How can Azerbaijan meet its Paris Agreement commitments: assessing the effectiveness of climate change-related energy policy options using LEAP modeling

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Abstract

Azerbaijan has committed to cut GHG emissions by 35% by 2030 under the Paris Agreement. By applying LEAP, a well-regarded forecasting model based on inventories defined under the IPCC (Intergovernmental Panel on Climate Change), GHG emissions projections are modeled in three scenarios: a without measures (WOM) scenario or business-as-usual, which assumes no change to current behavior, a with existing measures (WEM) scenario, which takes into account currently planned measures in Azerbaijan, and an EU policy scenario, which mirrors the existing mitigation measures of the European Union. The WOM scenario of total GHG emissions from the energy sector indicates that from 2010 to 2030, total emissions will increase by 67% in Azerbaijan. In the WEM scenario, forecasted GHG emissions are only 29.7% lower than the base year and still above the nation's Paris Agreement commitment. In the EU policy scenario, projected GHG emissions are 37.2% lower than the base year. Therefore, current mitigation measures are insufficient for Azerbaijan to meet its commitments to the Paris Agreement, and stronger measures than currently planned are necessary. Because of its status as a developing nation with limited resources, Azerbaijan must have funding from developed nations promised under the Paris Agreement to transition towards a less carbon-heavy economy.

1. Introduction

The Republic of Azerbaijan became a member of UNFCCC (United Nations Framework Convention on Climate Change) in 1995 and endorsed the Kyoto Protocol in 2000. Although Azerbaijan is a non-Annex I country, its responsibilities are developing, fulfilling, and publishing national and regional programs attempting to decrease the impacts of global climate change. The country signed the Paris Agreement in 2016 and committed to decrease the level of GHG emissions by 35% in 2030 compared to the base year (1990) (Government of Azerbaijan, 2015).

The Paris Agreement was adopted at the 21st Conference of the Parties (COP) of the UNFCCC. The main objective of the Paris Agreement is to hold “the increase in the global average temperature to well below 2 ºC above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 ºC above pre-industrial levels”. According to Article 3 of the Paris Agreement, each party must determine, plan, and regularly report on its contributions to mitigate climate change (United Nations Framework Convention on Climate Change, 2015).

All nations have obligations under the Paris Agreement to cut emissions. Developed nations often have substantial government staff and NGOs who regularly track their progress. However, less developed nations have significantly fewer resources. Thus, this paper models GHG scenarios in the developing post-Soviet nation of Azerbaijan.

The energy sector in Azerbaijan is substantial, and growing. Presently, there are fourteen thermal and fourteen hydroelectric operating power stations (Government of Azerbaijan, 2015) to meet the energy demands of the Republic, and additional capacity is currently being constructed. Older facilities are being retrofitted. According to current energy efficiency policies, the use of fuel oil was completely replaced by natural gas in existing thermal power plants. This replacement reduces negative externalities on the environment and contributes to the mitigation of climate change.

In Azerbaijan, GHG emissions are chiefly generated during oil and natural gas production, including wells, drilling, testing, and commissioning, oil refining, gas processing, oil transport, natural gas transportation and storage, and distribution.

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Under the IPCC 2006 GHG Inventory Guidelines, GHG emissions are divided into two primary sources: stationary and mobile (Garg et al., 2006). Azerbaijan is a nation that focuses on heavy industry. Emissions from stationary sources include electricity generation, fuel combustion in manufacturing industries and construction, commercial and the public sector, and also the energy industry's own use. Emissions emitted from aviation, road transport, rail, and shipping categories are included in mobile sources (The Ministry of Ecology and Natural Resources of the Azerbaijan Republic, 2015). Azerbaijan is a heavy industrial nation with fossil fuels at its heart. In 2018, stationary sources comprised 86% of GHG emissions, with mobile sources encompassing the rest of GHG emissions (Government of Azerbaijan State Statistical Committee, 2020).

Arriving at a finer grain of detail, in the first Biennial Update Report of Azerbaijan to UNFCCC, the energy sector was responsible for 75.6% of overall national emissions in 2010 (Government of Azerbaijan, 2014). In the second Biennial Update Report, 79.6% of GHG emissions in 2015 were released by the energy sector (Government of Azerbaijan, 2018). Thus, to meet treaty commitments, the energy sector is a stakeholder that must make a substantial contribution to these efforts (For further details of announcements by the Government of Azerbaijan, See Appendix A).

