effects: the choice of cooking fuel and stoves may be ted to unobserved health behaviour which also affects health out- es. For example, better respiratory health in households that cook h cleaner fuels may be due to better access to information on health evention which may also impact on other health-related behaviours uflo *et al.*, 2008). Moreover, many of the studies do not consider the ssible mitigation of the reduction in smoke inhalation due to be- avioural responses of people who may not necessarily use and maintain ookstoves properly over time, after the first wave of promotion and distribution.

Only a handful of studies evaluate the health impacts of the adoption of improved cooking stoves using randomized controlled trials on the field. The project RESPIRE (Randomized Exposure Study of Pollution Indoors and Respiratory Effects) is a medical experimentation on the respiratory consequences of indoor air pollution and on the potential benefits from the introduction of more modern techniques in Guate- mala. The use of improved cookstoves reduces carbon monoxide exposure by 50 to 60% over the 18 months following the distribution of cookstoves, with consequent significant reductions in risk of respiratory disease, such as pneumonia, (Smith *et al.*, 2011; Smith-Sivertsen *et al.*, 2009).

Another study in India based on longer time span and a larger sample shows that the introduction of modern cooking stoves has only modest health effects which tend to vanish in the longer period (Hanna, Duflo and Greenstone, 2012). This is mainly due to the fact that the use of such new technologies is not always continued over time and maintenance is often neglected. A partial confirmation of such problems is provided by Simons *et al.* (2014) who find significant Hawthorne effects[1] during the period of cookstoves performance measurement by researchers with respect to "normal" household behaviour. Dherani *et al.* (2008) use meta-analysis and find that that risk of pneumonia in young children is increased by exposure to unprocessed solid fuels by 80%. Using different non-experimental techniques, other studies highlight the causal relationship between modern cooking stoves and health improvement (among several, Ezzati and Kammen, 2002, Ezzati *et al.*, 2000, Silwal and McKay, 2013, Gajate-Garrido, 2013, Mueller *et al.*, 2013, Yu 2011).

Household welfare

Rigorous evidence on the role of improved cookstoves on time allocation, female and children conditions is quite scarce (Kohlin *et al.*, 2011). In rural areas, the collection of firewood, often performed by women and school-going children, takes time away from other productive pursuits, such as income generating activities and education (Barnes and Toman, 2006). Charmes (2006) analyses time use in several Sub-Saharan African countries, by looking at large-scale surveys, and finds that women spend 3-5 times as much time as men on domestic activities like collecting firewood and cooking. However, if we look at the two activities separately, it turns out that the picture is more balanced between men and women for firewood collection, whereas cooking activities are largely dominated by women. Bensch and Peters (2012) find that the use of improved cookstoves causes a significant reduction of about one third in the amount of firewood necessary for cooking, with consequent

[1] The Hawthorne effect is when individuals change an aspect of their behavior in response to their awareness of being observed.

time saving and decrease in stated respiratory diseases. Similarly, Beltramo and Levine (2013) show slight declines in wood use in large Senegalese households, after the introduction of solar ovens. Though, no effect on time dedicated to wood collection is found. This result is corroborated by Burwen and Levine (2012) in a study on Ghana and by Hanna *et al.*, 2012 in India, where no effect on wood use and expenditure was found.

2.2. Economic development and environmental sustainability

Energy is the engine of economic growth: in 2012, compared to 2000, world real GDP increased by an average annual rate of 2.7% while, on the same horizon, primary energy demand grew by 2.4%. According to data from World Energy Outlook (IEA 2014a), in the last two decades, energy demand increased by a factor of 1.5 (almost 2% per year) fuelled by non-OECD countries economic growth. In the New Policies scenario (NPS) of IEA – which accounts for the implementation of current planned government policies – in 2040 world demand for energy increases by more than 30% to 18.3 billion toe (Gtoe), from 13.5 Gtoe in 2012. In the most "green" scenario (called "450 ppm"), where several policies to decarbonize the energy system and to boost energy efficiency are considered to have been implemented, world energy use remains under 16 Gtoe (increasing by slightly less than 20% compared to 2012).

Such increase in energy demand is very likely to be still largely based on fossil fuels: in 2040 coal, oil and gas are expected to satisfy the majority of energy use (74% and 59% in the two aforementioned IEA scenarios). Although there does not seem to be a pressing issue in terms of the physical availability and extent of reserves, an increasing amount of investments in the energy sector are needed: in 2013 energy investments amounted to more than 1,600 billion dollars. Without these investments, unfulfilled energy demand could put pressure on energy costs with negative spillovers on economic growth.

