LEDS GLOBAL PARTNERSHIP

USAID FROM THE AMERICAN PEOPLE

LEDS in Practice

May 2017

Benefits of low emission development strategies

The case of clean energy policies in Bangladesh

Bansari Saha, Andrew Kindle, Pamela Cookson, and Rachita Vaidya, ICF, USA

Key messages

Based on detailed modeling analysis, the benefits of increasing clean energy in Bangladesh's power generation mix relative to 'business-as-usual' could generate the following cumulative results by 2030:

- reduce greenhouse gas emissions by up to 20%
- generate domestic employment of up to 55,000 full time equivalent jobs
- save up to 27,000 lives, and over US$ 5 billion (BDT 420 billion).

Clean energy alternatives should be the preferred choice over continued reliance on conventional electricity sources, and should be considered when making long-term planning decisions regarding energy generation.

Introduction

Mitigating climate change is often thought to detract from other national goals, such as economic growth, job creation, and improved public health. Reducing greenhouse gas emissions, for example, is commonly seen as a barrier to expanding electricity capacity in a cost-effective manner. Recent analysis conducted for Bangladesh, however, suggests that the opposite could be true. Expanding capacity in the electricity sector can actually be achieved cost-effectively through clean energy options (renewables and energy efficiency), which not only reduce greenhouse gas emissions, but also increase jobs and improve human health by reducing air pollution.

Work under the United States Agency for International Development (USAID) Catalyzing Clean Energy in Bangladesh (CCEB) program[1] has shown that clean energy can provide Bangladesh with not only cost-effective greenhouse gas mitigation, but also affordable electricity, and the same could hold true for countries in similar circumstances. The analysis was based on modeling using detailed plant-level data from the Bangladesh power sector. The model is deployed at the Bangladesh Power Development Board (BPDB) as part of a suite of tools to help analyze the economic effects (e.g. power prices, fuel demand, and jobs) of various power system development scenarios.

This case study summarizes the Resources to Advance LEDS Implementation (RALI) project's modeling efforts and quantifies the potential job impacts associated with two different clean energy scenarios, as well as the health benefits derived from cleaner air. Taken together, these benefits to people and the economy demonstrate unambiguously that clean energy alternatives should be the preferred choice over continued reliance on conventional electricity sources, and should be considered when making long-term planning decisions regarding energy generation.

Background

As a low-lying country situated in one of the world's largest river deltas, Bangladesh is highly vulnerable to the consequences of climate variability and change. The country is the eighth most populous in the world[2] and one of the most densely populated.[3] Almost one third of its people live below the poverty line, and only about 60% of the population has access to electricity.[4] At the same time, Bangladesh is coping with a serious energy crisis as a result of sluggish growth in energy supplies and intense expansion of energy demand. Furthermore, challenges associated with urbanization (especially in Dhaka, Chittagong and Khulna metropolitan areas) have led to concerns over livable environments, with problems relating to air pollution, noise pollution, and waste disposal, among others.[5]

Within this context, Bangladesh has taken a leadership role in addressing climate change adaptation and mitigation through the national Bangladesh Climate Change Strategy and Action Plan 2009, which outlines its LEDS. This plan includes a climate change management strategy that prioritizes climate adaptation as well as mitigation.[6] The plan is supported further by the Perspective Plan of Bangladesh 2010–2021, which provides a road map for accelerated growth, specifying broad approaches to eradicate poverty, inequality, and human deprivation with the goal of making the transition to a middle-income economy by 2021.[7] The Government of Bangladesh has also prepared its National Sustainable Development Strategy 2010–2021 to balance the economic, social and environmental requirements of development.[8] Together, these strategies and plans outline a number of national priorities, including:

- protecting Bangladesh from the effects of climate change and global warming, addressing both climate change mitigation and adaptation
- accelerating economic development and reducing poverty through sustained growth and a drastic reduction in unemployment
- addressing the country's energy crisis by increasing energy supply, and promoting energy conservation and efficiency
- achieving an urban reality that can enhance capacity to live a healthy life by addressing key problems in urban areas, including air pollution.

Many of these priorities are reiterated in Bangladesh's September 2015 Intended Nationally Determined Contribution, under which the country commits to reducing its greenhouse gas emissions by 5% from 'business-as-usual' levels in 2030 in the power, transport and industry sectors, or by 15% in these sectors, conditional on international support. The unconditional contribution reflects actions and targets already in place, such as those outlined in the Energy Efficiency and Conservation Master Plan 2015, and the Renewable Energy Policy 2008. For example, Bangladesh aims to reduce energy intensity per unit of gross domestic product by 20% by 2030 compared with 2013 levels; implement energy efficiency measures for buildings, industry, and products; and achieve 10% of its energy from renewable sources by 2020.[9]

To begin the journey towards these goals, the Government of Bangladesh (with help from international donors) has been collecting and analyzing data, and modeling different scenarios for developing the energy sector in ways that can increase access to affordable energy while minimizing greenhouse gas emissions. The analytical work undertaken under CCEB was intended to complement Bangladesh's existing modeling, and provide insights into clean and affordable energy sector development options.

Methodology

This paper builds on work conducted under USAID's CCEB program. The program aims to enhance capacity for LEDS in Bangladesh and help policy-makers understand the potential of clean energy development to expand (not replace) the country's existing capacity, considering both immediate impacts on greenhouse gas reductions and consumer electricity prices. As part of CCEB, ICF developed a bottom-up, scenario-based model of the Bangladesh power sector called the Power Sector Policy Analysis Model (PSPAM). It was developed using detailed plant-level data on the Bangladesh power sector. A key source of data for this case study was the Power System Master Plan (PSMP), which describes Bangladesh's road map for energy policy and power expansion based on future energy demand projections and supply options. PSPAM uses bottom-up emission estimates, along with cost and performance data for the power sector, to analyze system generation costs, capacity, and fuel mix, power prices, and power sector subsidy levels, as well as carbon dioxide (CO_2) emissions. PSPAM allows policy-makers to focus on high-level results across multiple scenarios that are relevant for policy discussions.