This study will inventory and model Azerbaijan's current and predicted GHG emissions and model 3 scenarios, up to 2030, including a business as usual scenario, a scenario encapsulating currently planned initiatives, and a final scenario using the EU as a model with even more sweeping cuts, to learn what will be required to meet the nations' Paris Agreement commitments. The analysis of GHG inventories allows researchers to estimate which categories have the most considerable impacts on a country's emissions, and it will assist in prioritizing national mitigation measures.

2. Methodology

2.1. The long-range energy alternatives planning system

This study applied the LEAP forecasting system for GHG emissions for several reasons. Firstly, LEAP was created to model conditions in the energy industry and for GHG mitigation analysis. This methodology has been used by almost 200 nations, and countries, both developed and developing, use this technique in producing reports for the UNFCCC (Stockholm Environment Institute, 2005). Secondly, UNFCCC suggested several modeling programs for Non-Annex I nations to use in reporting. In comparison with other modeling programs, LEAP can perform robust analyses with less required data (United Nations Framework Convention on Climate Change, 2008). Thirdly, although straightforward, LEAP offers robust analyses to compare a menu of policy choices, allowing developing nations access to strong planning mechanisms previously reserved for more developed countries.

The LEAP system is a unified modeling tool applied for energy policy analysis and climate change mitigation assessments (Stockholm Environment Institute, 2005). It can model many scenarios of predicted energy demand and environmental impact. It examines how energy is created, transformed, and used, and it can control for population growth, economic growth, and income per capita (Cai et al., 2008). LEAP modeling includes a flexible structure that provides both end-user power and ease of use (United Nations Framework Convention on Climate Change, 2008). LEAP modeling has been applied to estimate energy consumption and GHGs in industries and economies around the world (Price et al., 2006).

LEAP is well-regarded and frequently used in modelling, too. It has been used to model the transport sector in India (Bose, 1996), landfill gas generation in Korea (Shin et al., 2005), long-term energy demand forecasting in Taiwan (Huang et al., 2011), and energy transitions toward a low-carbon economy in Beijing (Feng and Zhang, 2012). LEAP has been used to forecast direct energy consumption in Nigerian households, and it has been applied in other African countries such as Ethiopia where it was used to consider alternative scenarios for the energy requirements of the nation, modeling up to 2050 (Senshaw, 2014). It analyzed energy demand and pollutant emissions for the Greek road transport sector from 2010 to 2035 (Bitos, n.d.) along with the same sector in Taiwan (Liao et al., 2011). Also, it calculated aggregate trends in energy supply and demand due to the anticipated explosion in natural resource exploitation in Mozambique (Mahumane and Mulder, 2016). LEAP modeled CO2 released from the energy and cement industries in Beijing, Tianjin and Hebei Province from 2009 to 2050 (Liu et al., 2011).

Beyond specific sectors, it is often used to model entire national systems. It was recommended in a meta-analysis as an excellent model to forecast CO2 emissions, as is done here (Abdullah and Pauzi, 2015). In Turkey, LEAP determined the greatest emissions efficiency per unit of GDP. Several techniques were considered, and IPCC's LEAP was found to be the most effective (Say and Yücel, 2006).

In calculating GHG emissions from the transport sector, the Tier 1 approach is usually applied, which is comparatively simple among the methods suggested by the IPCC (Sim et al., 2015), while the Tier 3 method demands more detailed data (Graham et al., 2008). Country-specific greenhouse gas emission factors were developed at the Tier 3 level, determined by IPCC guidelines for diesel-electric emissions, modeling line-haul railway traffic in the domestic transport sector of the Republic of Korea (Kim et al., 2017). This is possible given Korea's fine-grained detail at the source level, but it requires institutional capacity not available in all nations.

2.2. Climate change-related energy policies and mitigation measures

Three scenarios have been constructed. These policy and mitigation measures (PAMs) will be described in turn.

1. PAMs that are easy goals to achieve.

In Azerbaijan, GHG emissions are chiefly generated during oil and natural gas production, including drilling, testing, and commissioning, oil refining, gas processing, oil transport, natural gas transportation and storage, and distribution. Relatively-cleaner natural gas is now more frequently used in electricity generation. According to the State Statistical Committee, in 2018, renewables comprised only 1.7% of energy generated. This is the business as usual scenario, without any additional measures (WOM).