According to IEA, overall annual investments required to match the projected world energy demand over the period 2014-2040 in the NPS will amount to 2,000 G$ (2013 dollars) – 25% more than in 2013 – 50% of which would be devoted to oil and gas upstream activities.

Although global energy demand is likely to be mainly met with fossil fuels, according to all scenarios, there is ample scope for a shift towards low-carbon fuels, particularly in power and heating sectors Energy from renewables is estimated to exceed 3 Gtoe with a share ranging from 15% to 25% of total energy supply, while natural gas may provide around 25% of energy.

The IPCC confirms and strengthens the view that climate change is a clear and present danger. From 1750 to 2011, cumulative emissions amounted to 2,040 Gt of CO_2 – 50% of these emitted in the last 40 years – and it is estimated that about 40% have accumulated in the atmosphere (IPCC 2013). Consequently, atmosphere GHG concentration has increased and it is extremely likely that more than half of the observed increase in global average surface temperature from 1951 to 2010 is caused by the anthropogenic GHG emissions (IPCC 2014).

Limiting the increase in the global temperature to 2°C requires a drastic reduction in fossil fuel use: to obtain a 50% probability that the temperature increase will be below this threshold, GHG concentrations must remain under 450 ppm. According to NPS, the emissions limit wil be hit by 2040.

Mitigation strategies should include a mix of actions consisting primarily, in improving energy efficiency (thus reducing energy use) decarbonizing energy supply (*e.g.* increasing renewable share in powe generation, phasing out coal-fired plants unless assisted by carbon capture and storage technologies) and enhancing carbon sinks.

2.3. *Access to energy and environmental sustainability*

Investments in energy access for the satisfaction of basic need require a substantial scaling up compared to the current situation, bu the needed amount is negligible if compared with what is needed t satisfy future energy demand: 45 to 86 G$ per year, is a small fractio (3 to 5%) of the average global energy investments in 2013, equal t 1,600 G$ (IEA 2014a, Pachauri *et al.*, 2013). Moreover, it has been show that providing energy access to 3 billion people is likely to have a lim ited impact on emissions and climate change. Most of the growth i emissions is coming and expected to come from the global upper an middle class. Providing global energy access not only for satisfaction c basic needs but also for productive uses would increase energy deman by at most 10%, with limited impact on GHG emissions (0.7% accorc ing to IEA) and temperature increase even if energy was to be met with fossil resources (Chakravarty and Tavoni, 2013).

A retrospective study over the last three decades in India shows that improvements in household electricity access for more than 650 million people connected since 1981 contributed 3-4% to national GHG emissions growth. Although this is a marginal share of global emissions, it does not detract from the importance for developing countries to start reducing the carbon intensities of their electricity generation to ensure sustainable development (Pachauri, 2014).

3. Challenging the trilemma

3.1. The international agenda

Sustainable energy development entered the international inter-governmental agenda for the first time at the United Nations General Assembly in 1997. In 2000 the World Energy Assessment first addressed the nexus among energy, social issues, health and environment in a general context of energy access, security and efficiency, particularly at the rural level. Several subsequent international appointments set energy sustainability as a priority for global development: the Ninth Session of the Commission on Sustainable Development in 2001, the World Summit on Sustainable Development (WSSD) in Johannesburg in 2002. In the latter, energy access was recognized as a crucial aspect for the achievement of the Millennium Development Goals, calling for the implementation of sustainable patterns of energy production and use. In 2010 the Advisory Group on Energy and Climate Change to the United Nations' Secretary-General proposed to the international community a set of energy-related goals (AGECC, 2010), summarized as universal energy access by 2030. 2012 was declared the International Year of Sustainable Energy for All by the UN General Assembly, in order to catalyze global attention and commitment on these topics. In 2012 the SEFA – Sustainable Energy for All – program was launched, as one of the results of the Rio+20 Conference. Its main goal is to assure universal access to modern and sustainable energy by 2030, improving the rate of renewables in the energy mix and promoting energy efficiency. The objectives are to increase renewable energy which currently con-

stitutes 15% of the global energy mix to 30% and to double the globa
rate of improvement in energy efficiency by 2030.