This case study was conducted by the USAID RALI project using PSPAM, building on the greenhouse gas emissions accounting process for the power sector conducted under CCEB and initial analysis to explore the employment implications of different electricity generation technologies. It extends the knowledge base by quantifying the additional impacts of clean energy development in Bangladesh on: (a) full-time domestic jobs; and (b) premature morbidity and mortality associated with reductions in air pollutants. The RALI team explored two potential clean energy scenarios being considered in Bangladesh, and compared these to the business-as-usual plan for expanding the power sector (hereafter called the Reference Case), as outlined in the PSMP. The two clean energy scenarios include one with moderate clean energy adoption goals that would be achievable in the short term, and a more ambitious scenario with goals that would be achievable in the long term. Taken together, these two scenarios allow policy-makers to understand the impacts of gradually ramping up clean energy ambitions.

Clean energy scenarios for Bangladesh

Two clean energy scenarios were modeled in this analysis and compared with their current projected growth path under the Reference Case. These scenarios were developed by CCEB in close coordination with Bangladesh energy experts at the BPDB and Power Cell, the two main agencies responsible for the power sector in Bangladesh.

Reference Case

The Reference Case scenario for Bangladesh is based on the country's current trajectory for developing the power sector, as outlined in the PSMP. This scenario is based on a development plan using the least-cost[10] power sources to diversify the fuel mix in the future, including domestic coal, imported coal, natural gas, liquid fuel, and limited use of renewable energy. The Reference Case scenario still relies heavily on fossil fuels, where coal (both domestic and imported) constitutes 46% and natural gas constitutes 34% of the fuel mix.

Clean Energy Policy 1 scenario: short-term clean energy options

The first of the alternative clean energy scenarios focuses on changes that could relatively easily and cost-effectively[11] make the transition in the power sector to cleaner energy options. These changes are considered to be the low-hanging fruit, or changes that could be implemented in the short term (i.e. by 2020), as described in Box 1.

Box 1. Clean Energy Policy 1 scenario

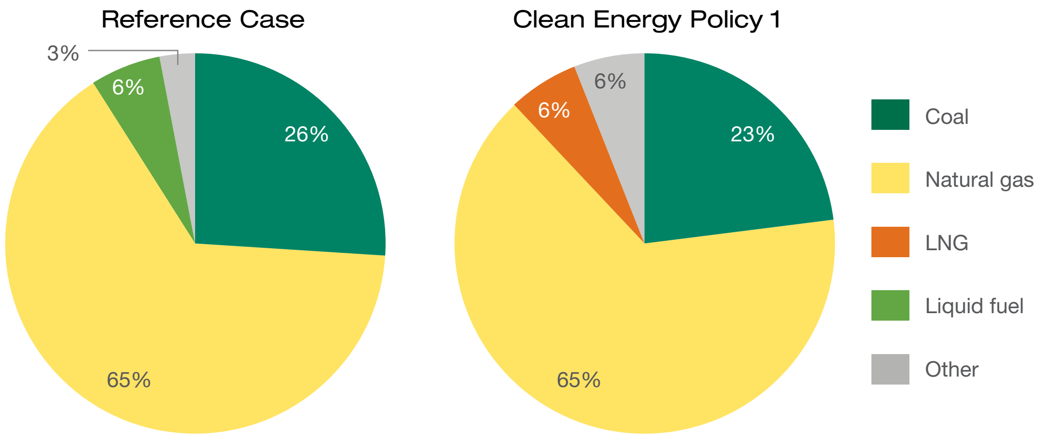
Short-term (by 2020) changes to power mix that can be achieved easily with costs comparable to those of increasing fossil fuel generation:

Fuel switching from liquid fuels to liquefied natural gas (LNG): the modeling assumes that many plants that currently use liquid fuel (diesel or furnace oil) can be retrofitted to use the cleaner-burning LNG that Bangladesh is planning to import.

Using domestic biomass feedstock: the modeling assumes Bangladesh can 'co-fire' up to 10% of domestically generated biomass feedstock (mostly from waste) at existing and new coal plants to reduce dependence on coal.

Figure 1 compares the fuel types that would be used in Bangladesh's electricity generation mix in 2020 under the Reference Case and the Clean Energy Policy 1 scenario. The figure shows a shift from about 6% of electricity being generated by liquid fuel (diesel or furnace oil) in the Reference Case to 6% being generated by liquefied natural gas (LNG), which is far less polluting but slightly more expensive.[12] Similarly, the amount of energy generated by coal decreases by 3% in the Clean Energy Policy 1 scenario, subsequently increasing the 'Other' category due to the use of biomass as a fuel co-fired with coal. Based on extensive discussions with energy experts in Bangladesh, these changes were considered to be relatively easy to implement since they would require no additional investments in energy infrastructure and would be feasible within Bangladesh's current plans for the growth of the overall energy sector as articulated in the PSMP.

Figure 1. Generation mix by fuel type, 2020 (%GWh)



Clean Energy Policy 2 scenario: long-term clean energy options

In addition to the cost-effective clean energy options Bangladesh has at its disposal in the short term, there are other options that are likely to take longer to implement but would still be cost-effective[13] and have a high impact on jobs, greenhouse gas emissions, and health in the long term (i.e. by 2030). Greater infrastructure investments would be required to implement these changes and, possibly, regional cooperation. Options considered under this scenario are presented in Box 2.

According to the modeling conducted under CCEB, the overall effect of the policies in this scenario would be to reduce grid-based electricity demand by about 9% in total by 2030. The scenario combines investments in demand-side measures with supply-side options to increase efficiency in how electricity is used, thereby reducing the need for increased generation in the long term.

Box 2. Clean Energy Policy 2 scenario

Changes to the electricity sector considered in the long term (by 2030) but cost-effective:

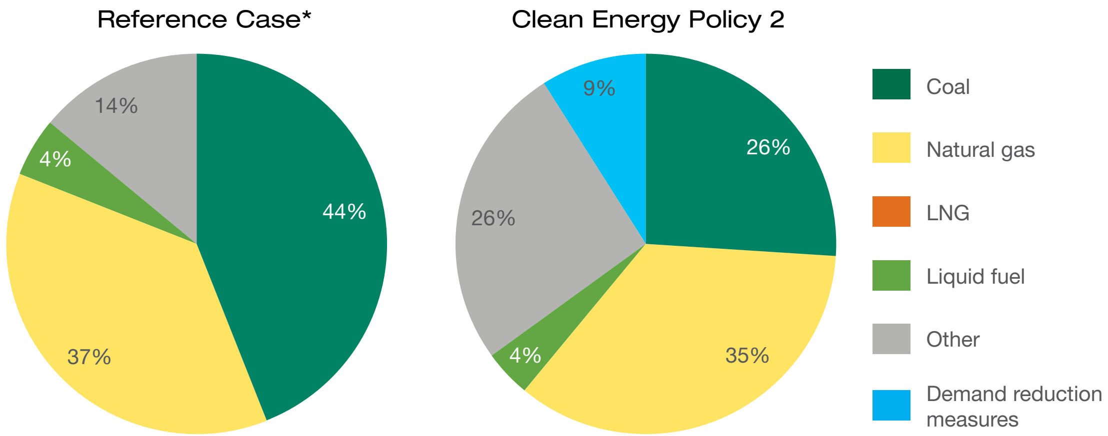
Increased cross-border electricity imports: the modeling assumes Bangladesh increases power imports from 5% (under the Reference Case) to about 20% by 2030.