2. PAMs that are moderately difficult to achieve goals that have been set by policymakers of Azerbaijan (Government of Azerbaijan, 2018):

This scenario is the current plan for Azerbaijan for the foreseeable future. The government plans to adopt the following: electricity network upgrades, compact fluorescent lamp lighting initiatives, increasing forest creation, small hydro facilities, improved insulation, sustainable land management, onshore wind stations, small solar installations, municipal solid waste to electricity conversion, biogas, and fossil fuel elimination subsidies. Azerbaijan has a target to increase the share of renewable energy to 20% of electricity generated. This is the with existing measures scenario (WEM).

3. PAMs that are difficult to achieve:

Much greater emphasis on renewable energy: Azerbaijan is a developing country, which gained independence after the Soviet Union collapsed but suffered long and sustained economic decline. There is an adequate amount of renewable energy potential in Azerbaijan. However, these comprised only 1.7% of production and 0.4% of consumption in 2018, according to the State Statistical Committee. Due to the dominant share of oil and gas in energy production and consumption, it is quite a stretch to move from fossil fuels to renewable energy. First of all, it is unaffordable for Azerbaijan; secondly, it does not increase economic output in the short run. However, just because it is difficult does not
make it impossible. Azerbaijan has made Paris Agreement commitments for GHG emissions reductions.

The EU has implemented much stronger energy targets, with renewables making up 32% of the energy sector and requiring a 32.5% improvement in energy efficiency. Although requiring a large financial stretch, these PAMs promise a dramatic drop in GHG emissions. This is the EU scenario.

2.3. National Greenhouse Gas Inventories

The IPCC Guidelines for National GHG Inventories are globally accepted methodologies to calculate and record anthropogenic GHG emissions and removal of GHGs within national boundaries. These guidelines are being applied by all Parties to the UNFCCC (Task Force on National Greenhouse Gas Inventories, 2014).

The advantages of the IPCC Inventory Software are: a straightforward interface providing for efficient modeling, well-defined structures and calculations that prevent errors, simplicity managing vast amounts of data, and a smooth transfer to reporting formats (Air Quality Governance in the ENPI East Countries, 2013). Considering these benefits, this study has conducted a GHG emissions inventory using IPCC Inventory Software (Version 2.54).

Three Tiers were introduced in the 2006 IPCC Guidelines for calculating emissions from fossil fuel combustion (Garg et al., 2006). Tier 1 is the most accessible to use, while Tier 3 produces the most precise results.

The Tier 1 method examines the fuel that is burned and applies well-known and studied averages to determine emissions. If one can find the amount of coal burned, GHG emissions can be predicted using Tier 1 methodology (Garg et al., 2006).

The quality of these emission factors varies between gases. For CO₂, emission factors principally depend upon the carbon content of the fuel. Combustion conditions (e.g., combustion efficiency, carbon retained in slag and ashes) are comparatively insignificant. Hence, CO₂ emissions can be calculated reasonably accurately based on the total amount of fuels combusted, and the averaged carbon content of the fuels (Garg et al., 2006).

While CO₂ is reasonably consistent in its emissions, CH₄ and N₂O show more variance in GHG emissions and are harder to predict. Unlike for CO₂, using average emissions will create more distortions in modeling for these gases, which will vary based on the composition of fuels and how they are burned. This presents significant uncertainties (Garg et al., 2006).

The Tier 2 method includes more variance that attaches based on national generation conditions. What is burned, and how it is burned is tracked in this method. It is more precise but requires greater detail about local-level conditions (Garg et al., 2006).

Tier 3 focuses on what emissions are directly measured at individual facilities that are being directly monitored. This provides the best data but incurs the greatest expense (Garg et al., 2006).

In Azerbaijan, only the Tier 1 approach is currently possible. Tier 2 and Tier 3 are not affordable in Azerbaijan. It is necessary to have the results of laboratory analyses for at least a five-year time period for all emissions, as well as the Associated Petroleum Gas for every inventory year required to apply Tier 2 and Tier 3 approaches. All results should be performed by accredited laboratories, which is very expensive and unavailable in Azerbaijan (Government of Azerbaijan, 2018), unlike in developed nations with significantly more resources.