3.2. *Electrification programs*

There are large variations in electrification rates across and withi regions. According to the World Energy Outlook 2011 (IEA, 2011) tran sition economies and countries belonging to the OECD have almos universal access. North Africa has an access rate of 99%, Latin Americ 93.2%, China and East Asia 90.8%, and the Middle East 89%. By con trast, South Asia has an electrification rate of 68.5% and Sub-Sahara Africa only 30.5%. People without electricity in these two regions ar 493.4 million and 585.2 million, respectively, accounting for more tha 80% of the total world population without electricity (IEA, 2011). Th majority of people lacking access to electricity live in rural areas. Som countries have made progress in connecting remote rural areas to elec tricity. In particular, several emerging economies have included rura electrification programs in their socio-political agenda in order to re duce the strong existing urban-rural divide.

Some examples of large national rural electrification programs ar represented by Brazil, China and India which have achieved more tha 65% electrification rate through significant public investments.[2]

For example, Brazil since 2003 has run the national program fo rural electrification "Luz para todos" which enabled the connection o more than 14.5 million individuals by 2011 and the reduction of th share of people disconnected from electricity to less than 2%, mostl concentrated in the Amazon region. The program has been realize through the cooperation of the central government, the holding com pany of the Brazilian electricity, utilities and rural electrification co-op eratives. The program required investments in grid expansion (approx imately $7 billion) and an increase in generating capacity which exploi ed the presence of large hydroelectric power stations (Niez, 2010). Peo ple have benefited from electricity connection free of charge and socia tariffs with discounts decreasing (from 65%) as energy consumptio increases.

[2] For a more detailed overview of the electrification programs in emerging countries, see Ni (2010).

Another example of strong political commitment towards universal electricity access is China where in 2009 only 8 million people lacked access to electricity (in 1976 it was 50% of the population) (IEA, 2011). This was possible through a great effort by the government in the development of the grid and the increase of power generation using primarily coal and distributed small hydroelectric stations. Recently, China has made an effort to introduce renewable energy programs both in rural and urban areas. However, problems related to the quality of electricity supply, the role of private sector, pricing of energy and long-term maintenance investments remain unresolved.

In 2005, a total of 412 million people in India had no access to electricity, with 380 million of them (92% of total population) living in rural areas and 32 million in urban areas (IEA, 2007). According to the Census of 2011, in India 67.2% of the population is electrified, with an urban electrification rate reaching 92.7% and a rural rate of only 55.3% (Census 2011, Government of India). The challenge of rural electrification has been faced through the government-led Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) scheme and the Remote Village Electrification Programme since 2005. The first scheme was meant to reach all rural un-electrified households through grid extension, allowing poor people to connect for free;[3] the second one aimed to complement the previous program with measures for the provision of basic lighting/electricity facilities through renewable energy sources. In 2013, 32,227 villages of India have yet to be provided with electricity[4] access which corresponds to 5.4% of Indian villages (Central Electricity Authority).

International institutions and regional development banks have collaborated with governments in projects of rural electrification. For example, the World Bank has supported more than 120 projects since 1980, particularly in Latin America and Sub-Saharan Africa, by promoting the growth of off-grid electrification using renewable energy technologies. Most of such projects have aimed to increase the energy supply, through infrastructure development, rather than explicitly target poverty issues (IEG, 2008).

[3] Tariffs vary from state to state and in some cases are based on metered supply in others are flat.

[4] A village is deemed electrified, if 10% of all the households of the village have electricity access and if electricity is provided to public spaces such as schools, panchayat officers, health centres, community centres and dispensaries.

3.3. *Initiatives for adoption of improved cookstoves*

The implementation of policies at the national level aimed at improving cooking strategies and avoiding health problems related to high exposure to IAP have followed three main strategies. The first one tried to promote cleaner fuel adoption through the substitution of biomass with kerosene, LPG or LNG. This has been the case for Ecuador and Indonesia, where poor households could benefit from subsidized kerosene for cooking (Barnes and Halpern, 2000). However, drawbacks emerged such as the high cost of kerosene and LPG and difficulties in supplying them in remote areas, given poor infrastructure. More recently, a second practice has seemed to prevail: improved cooking stoves which use wood and biomass in a more efficient way while reducing exposure to air pollutants through the introduction of a chimney. The important pros of the substitution of cookstoves rely on the fact that the technology is relatively easy to upgrade using local materials and producers (which may lead to job creation in the area and use of local materials), prices are affordable even for poor households and the final product is similar to traditional cookstoves, allowing the minimization of the cultural "gap" derived from the introduction of a new technology. A third option is the introduction of small scale bio-digesters for the production of biogas at community and household level, though a wide diffusion of such technologies has been slow in several developing countries.[5]

Several emerging countries are developing initiatives for the diffusion of improved cookstoves for the large proportion of households still relying on traditional technologies. For example, India has launched several programs since 2006-07 to promote biomass pellets stoves and more efficient ceramic stoves employing wood, however no subsidy to the purchase was envisaged. In 2009 the National Biomass Cookstoves Initiative was started on a larger scale (Venkataraman *et al.*, 2010).