Demand-side improvements: assumes investing in increased generation to reduce demand for grid-sourced electricity supply by:

- **increasing energy efficiency** to reduce electricity demand from industrial and commercial sectors
- **increasing off-grid solar** by continuing investment in the immensely successful Solar Home Systems program (funded by the World Bank) instead of focusing on connecting everyone to the grid
- **reducing technical system losses** by investing in improving the transmission and distribution network.

Figure 2 compares the generation mix by fuel type in 2030 in the Clean Energy Policy 2 and the Reference Case. A 9% reduction in demand is achieved in the Clean Energy Policy 2 alternative scenario due to demand reduction measures. The increase in the 'Other' fuel type, from 14% to 26%, is driven by the increased cross-border power imports (likely to come from India and/or Nepal and assumed to be primarily hydro), reducing the need for domestic fossil fuel power generation.[14]

Figure 2. Generation mix by fuel type, 2030 (%GWh)



* Numbers add to 99%, due to rounding.

Quantifying the impacts of clean energy policies

This section presents the impacts of increased use of clean energy on greenhouse gas emissions, job creation, and human health according to the PSPAM modeling. The job and health estimates were calculated based on publicly available data and information, an approach that could be replicated for other countries.

Greenhouse gas emissions

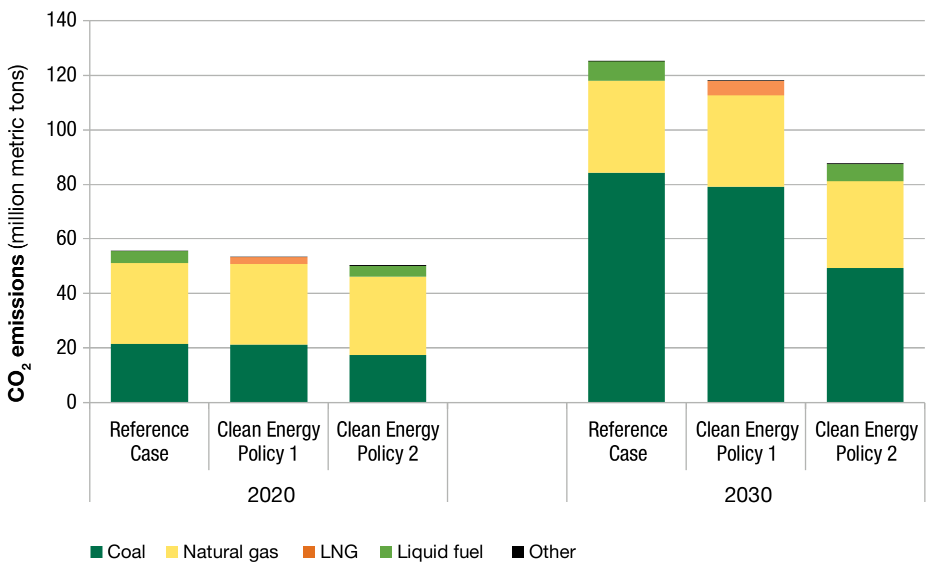
The analytical modeling conducted under CCEB focused primarily on estimating the impacts of various clean energy policies on greenhouse gas emissions. Figure 3 compares CO_2 emissions by fuel type for the three policy scenarios. It shows that CO_2 emissions are lower for the two policy options compared with the Reference Case in both 2020 and 2030. Under Clean Energy Policy 1, projected CO_2 emissions in 2020 are lower by a modest 2 million metric tons of CO_2 ($MMTCO_2$), or 3.7% less than in the Reference Case. Cumulative emissions between 2016 and 2020 are lower by 8.3 $MMTCO_2$ or around 3.2% under Clean Energy Policy 1 compared with the Reference Case. These reductions in emissions are attributed to the use of cleaner energy sources, namely biomass and LNG in place of coal and liquid fuels, respectively.

However, greater emission reductions are achieved under Clean Energy Policy 2. In 2030, greenhouse gas emissions would be lower by 37.6 $MMTCO_2$ or 30% compared with the Reference Case. Cumulatively, between 2016 and 2030, total emissions would be lower by 234.1 $MMTCO_2$ (20%) under Clean Energy Policy 2 compared with the Reference Case. Most of the emission reductions are driven by the decrease in electricity demand under this policy scenario. These demand reductions could be achieved by investing in enhanced energy efficiency in the industrial sectors.[15]

Job creation

Another important priority for Bangladesh is generating new jobs. The country is currently experiencing a high demand for electricity, reflecting the growing population and economy. As energy production is increased from various sources to meet this demand, there is significant potential for job growth, in both the energy sector and the wider economy. For the power sector, this job growth could occur anywhere along the supply chain involved in building and operating new power plants. Moreover, a more dependable supply of electricity generated from

Figure 3 Projected 2020 and 2030 emissions by scenario and technology type



Note: Total emissions in all scenarios are expected to be higher in 2030 than in 2020 due to population and economic growth

a wider range of sources will enhance economic opportunities for all Bangladeshis, thus leading to greater job opportunities across all economic sectors.

Jobs associated with electricity markets include those in construction, installation, manufacturing, operations, maintenance, upstream fuel extraction, and processing, as well as jobs associated with energy efficiency investments. Each type of energy has different requirements for labor. For example, some solar projects may need few workers for installation, but a larger numbers of workers are required during maintenance. Timeframes can be another factor determining the numbers of jobs created. For larger plants with complex infrastructure, the construction and installation period may generate more jobs, but these jobs are usually temporary, ending when the structures are complete. Other technologies may have a greater need for operation and maintenance jobs, and these positions may last longer. Thus, it is important to make the distinction between long-term and short-term jobs when estimating the employment impacts of energy sector policies. More importantly, depending on the type of fuel being considered for electricity generation, some of the upstream jobs may not benefit the local economy, as when fuel for generation is imported from another country. This is the case with Bangladesh's current plans, which include a heavy reliance on imported coal.