However, all methods are approved and widely used in modeling. All will effectively model CO₂ although there is greater variance with other GHGs. The perfect should not be the enemy of the good, and this study will use a Tier 1 analysis to inventory and model Azerbaijan’s energy emissions.

To perform a Tier 1 estimation of GHG from stationary combustion (Gomez et al., 2006):

\[
\text{Emissions}_{\text{GHG, fuel}} = \text{Fuel consumption}_{\text{fuel}} \times \text{Emission Factor}_{\text{GHG, fuel}}
\]

Where:

- Emissions \( \text{GHG, fuel} \) = Emissions of a given GHG by type of fuel (kg GHG)
- Fuel consumption \( \text{fuel} \) = Amount of fuel combusted (TJ)
- Emission Factor \( \text{GHG, fuel} \) = default emission factor of a given GHG by type of fuel (kg gas/TJ).

For CO₂, it includes the carbon oxidation factor, assumed to be 1.

To calculate the total emissions by gas from the source category, emissions are calculated in the following equation (Gomez et al., 2006):

\[
\text{Emissions}_{\text{GHG}} = \sum \text{fuel} \times \text{Emission Factor}_{\text{GHG, fuel}}
\]

Where:

- Emissions = emission in kg
- \( EF_{\text{a}} \) = emission factor (kg/TJ)
- \( \text{Fuel}_a \) = fuel consumed, (TJ) (as represented by fuel sold)
- \( a \) = fuel type.

The equation for the Tier 1 method for calculating CO₂ emissions from road vehicles are expressed as (Waldron et al., 2006):

\[
\text{Emission} = \sum_a \left[ \text{Fuel}_a \times \text{Emission Factor}_a \right]
\]

Where:

- Emissions = emission in kg
- \( EF_{\text{a}} \) = emission factor (kg/TJ)
- \( \text{Fuel}_a \) = fuel consumed, (TJ) (as represented by fuel sold)
- \( a \) = fuel type a (e.g., diesel, gasoline, natural gas, LPG).
GHG emissions from “Other Sectors” category has been estimated based on the data obtained from the State Statistical Committee. This category includes commercial and public services, households, agriculture, forestry, and fishing industries (Herold et al., 2006) (for more details, please refer to Appendix B, Table 4). Tier 1 approach and default emission factors for developing countries have been used in the estimation.

Fugitive emissions from the “Oil and natural gas” category have been calculated under requirements shown in the 2006 IPCC Guidelines (Herold et al., 2006) (for more details, please refer to Appendix B, Table 5). This study includes the evaluation of CO₂ and N₂O emissions from “Oil and Natural Gas” categories. The Tier 1 approach and default emission factors for developing countries have been applied in the calculation.

The GHG emissions inventory for the years 1990–2013 has already been performed and published in The First and Second Biennial Update Report of the Republic of Azerbaijan to the UNFCCC. This study inventoried GHG emissions for the year 2014 and 2015. The result of twenty-five years have been compared to determine the trends in GHG emissions in the energy sector and as a reliability check.

2.4. LEAP model

LEAP allowed the creation of a model of Azerbaijan’s energy sector through a simulation it taking into account energy demand and supply, forecasting emissions to 2030, and analyzing the outcomes of different climate change-related policies.

The study encompasses historical data and projections of energy consumption and GHG emissions. The research set a historical period by applying the data on energy consumption from 2010 to 2015. Forecasts to 2030 are based on Azerbaijan’s pledge of a 35% decrease in GHG emissions by 2030, in comparison with a 1990 base year. Thus, the historical and projection periods are 2010–2015 and 2016–2030, respectively.

By applying LEAP, scenarios can be developed and then compared to evaluate power needs, advances achieved and prices paid, and any damage to the natural environment (United Nations Framework Convention on Climate Change, 2008). Scenarios all for “what if” analyses, such as: what if more efficient devices are applied, what if different electric generation capacity development strategies are implemented, what if new natural reserves of oil and gas are found, what if renewable energy technologies occupy greater percentages of total energy consumption are possible to be modeled.

The initial scenario of the research is the WOM scenario visualizes a future with no additional mitigation measures, and historical trends are fundamental drivers of energy use and emissions proceed. Simply, it considers the past is an inherently trustworthy model for the future. The WOM scenario was developed according to these assumptions, which include population and economic growth, greater expertise in production techniques, and no strong climate-related programs.