Since early 1980s China launched a national program for the dissemination of efficient and improved coal stoves (with chimney) at subsidized prices which led to rapid stove dissemination. After 1990 the subsidy was suspended and households bore the entire burden of the purchase (Sinton *et al.*, 2004). China is reported to have been able to

[5] For a review and classification of available cookstove and biogas technologies, see Mapelli and Mungwe (2013).

ute over 35 million improved cookstoves over the last decades et al., 2008).

oking at some African cases, through joint government, donor, GO effort, Kenya distributed around 1.5 million improved stoves twenty years) at prices ranging from $1.5 to $6.5 and Ethiopia outed a similar number of improved charcoal stoves (over ten) at $2-$4. (Duflo *et al.*, 2008; World Bank 2010).

September 2010, Hillary Clinton announced the formation of the al Alliance for Clean Cookstoves (GACC), which calls for 100 million s to adopt clean and efficient stoves and fuels by 2020 and aims aw international attention to this issue, by mobilizing support from le range of private, public and non-profit stakeholders at the global vel.

Despite much praise for action taken, improved cookstove diffusion t part of the agenda of interventions by international agencies, for nple, by 2010 the World Bank financed less than 20 improved stoves ects worldwide, mainly in Sub-Saharan Africa (World Bank, 2010).

Policy recommendations

Global access to modern energy services needs to enter the nation- gendas of several countries which lag behind. Political will is the t condition to achieve the goal. Governments should credibly commit implement sustained, targeted and responsive policies. The follow- dimensions should be taken into consideration:

1) Policy-making and institutional framework.

The first important role of politics lies in the definition of basic eds to be satisfied and guaranteed universally from which a threshold quantity of energy needed and made available to all could be drawn. ce such conditions are met at the national level, international coor- nation efforts in carrying on policies aimed at decarbonizing, stimu- ing private investments to improve the efficiency of energy systems d limit carbon emissions (by reducing the contribution of hydrocar- ns to the energy mix) and collaborating to meet the objective of uni- rsal access to energy are needed.

Fighting energy poverty through, for example, the realization of ectricity infrastructures, particularly large-scale ones, as well as clean/

efficient fuel substitution or improved cookstoves programs require the direct commitment of governments both in terms of direct investments and of promotion of private-sector partnerships and investments through adequate institutional infrastructures and regulation. Private sector investments for the expansion of energy supply are possible when the institutional and legal framework are favorable. Weak rule of law and property rights hamper investments. Governments should enable and support private sector investments in the expansion of energy services by guaranteeing adequate regulation and legal environment, while reducing bureaucracy. New business models and mechanisms to incentivize private sector involvement and cost recovery should be developed.

Developing countries should also improve their capability of absorbing large amounts of capital by increasing quality implementation capacity. At the same time, crucial political economy factors such as corruption and lack of transparency should be actively tackled through adequate institutional controls and rule of law, given their pervasive presence in big infrastructural projects, such as in energy, and their negative impact on the economy.

Universal access to energy should be pursued through the definition of clear objectives, procedure and the identification of suitable subjects for their implementation, on the base of considerations of opportunity and efficiency. Development strategies and consequent actions should focus more on the needs of local communities and include multidimensional perspectives and expertise. General and local considerations should guide the process of policy decision-making of the public authority. A need-based approach focused on local communities should include detailed local assessments of demand and options for expanding access, and their wider socio-economic and environmental impacts. Access to energy should be considered also in relation to other dimensions such as affordability, quality (safety), quantity, sustainability, reliability and availability. The typical top-down decision making process, where priorities and implementation decisions are more centralized, should be integrated with participative bottom-up approaches in order to foster community empowerment.[6]

[6] Community empowerment refers to the process of enabling communities to increase control over their lives. Rural energy access can be an important ingredient in the process of social, economic and political change which is built on a bottom-up approach. Projects aiming to expand energy access to rural areas should involve local communities in the implementation phase, al

Coordination across policy domains can contribute to more effective policies: identifying and estimating multiple benefits and gains can help coordination across policy domains and stimulate leverage synergies in investments. A key condition for successful policies and programs is cooperation and coordination among the different players involved in the challenge, public and private sectors, academia, international organizations and NGOs. Indeed, energy poverty is so urgent and so complex that different actors can no longer act in isolation: their efforts need to be put together to maximize efficiency and effectiveness. Multi-stakeholder and multi-expert partnerships are viable strategies to face the complexity of problems and to provide complete solutions.