A survey of the economic literature conducted under CCEB found evidence that clean energy options (renewables and energy efficiency) usually create more jobs per unit of electricity generation (GWh) than conventional fossil fuels. In particular, the CCEB analysis relied on a study by Wei et al.[16] that provides a comprehensive summary of unit jobs created in Organisation for Economic Co-operation and Development (OECD) countries by the introduction of different technologies, including short-term jobs in construction, installation, and manufacturing as well as long-term positions in operations and maintenance. Wei et al. considered both direct and indirect jobs in the utility sector,[17] but not 'induced' job impacts, which can occur through added consumer spending from the income generated by the other job types. The estimates from Wei et al. were adjusted by CCEB to reflect domestic conditions in Bangladesh and to account for 'leakages' where applicable (due to imported fuels for certain technologies).[18]

Table 1 provides a summary of these direct and indirect estimates for 2020 and 2030,[19] with jobs measured in job-years (a measure describing one full-time job for one year). Because these estimates do not include induced job impacts, they should be considered as a conservative lower bound. It should be underscored that the analysis focused on the impacts of *expanding* electricity generation, not on *replacing* existing sources; thus, all theoretical job impacts are incremental (i.e. there is no job displacement).

Table 1. Estimated unit jobs created by technology type (2020–2030)

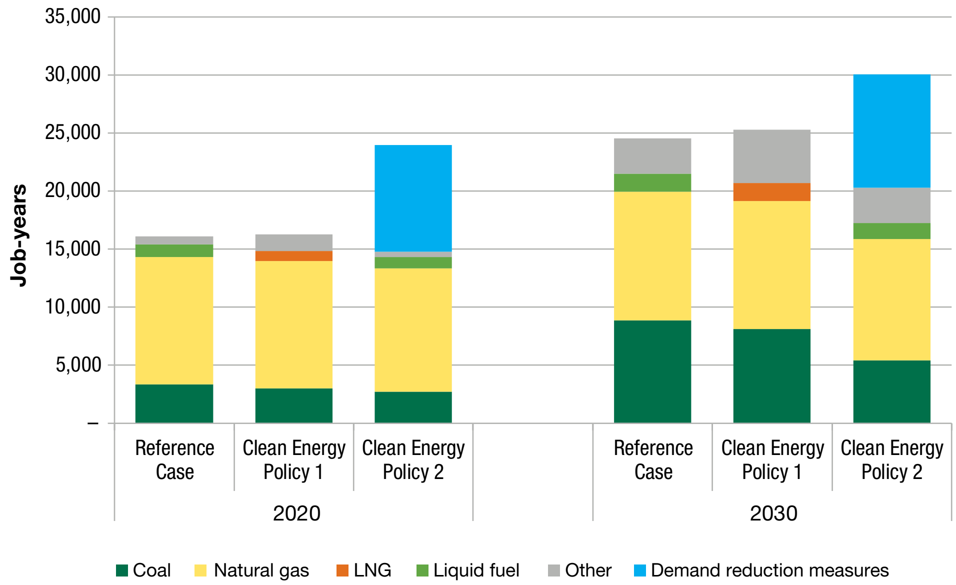
Technology	2020 job-years/GWh	2030 job-years/GWh
Coal (domestic)	0.19	0.16
Coal (imported)	0.09	0.08
Biomass	0.37	0.31
Natural gas	0.19	0.16
Liquefied natural gas	0.30	0.26
Liquid fuel	0.39	0.33
Hydro	0.47	0.40
Solar	1.51	1.28
Wind	0.30	0.25
Nuclear	0.25	0.21
Cross-border	0.02	0.01
Reduced system losses	0.32	0.28
Energy efficiency	1.33	1.13
Off-grid renewables	1.51	1.28

According to this data, investing in energy efficiency in Bangladesh could lead to more than six times the job impacts compared with coal-based generation. The ratios are even higher for some of the renewable technologies when compared with coal-based jobs. For example, solar-powered electricity generation could provide the most jobs per GWh of any technology type in Bangladesh, at a rate of 1.51 job-years/GWh in 2020 and 1.28 job-years/GWh in 2030. Not surprisingly, importing power was the least labor-intensive, as most jobs are concentrated in the exporting country. Cross-border imports are thus expected to offer the lowest job benefits for Bangladesh, at a rate of 0.02 job-years/GWh in 2020 and 0.01 job-years/GWh in 2030.

Building on this work, the RALI team applied the job estimates by technology type in Bangladesh to PSPAM in order to quantify the domestic job impacts under each of the three energy policy scenarios (see Figure 4). Under Clean Energy Policy 1, the total number of job-years would increase slightly by about 1.2% (or around 200 job-years) in 2020 compared with the Reference Case. Cumulatively, from 2016 to 2020, Clean Energy Policy 1 represents an increase of nearly 830 job-years compared with business as usual. Clean Energy Policy 1 is not expected to provide a significant boost to domestic jobs as the overall changes are relatively small and, to some extent, activity is moved from domestic liquid fuels to imported LNG. Making the transition to biomass co-firing helps domestic job creation, providing a positive boost that counterbalances the losses due to decreased reliance on imported LNG, for a slight net positive overall impact on jobs. Thus, moving Bangladesh from business-as-usual reliance on fossil fuels to a cleaner energy path is not only good for reducing greenhouse gas emissions, it is also marginally better for national economic development.

In contrast, the job impacts under the long-term policy scenario, Clean Energy Policy 2, are more significant. Specifically, employment is projected to be greater by about 22% (around 5,500 job-years) in 2030 under this scenario compared with the Reference Case. Cumulatively, from 2016 to 2030, the Clean Energy Policy 2 scenario would lead to an increase of over 55,000 job-years. Even though this scenario includes reductions in the need for power generation, there could still be a significant increase in domestic employment because energy efficiency tends to have a high per unit job creation potential (see Table 1). Thus, significant job increases are projected in this scenario at costs that are comparable to those of Bangladesh's current energy sector growth

Figure 4. Jobs by technology type



path. Over the long term, the Clean Energy Policy 2 scenario would not only be good for reducing greenhouse gas emissions cost-effectively, it would also help Bangladesh make progress on economic development goals by significantly increasing domestic employment.