With a WEM scenario, various programs to reduce the impact of climate change were included in the analysis of LEAP modeling. This simulation includes renewable energy programs and energy efficiency strategies which have been included in national development programs. Climate change-related policies, which were not considered in the WOM scenario, have been investigated in the WEM scenario as mitigation alternatives to determine the effects of policies and measures. In other words, the study determined how much GHG emissions would be reduced after fulfillment of relevant actions.

Finally, the EU scenario goes beyond current plans, with an adoption of the European Union’s strict plans for renewable and greater energy efficiency.

3. Results

3.1. GHG inventory results and trends

The GHG inventories for 2014 and 2015 years have been forecast according to the IPCC Guidelines. The Tier 1 approach and default emission factors for developing countries were applied in the estimation. The Global Warming Potentials (GWP) employed in the research are the potentials were determined for 100 years (GWP for CO₂ = 1, CH₄ = 21, N₂O = 310 (Clark and Jäger, 1997)) in the 2nd Assessment Report of the IPCC. The result of the inventory has been provided in Appendix C, Table 6 and Appendix C, Table 7 respectively.

As a consequence of the inventory, GHG emissions from the energy sector were 50,496 Gg in 2014, reaching 51,260 Gg in 2015. Thus, the research showed that total GHG emissions rose by only 1.51% between 2014 and 2015. According to the IEA, the Republic of Azerbaijan produced 25 TWh of electricity in 2015, chiefly from natural gas (86%) (International Energy Agency, 2017).

As demonstrated in Figure 1, the amount of CO₂ fluctuated from 1990 to 2015 (for more details, please refer to Appendix C, Table 8). There is a dramatic decrease from 1990-1994 because oil and gas production decreased after the Soviet Union collapsed. Although Azerbaijan announced its independence quickly, the country needed time to restart production.

The dramatic increase in the concentration of GHG emissions was observed in 2011, up 26% from 2010. Energy consumption in Azerbaijan in 2011 was up 9%. Oil and gas had a dominant share, which accounted for 83% in 2011 (Energy Charter Secretariat, 2013).

The amount of GHG emissions released by the energy sector decreased by approximately 20% in 2015 in comparison with the base year. This reduction can be explained by climate-related mitigation measures like the employment of modern technologies, capturing of associated gases in the oil and gas sector, and switching from fuel oil to natural gas in the energy industry for heat and power production.

Figure 1 shows that the amount of CH₄ decreased sharply from 1990 to 1994, and it was reasonably flat between 1994 and 2005. It surged the following two years, while staying reasonably constant since 2008. There was minor fluctuation in the amounts of N₂O in the first twenty years of the study. It increased drastically from 2010 to 2014, while there was a slight drop in 2015. CH₄ substantially increased as oil production leaped during the mid-to-late 2000s. N₂O also had a very large percentage increase slightly later, owing to the broad transition from coal to natural gas as the big driver of power generation in the early 2010s.

3.2. GHG emissions projections by applying LEAP

3.2.1. Key assumptions

Two key assumptions were applied in the research.

Population: The State Statistical Committee forecast that the population growth of Azerbaijan is 1.1% or 100 thousand people per year (Government of Azerbaijan, 2015).

GDP: The national development plan predicts an average GDP growth rate over 3% annually by 2025 (Musayev, 2017). The International Monetary Fund predicted a 2.275% average annual growth of GDP in Azerbaijan based on the prediction for 2017–2020 (Government of Azerbaijan, 2018). In this research, the annual growth of GDP is assumed to be in-between, at 2.5%. The exchange rate between the US dollar and AZN was assumed to be 15 = 1.7 AZN for 2016–2030 years.

Figure 2 demonstrates the population projections of Azerbaijan until 2030 (for more details, please refer to Appendix D, Table 9).

As it is illustrated in Figure 3 (for more details, please refer to Appendix D, Table 10), during the historical period (2010–2014), GDP per capita generally increased, but there was a significant decrease in 2015. This dramatic decline is precisely related to the drastic fall in oil prices (Development Center for Economic and Social, 2016). As expected for an oil-heavy nation, GDP figures are heavily influenced by the price of crude.

Three scenarios have been included in the paper: a business as usual scenario, without mitigation measures (WOM), a scenario capturing the current plans of Azerbaijan, with mitigation measures (WEM) and a stronger scenario that includes measures up to the level of those of the European Union, the EU policy scenario.
Figure 1. GHG emissions released from the Energy sector (1990–2015). *Source: Government of Azerbaijan State Statistical Committee.