2) Technology selection.

Once universal access to electricity is set among governments' priorities,[7] the challenges which need to be tackled, particularly in underdeveloped rural areas, relate to key strategic policy decisions regarding electricity generation, transmission and distribution.

Energy generation looks at the energy mix which maximizes country energy supply unexploited potential, among traditional and renewable resources. Allowing access to electricity for large shares of rural population requires increases in electricity supply by investing in new generation plants employing different resources, depending on individual countries' advantages. For example, China responded to the increase in demand by expanding electricity generation through coal thermal plants (IEA, 2011). It is estimated that solar and hydro power could meet a large part of Africa's future electricity needs. Wind and geothermal power can also contribute significantly in some areas (Sanoh *et al.*, 2014). Different mixes of policies and energy portfolios involve different investment commitments. Compared to 2012, global investments in clean energy should double by 2020 under the NPS and more than double in the 450 ppm projections. Achieving the 450 ppm target by 2040 implies an amount of global resources devoted to climate change mitigation of about 2,400 G$ per year (in 2013 USD), a substantial scaling-up compared to the baseline scenario (1,238 G$) (IEA 2014a).

lowing the full benefit and appreciation of the potential for future development, leading to community empowerment.

[7] About half of developing countries have declared electricity access target at national, urban and rural level. Less than 15% have set targets for access to modern cooking fuels or improved cookstoves (IEA, 2010).

Recent trends in climate finance are not encouraging: in 2013, global climate finance annual flows totaled about 330 G$, 25 below 2012 levels (Buchner *et al.*, 2014).

Another important aspect is related to the distribution of energy supply. Grid extension remains one of the most common means of universal electrification, given the advantages derived from economies of scale in energy production. However, reaching rural areas with electricity is not as rentable as urban areas, hence a strong commitment by governments is usually required. Alternatively, mini-grids can be installed when the grid extension option seems too expensive or as a back-up energy source in order to prevent the serious consequences of outages to key infrastructures such as hospitals or strategic firms; technical options include, for example, small hydro, biomass-powered generators, small geothermal, solar photovoltaics (PV), solar thermal, wind turbines, and hybrids consisting of more than one technology (with the possible inclusion of fossil-fuel-powered generation.). Energy options using small-scale, renewable energy systems are reliable and often cost-competitive options for electrification of households in dispersed or isolated communities.[8] For example in Nigeria, higher population density and more widespread coverage by the transmission grid tends to favor on-grid supply as the most cost-effective route to electricity access. Also in Ethiopia, a significant proportion of the population lives in areas that can be best connected through the grid. But the overall population density of Ethiopia is considerably lower – the number of people per square kilometer is half that of Nigeria – meaning that mini- and, especially, off-grid solutions are expected to play a much more prominent role. Successful case studies on the implementation of renewable sources for electricity supply in developing countries, particularly in remote rural areas, are represented, among others, by solar home systems in Bangladesh as described in Khandker *et al.* (2013), hydro-power generation in Tanzania by ACRA CCS, several joint projects of AVSI with some energy firms like eni, ENEL and ENDESA, solar electricity program in India by Greenpeace. Many energy access projects and good practices around the world have been collected and presented, with the aim of knowledge diffusion, by the website of WAME (http://www.wame2015.org/) and within the "Best climate practices contest on energy poverty alleviation" by the International Centre for Climate Governance (ICCG).

[8] For a review and classification of available systems and technologies, see Mandelli and Mereu (2013).

Regarding the access to improved cooking facilities, the local con-
t plays an important role in the definition of feasible and sustainable chnological solutions which may represent small improvements (not cessarily the best option in terms of efficiency, emissions, etc.) with spect to the previous technology, but that may assure some gains in e quality of life and energy efficiency.

In general, the introduction of new technologies should be always companied by a strong effort in local capacity building and awareness the local stakeholder, in order to ensure the sustainability of projects.

3) Financial mechanisms.