Public health

Many developing countries, including Bangladesh, face significant air quality challenges, particularly in large cities. Importantly, clean energy policies can improve air quality and, in turn, human health by reducing pollutant emissions. Specifically, cleaner energy displaces the combustion of fuels with high emission rates of sulfur dioxide (SO_2), nitrogen oxides (NO_x) and other pollutants. Such pollutants can cause premature death and morbidity from cardiovascular and respiratory illnesses, including morbidity from acute short-term exposure and chronic health effects from long-term exposure. Reducing emissions of these pollutants will result in avoided mortality and morbidity.

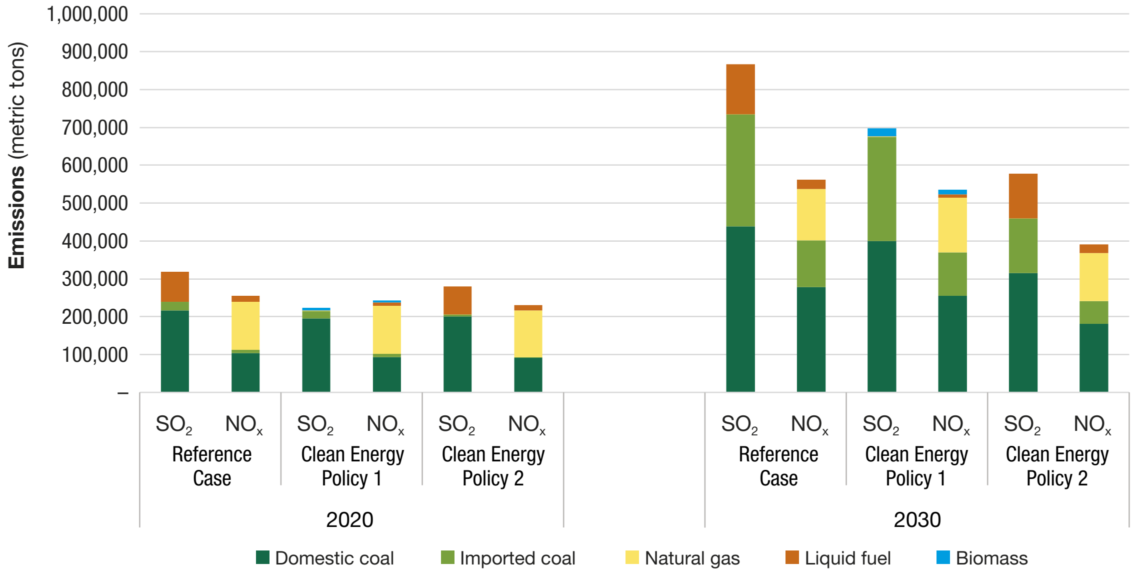
While research on the human health benefits of reducing pollutant emissions in developing countries is limited, this case study attempts to project health impacts from clean energy by using estimates available in the literature, as well as established economic principles. The first step involved estimating emission rates for two pollutants – SO_2 and NO_x – for the Bangladesh power fleet. The RALI team estimated emissions for each fossil fuel type using a three-pronged approach that combined expert knowledge, US data on emissions from electricity generators with no emission controls, and Bangladesh-specific data on the characteristics of electricity generators and fossil fuels.[20] The RALI team verified the estimated emission rates that were calculated for Bangladesh by comparing, when possible, average rates estimated for other developing countries by Mittal et al.[21] and APR Energy.[22] These emission rates (g/kWh) were applied to the annual generation (GWh) for each scenario modeled in PSPAM, and the resulting metric tons of emissions were used to estimate the health impacts.

Health effects were then estimated for Bangladesh using a *benefit transfer* methodology. This estimated health benefits for Bangladesh by adapting a study already completed to estimate health benefits from a similar but different context.[23] Specifically, health effects were estimated based on findings from a discussion paper by Resources for the Future, which estimated the impact of SO_2 and NO_x emissions from coal-fired power plants located in India on premature mortality rates in India, Pakistan, Bangladesh, and Sri Lanka.[24] Specifically, this study estimated that there were 10 deaths per 1,000 metric tons of SO_2 and nine deaths per 1,000 metric tons of NO_x emitted from coal-fired power plants. While these estimates were based on the Indian context, the study did consider the impact of emissions from India on premature deaths in Bangladesh; thus, the numbers are likely to be applicable to Bangladesh as good 'orders-of-magnitude' estimates.[25]

Next, the team converted premature deaths into monetary damages using results from research that monetizes premature deaths from switching vehicles to compressed natural gas in Dhaka.[26] It should be noted that the estimates of pollutant emissions and health effects presented here are probably conservative (i.e. low), given that emissions of particulate matter were not considered, and the study used a methodology that accounted only for health effects on individuals older than 30 years.

Figure 5 shows the projected impacts of the clean energy policy scenarios on SO_2 and NO_x emissions. In 2020, the Reference Case SO_2 emissions were the largest of the three scenarios, driven almost entirely by coal and liquid fuels, which have a high sulfur content. SO_2 emissions in 2020 under Clean Energy Policy 1 would be reduced by over 95,000 metric tons (30%) relative to the Reference Case due to the replacement of high-sulfur liquid fuels with LNG. Another notable change under Clean Energy Policy 1 is the 10% lower level of SO_2 emissions from coal due to the introduction of co-firing with biomass, which has a much lower sulfur content than coal. In 2030, SO_2 emissions in the Reference Case are again from coal and liquid fuels. Clean Energy Policy 2 is projected to result in the largest decrease in SO_2 emissions relative to the Reference Case, at over 289,000 tons (33%). These lower levels are due to the demand-side improvements and an increase in power imports, which result in significant reductions in coal and liquid fuel consumption, and thus lower SO_2 emissions.

Figure 5. Projected SO_2 and NO_x emissions by fuel type for 2020 and 2030

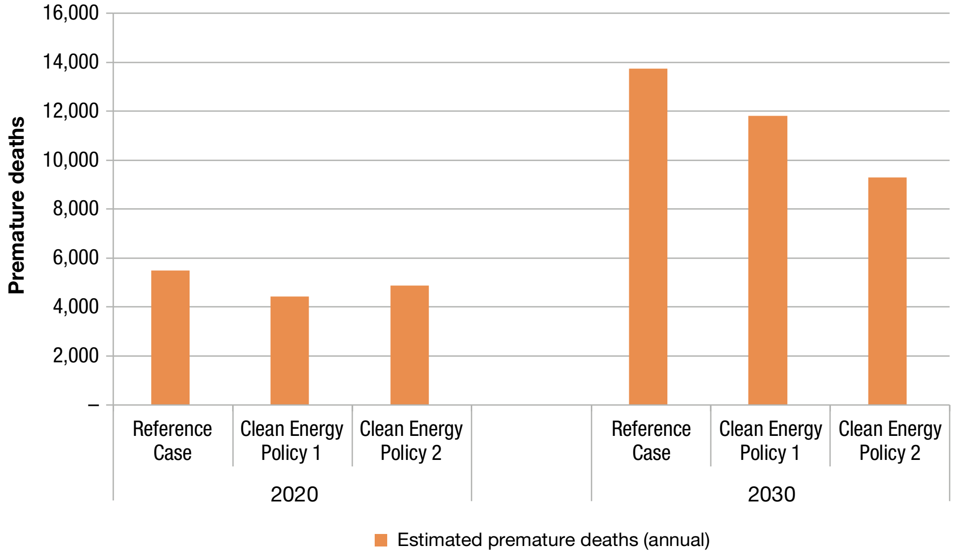


Note: Total emissions in all scenarios are expected to be higher in 2030 than in 2020 due to population and economic growth

Changes in NO_x emissions differ among the scenarios from those for SO_2 emissions for an important reason; while SO_2 emissions are driven primarily by the sulfur content of a fuel, NO_x emissions originate from both the nitrogen content of a fuel and from conversion of nitrogen in the ambient air. Therefore, natural gas is responsible for a larger portion of NO_x emissions across all scenarios. In 2020, Clean Energy Policy 1 is projected to reduce NO_x emissions by just over 11,000 metric tons (4.5%) relative to the Reference Case. This is because, although liquid fuels are replaced by significantly lower carbon and sulfur LNG, the NO_x emission rates for LNG are only slightly lower. In 2030, Clean Energy Policy 2 is projected to reduce NO_x emissions by about 170,000 metric tons (30%) relative to the Reference Case, again driven by decreases in fossil fuel generation due to increased imports and demand reduction.

Using the approach discussed above, it is estimated that Bangladesh's reliance on power generation from fossil fuels under the Reference Case could lead to about 5,500 premature deaths in 2020, increasing to almost 14,000 in 2030. Cumulatively, between 2016 and 2030, it is estimated that there will be almost 123,000 premature deaths under the Reference Case due to SO_2 and NO_x emissions from high-emitting fossil fuel generation, representing an economic cost of over US$ 23 billion (BDT 1.840 trillion) (see Figure 6).

Figure 6: Estimated annual impacts from NO_x and SO_2 emissions



Compared with Bangladesh's health costs under the Reference Case, adoption of Clean Energy Policy 1 could avoid more than 1,000 premature deaths in 2020. This would be due to large reductions in SO_2 emissions as a result of moving from liquid fuel combustion to LNG, as well as changing from conventional coal power generation to co-firing with biomass. The avoided premature deaths could represent an annual cost saving of about US$ 200 million (BDT 16.0 billion). Cumulatively, between 2016 and 2020, it is estimated that more than 5,000 premature deaths could be avoided by adoption of Clean Energy Policy 1, representing a cumulative cost saving of US$ 980 million (BDT 78.4 billion). This policy scenario, which focuses on replacing liquid fuels with LNG, shows that significant health benefits can be achieved by replacing high sulfur content fuels with those with a lower sulfur content, such as LNG and natural gas. (Lower levels of SO_2 emissions are the primary source of avoided premature deaths under this policy scenario.)

Clean Energy Policy 2 is projected to have even larger health benefits. It is estimated that Bangladesh could avoid almost 4,500 premature deaths in 2030 due to large reductions in fossil fuel generation leading to lower SO_2 and NO_x emissions. This would represent an annual cost saving of US$ 850 million (BDT 68.0 billion). Cumulatively, between 2016 and 2030, Bangladesh would avoid more than 27,000 premature deaths under Clean Energy Policy 2 compared with the Reference Case, representing a cost saving of more than US$ 5 billion (BDT 420 billion).

In short, clean energy policies that focus on long-term reductions in coal-fired electricity as well as reduced energy demand can result in significant health benefits. This is due primarily to lower consumption of high sulfur content fuel and lower NO_x emissions associated with reduced combustion-based generation.

Summary of findings

This study shows that significant development benefits are associated with clean energy. These should be considered when making long-term planning decisions regarding energy generation. Such benefits can be achieved cost-effectively by gradually ramping up clean energy policies. In 2020, under Clean Energy Policy 1, greenhouse gas emissions in Bangladesh would be lower by 2.0 $MMTCO_2$ compared with business as usual, domestic employment would increase by 200 job-years, and improved air quality would lead to the avoidance of 1,000 premature deaths equivalent to savings of US$ 200 million (BDT 16.0 billion). Cumulatively, by 2020 it is estimated that Clean Energy Policy 1 would avoid 8.3 $MMTCO_2$ compared with the Reference Case, create 830 job-years, and avoid more than 5,000 premature deaths, equivalent to saving US$ 980 million (BDT 78.4 billion). In 2030, under Clean Energy Policy 2, the long-term option, greenhouse gas emissions would be reduced by 37.6 $MMTCO_2$ compared with the Reference Case, domestic employment would increase by 8,000 job-years, and improved air quality would lead to the avoidance of 4,400 premature deaths, equivalent to savings of US$ 850 million (BDT 68.0 billion). Cumulatively, by 2030 Clean Energy Policy 2 would avoid emissions of 234.1 $MMTCO_2$, create over 55,000 job-years, and prevent over 27,000 deaths, equivalent to saving US$ 5 billion (BDT 420 billion).