The push to universal access should balance the long-term sustain-bility of projects, essential in order to attract necessary large private vestments, with the issue of affordability for the poor. Affordability lates to the capability of households to be financially and economi-lly capable of accessing and using electricity. Progressive tariffs, life-ne tariffs (households consuming below a certain amount per month ceive a subsidy), targeted price support, subsidies on modern fuels or ther innovative financing solutions, such as microcredit, are among e possible tools governments can adopt to help the access to and use f electricity by rural and poor households (Winkler *et al.*, 2011). Incen-ves towards greener and more environmentally sustainable solutions ould be financed through the phasing out of fossil fuel subsidies (FFS), rather common policy tool in many emerging countries, particularly mong fossil fuel producers. Even if FFS have the purpose of shielding e fragile segments of the population, there is evidence that often they re generally regressive, *i.e.* they benefit wealthy households relatively ore (IEA, 2011; World Bank, 2014). FFS also provide an incentive to se more carbon-intensive sources of energy: about a sixth of global HG emissions receives an indirect incentive of 110 $ per ton from ubsidies and curbing FFS could reduce emissions by 360 Mt in 2020 oosting energy efficiency policies (IEA, 2013).

4) Research.

Technical and scientific research plays also a crucial role in the dentification of technological solutions which can be implemented at ocal level in order to solve energy poverty issues.

Research and academia can contribute to the improvement of differanalysis (CBA) which provides, in broad terms, a systematic way of comparing the costs and benefits of a project or policy so that project selection promotes the efficient allocation of scarce resources. Policy making should consider and be guided by scientific evidence based on methods and analyses that try to show what works and what does not, and possibly – most importantly but most difficultly – why, revealing key elements on the process of development. This can be obtained through the implementation of impact evaluation methods with the use of counterfactual analysis. Impact evaluation analysis allows the active and rigorous search for the most cost-effective and efficient modalities, across different project designs, with clear benefits to the decision process.

5) Individuals and informal institutions.

Individual decisions on the adoption of products and behavior which may be beneficial to the quality of life, such as the decision to connect to electricity or to buy a healthier cookstove, is an important factor of development. A central puzzle in development is that effective, inexpensive technologies with the potential to address important problems exist, but are often not adopted or used by the citizens of poor countries. In other words, small changes in behaviour or limited investment requiring an immediate effort or cost in exchange for longer term benefits and returns are often not undertaken by people. When analyzing low levels of technology adoption in developing countries we must recognize that the poor face fundamentally different constraints than their counterparts in developed nations. People may simply not have the money (or willingness) to spend on a new product like an improved stove, when their outside option (cooking with a traditional stove) is free. They may lack information about the health consequences of their current practice. They may be too risk averse to spend money on a technology with uncertain benefits, especially when they are extremely poor and face competing demands for those funds. It was found that propensity to adopt modern cookstoves differs for women and men: women have a stronger preference towards the new technology but lack sufficient authority and bargaining power within the household to impose their decision on men (Miller and Mobarak, 2013). It is also highlighted the important role of opinion leaders, peer influence, social learning and social networks in conveying information on the attributes of the new technology and decisions to adopt (Miller and Mobarak, 2014, Bonan *et al.*, 2015). Learning the drivers of adoption, diffusion and continuous use of healthier and more efficient products is of great relevance in order to strengthen evidence-based actions and policies. Further research should focus on the roles of household level decision-making, gender, cultural traits, liquidity and credit constraints, but also behavioural factors, local institutions and social networks. Further analysis and investigation is needed to identify the effective (marketing) strategies and incentives structures which should be implemented by policy makers, international organizations, NGOs in order to diffuse the adoption of beneficial behaviours and products. Such strategies should be particularly focused on two types of actors. Firstly, informal institutions, largely widespread in the developing world, should be involved in diffusing good practices and technologies to a larger extent, given their potential in diffusing information, awareness and welfare improving behaviours and products. Secondly, women, who represent key players in many processes of technology shift. Starting from the fundamental role of women in development processes, some aspects of energy access policies should be designed in order to have a greater impact on women empowerment.

Conclusion

Universal access to modern energy services, environmental sustainability and economic development, as a typical trilemma, are three elements which are difficult to reconcile. Radical changes are required worldwide, in order to pursue a more sustainable and equal future for humanity: access to modern energy can really support development and improve quality of life of disadvantaged people in developing countries, at relatively low cost in terms of global investment and environmental impact. Moving towards energy efficiency and cleaner energy production are global objective to be sustained in order to limit the effects of climate change. The trilemma could be therefore successfully tackled with coordinated effort at different levels, involving international organizations, governments, public and private actors, but also individuals and communities.

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