Table 2. Results summary

Impacts relative to Reference Case	Clean Energy Policy 1 (short-term option)		Clean Energy Policy 2 (long-term option)	
	In 2020	Cumulative (2016–2020)	In 2030	Cumulative (2016–2030)
Climate benefits: greenhouse gas reductions ($MMTCO_2$)	2.0	8.3	37.6	234.1
Job benefits: increase in job-years	200	830	8,000	55,000
Health benefits: avoided premature deaths	1,000	5,000	4,400	27,000

Replicability and lessons learned

This case study demonstrates that a gradual transition to clean energy would not only reduce Bangladesh's greenhouse gas emissions cost-effectively, it would also promote other, more direct development benefits by generating jobs and reducing premature deaths caused by unhealthy air. These types of positive benefits are likely to be achieved in other countries that generate power mainly from coal and liquid fuels.[27]

This case study also demonstrates that the impacts of clean energy policies on human health and employment can be quantified with fairly limited country-specific data based on existing research. Specifically, human health impacts can be estimated with no need for detailed, country-specific emissions monitoring and modeling, nor detailed historical data, as long as there is some knowledge of the types of fuels being used and certain characteristics of the fuels, most importantly sulfur content.

Similarly, there are robust data from research, particularly for OECD countries, on the employment potential of different electricity generation technologies. This data can be customized for a developing country to reflect its unique domestic conditions, which are different from those of a developed country context. This was done under the CCEB program for Bangladesh using the Wei et al. study. While research to estimate these types of benefits is generally limited, this case study shows that by using data and information from the published literature, it is possible to obtain 'orders-of-magnitude' estimates of health and employment benefits with limited effort, and thus provide insights that could be useful for policy making. Similar estimates may be developed by using readily available tools, such as the International Jobs and Economic Development Impacts (I-JEDI) model, developed by the National Renewable Energy Laboratory with support from USAID to estimate the gross economic impacts from wind, solar, biomass, and geothermal energy projects. The I-JEDI outputs can feed into a broader development impact assessment framework and provide valuable information for specific LEDS actions, supporting prioritization and informed decision-making.[28]

Many countries have the types of data (often developed through long-term power system planning, such as the data used to produce reports similar to the Bangladesh PSMP) that would allow them to undertake an analysis similar to that performed in this study. A data source like the one used for Bangladesh – containing data on power plant fuel type, size, annual generation, and efficiency – would be appropriate. Aggregated data could be used for a similar analysis if it includes a breakdown of the fuel mix and annual power generation.

Glossary

BDT	Bangladeshi Taka (currency)
BPDB	Bangladesh Power Development Board
CCEB	Catalyzing Clean Energy in Bangladesh
LEDS	Low emission development strategy/strategies
LNG	Liquified natural gas
$MMTCO_2$	million metric tons of carbon dioxide
PSMP	Power System Master Plan
PSPAM	Power Sector Policy Analysis Model
RALI	Resources to Advance LEDS Implementation project

Notes

1. The CCEB program was designed to support and enhance energy security, economic growth, and climate change mitigation in Bangladesh. This US$ 15 million project commenced in 2012. More information can be found at *http://www.cleanenergy-bd.org*.
2. The population of Bangladesh was 149.8 million in 2012 (Planning Commission 2013, see Note 8).
3. The population density of Bangladesh was 1,015 people per square kilometer in 2012 (Planning Commission 2012, see Note 5).
4. World Bank (2016) *Sustainable Energy for All* (SE4ALL) Global Electrification database (*http://data.worldbank.org/indicator/EG.ELC.ACCS.ZS*).
5. Planning Commission (2012) *Perspective Plan of Bangladesh 2010-2021: Making Vision 2021 A Reality*. General Economics Division, Planning Commission, Government of the People's Republic of Bangladesh (*http://bangladesh.gov.bd/sites/default/files/files/bangladesh.gov.bd/page/6dca6a2a_9857_4656_bce6_139584b7f160/Perspective-Plan-of-Bangladesh.pdf*).
6. Ministry of Environment and Forests (2009) *Bangladesh Climate Change Strategy and Action Plan 2009*. Government of the People's Republic of Bangladesh: Dhaka, Bangladesh (*http://cmsdata.iucn.org/downloads/bangladesh_climate_change_strategy_and_action_plan_2009.pdf*).
7. Planning Commission (2012) Op. cit.
8. Planning Commission (2013) *National Sustainable Development Strategy 2010-2021*. General Economics Division, Planning Commission, Government of the People's Republic of Bangladesh: Dhaka, Bangladesh (*http://www.plancomm.gov.bd/wp-content/uploads/2013/09/National-Sustainable-Development-Strategy.pdf*).
9. ICF International (2016) *Analysis of Intended Nationally Determined Contributions (INDCs)*. Prepared for the United States Agency for International Development (USAID) Resources to Advance LEDS Implementation (RALI) Program under Agreement No. AID-OAA-LA-14-00010, June 2016 (*http://www.climatelinks.org/sites/default/files/asset/document/INDC White Paper - June 2016_public_RALI.pdf*).
10. 'Least cost without accounting for any externalities, such as health costs.
11. Cost effectiveness is defined in terms of the average cost of generation of electricity, which is assumed to be a measure of the price of electricity for consumers (assuming constant cost of distribution). Under Clean Energy Policy 1, the average cost of generation was estimated to decrease by 2–3% over the Reference Case, since costs for liquid fuels and LNG are comparable, and biomass—which is domestically available–would cost less than imported coal.
12. Bangladesh has already developed plans to import LNG from the Gulf nations. This scenario assumes part of that existing imported LNG capacity can be dedicated to the power sector.
13. As stated in Note 11, cost effectiveness is defined in terms of the average cost of generation of electricity, which is assumed to be a measure of the price of electricity for consumers (assuming constant cost of distribution). Under Clean Energy Policy 2, average generation costs over the long term are estimated to be marginally higher than those of the Reference Case (by 2–3%) due to the slightly higher costs of implementing energy efficiency measures compared with using conventional generation technologies.
14. For example, it has been estimated that India has untapped hydropower resources equivalent to 150,000 MW, while Nepal has untapped hydropower resources of over 80,000 MW; such resources have been linked to potential proposals for joint or multilateral cooperation through the South Asian Association for Regional Cooperation (SAARC). See Islam, M. (2013) The SAARC Grid: Policy, Regulatory, Infra-structure, Contractual Issues in Cross Border Trade of Electricity. Presentation given at the Asia Energy Security Summit in Bangkok, Thailand, 1 March 2013 (*http://www.slideshare.net/IPPAI/the-saarc-gridpolicy-regulatory-infrastructure-contractual-issues-in-cross-border-trade-of-electricity*).
15. Additional energy savings could be achieved in the commercial and residential sectors, but such savings were not included in the modeling analysis.
16. Wei, M., Patadia, S., and Kammen, D.M. (2010) Putting renewables and energy efficiency to work: How many jobs can the clean energy industry generate in the US? *Energy Policy,* 38: 919–931.
17. Indirect jobs refer to upstream jobs related to the supply chain effects due to interlinkages between industries.
18. Wei et al. (2010) Op. cit. provides job estimates (measured in job-years/GWh) for different technologies across OECD countries. In order to apply these estimates to Bangladesh, CCEB adjusted them to account for two key differences: a) differences in labor productivity, based on Rutovitz, J. and Atherton, A. (2009) *Energy Sector Jobs to 2030: A Global Analysis* prepared for Greenpeace International by the Institute for Sustainable Futures, University of Technology, Sydney (*http://www.greenpeace.org/brasil/PageFiles/3751/energy-sector-jobs-to-2030.pdf*); and b) differences in the proportion of imported versus domestic sources of fuel (assuming that use of imported fuel will result in the fuel sector related job benefits accruing to the country that sells the fuel to Bangladesh). For more information on the data and methodologies used for these adjustments, see ICF International (2014) *Report on Implications of Energy Policy Choices on Employment and Economic Growth*. Document prepared for review by USAID by ICF International, subcontractor to Deloitte Consulting LLP under the Catalyzing Clean Energy in Bangladesh project, Contract Number: AD-388-C-13-00001.
19. There is no distinction made in these estimates between direct versus indirect jobs because of the lack of data. Evidence from other research, however, can inform the approximate contributions of direct and indirect jobs from the total unit jobs estimated here. Typically, the indirect job multiplier tends to be between 0.5 and 1.5. That is, for every direct job created, there is the likelihood of another 0.5 to 1.5 jobs created indirectly in upstream sectors that provide the inputs needed for the direct impacts. For example, Wei et al. (2010) Op. cit. argues that their meta-analysis data for OECD countries showed an indirect job multiplier of 0.9. For developing countries, the indirect job multiplier could be higher due to lower labor productivity. See ICF International (2014) Op. cit.

20 Two sets of U.S. data on emissions from electricity generators and fossil fuels with no emission controls were used. The first was 1995–2002 U.S. EPA Continuous Emission Monitoring System Data for coal and natural gas generators with no emission controls retrieved from the U.S. EPA's Air Markets Program Data queries (undated) available at the U.S. EPA's Clean Markets Division website (*http://ampd.epa.gov/ampd*). Regressions were then run on this data to estimate emission rates for generators based on unit size, boiler type, and heat rate information. The second set of data used was the U.S. EPA's *AP-42:* Compilation of Emission Factors (1995; *http://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emission-factors*), with emission factors for liquid fuel generators with no emission controls subsequently scaled according to the size and heat rate of Bangladesh generators.

21 Mittal, M., Sharma, C., and Singh, R. (2012) Estimates of Emissions from Coal Fired Thermal Power Plants in India. International Emission Inventory Conference, Tampa, Florida: U.S. EPA.

22 Mittal et al. (2012) Op. cit. estimates emission rates for coal generators in India that are consistent with estimates obtained by the RALI team for Bangladesh coal generators using coal with similar specifications. APR Energy was identified as a supplier of rental power units for Bangladesh by an article in an electricity industry magazine, *POWER*. Technical data from its website was used to verify RALI estimates for relevant generators in Bangladesh. See APR Energy (undated) Diesel Power Module (*http://www.aprenergy.com/sites/default/files/apr_energy_diesel_power_module_1.pdf*).

23 The benefit transfer method represents an effective and efficient means for estimating health benefits when available time and resources cannot accommodate a primary data collection or modeling effort.

24 Cropper, M., Gamkhar, S., Malik, K., Limonov, A., and Partridge, I. (2012) The Health Effects of Coal Electricity Generation in India. *Resources For the Future Discussion Papers,* 12(25).

25 India is considered to be an appropriate proxy for Bangladesh given the countries' similar geographies, population age structures, life expectancy rates, urbanization levels, health expenditures, and other social, economic, and environmental characteristics.

26 Wadud, Z. and Khan, T. (2013). Air Quality and Climate Impacts Due to CNG Conversion of Motor Vehicles in Dhaka, Bangladesh. *Environmental Science & Technology*, 47(24): 13907–13916.

27 For example, studies have shown that air pollution in China and India, primarily from coal-fired power generation, has significant public health effects, including on mortality rates, which could be reduced by switching to cleaner power sources. See, for example, Rhodan, M. (2015) Study Finds Pollution in China Causes 1.6 Million Deaths a Year. *Time magazine*, 13 August 2015 (*http://time.com/3997626/china-pollution-study*); Bhattacharya, S. (2016) India and China Have Most Deaths From Pollution. *The Wall Street Journal, 16 Feb 2016* (*http://blogs.wsj.com/indiarealtime/2016/02/16/india-and-china-have-most-deaths-from-pollution*); *and Kan, H.*, Renjie, C., and Shilu T. (2012) Ambient air pollution, climate change, and population health in China. *Environment International*, 42: 10–19 (*http://www.sciencedirect.com/science/article/pii/S0160412011000535*).

28 For more information on these tools, visit Enhancing Capacity for Low Emission Development Strategies Development Impact Assessment Tools (*http://www.ec-leds.org/tools-page/development-impact-assessment-tools*).

The **Resources to Advance LEDS Implementation (RALI)** project is a cooperative agreement between the United States Agency for International Development (USAID) and ICF. The RALI project supports the U.S. Global Climate Change Initiative by helping developing countries speed their transition to climate resilient, low emission, and sustainable economic growth. RALI supports the technically rigorous development and implementation of low emission development strategies (LEDS) by providing tools, technical assistance, and resources to support USAID and its partners, as well as host country governments, in the implementation of LEDS. www.climatelinks.org/projects/rali

The **Low Emission Development Strategies Global Partnership (LEDS GP)** was founded in 2011 to enhance coordination, information exchange, and cooperation among countries and international programs working to advance low emission, climate resilient growth. LEDS GP currently brings together LEDS leaders and practitioners from more than 160 countries and international institutions through innovative peer to peer learning and collaboration via forums and networks. For the full list of participants and more information on partnership activities, see www.ledsgp.org

This case study is made possible by the support of the American people through the United States Agency for International Development (USAID). The contents are the sole responsibility of ICF and the LEDS GP and do not necessarily reflect the views of USAID or the United States Government.

Photo credit: ASaber91 CC BY 2.0 via Flickr

Design and layout: Green Ink (www.greenink.co.uk)