Figure 2. Population in Azerbaijan (WOM scenario).
3.2.2. Without measures scenario (WOM)

The key assumptions of population GDP, and data on the energy balance have been taken from the State Statistical Committee, and these were applied to LEAP in order to determine energy supply. In the WOM scenario, energy supply increases by 10% from 2016 to 2030 due to rising population and GDP (For more details, please refer to Appendix D, Table 11 and Appendix E, Figure 7).

As energy demand increases, the carbon intensity of energy has significant consequences. In the WOM Scenario, the carbon intensity of the energy supply is not predicted to drop significantly; it will decrease only by 4% from 2016 to 2030 (For more details, please refer to Appendix D, Table 12 and Appendix E, Figure 8).

Traditional energy resources of Azerbaijan principally consist of oil and natural gas. According to statistics from British Petroleum, Azerbaijan has about 7 billion barrels of oil reserves. The average production was 43 million barrels per year, as an average over the last five years. Annual oil production in Azerbaijan has begun to decrease, and in the forthcoming years, this drop will be notable. However, with the development of the Caspian Sea gas extraction, Azerbaijan has now become a gas exporter. BP announced that Azerbaijan reserves amounted to 1.1 trillion cubic meters (Vidadili et al., 2017). However, renewable energy resources, in particular hydropower, biomass, wind, solar and geothermal have great potential, even if they have not yet been actualized. In the WOM scenario, the share of natural gas will increase by 9.2%
from 2016 to 2030 (For more details, please refer to Appendix D, Table 13 and Appendix E, Figure 9).

All WOM scenarios show that energy intensity increases because of population and GDP growth. Other parameters, in turn, cause increases of GHG emissions levels. Figure 4 describes projections of GHG emission levels (For more details, please refer to Appendix D, Table 14).

The WOM scenario of total GHG emissions indicates that from 2010 to 2030, total emissions of GHGs increase 67% in Azerbaijan. Therefore, Azerbaijan cannot meet its commitment to the Paris agreement unless mitigation measures are implemented.

3.2.3. With measures scenario (WEM)

Unlike the WOM scenario, the WEM scenario includes several climate-change related policies. The research considered the renewable energy targets set by Azerbaijan. Renewable energy targets of the country are: a 20% share of renewable energy in the total energy sector, a 9.7% share of renewable energy in total energy consumption in residential areas, and a 20% improvement in energy efficiency (Vidadili et al., 2017).

When modeling applied the above-mentioned policies to the WEM scenario, the share of renewable energy rose significantly from 0.3% to 20% during the projection period (For more details, please refer to Appendix D, Table 15 and Appendix E, Figure 10).

Figure 5 illustrates how Renewable energy and energy efficiency targets of Azerbaijan would reduce GHG emissions by 2030.

The WEM scenario for total GHG emissions indicates that from 2016 to 2030, total emissions will be essentially flat. In the WEM scenario, forecast GHG emissions are only 29.7% lower than a base year of UNFCCC. Therefore, Azerbaijan cannot meet its commitment to the Paris agreement unless more aggressive climate change-related mitigation measures are implemented.

3.2.4. EU policy scenario

The EU scenario increases the influence of renewables. Renewable energy targets of the EU are: a 32% share of renewable energy in the energy sector and a 32.5% improvement in energy efficiency (European Commission, 2019).

When applying the above-mentioned policies from the EU policy scenario, the share of renewable energy rose significantly from 0.3% to 32% during the projection period (For more details, please refer to Appendix E, Figure 11).

Figure 6 illustrates how renewable energy and energy efficiency targets of EU policy would reduce GHG emissions by 2030.

The EU policy scenario for total GHG emissions indicates that from 2016 to 2030, total emissions would decrease by 26.3% in Azerbaijan.

In 1990, 63.9 thousand Gg GHG emissions were emitted by energy industries, which was 91% of total emissions. In the EU policy scenario, forecast GHG emissions are 37.2% lower than a base year of UNFCCC. Therefore, Azerbaijan can meet its commitment to the Paris Agreement if climate change-related mitigation measures of the EU are implemented.

3.3. Validation

With any type of modeling, there is always a question of its efficacy in a particular situation, even if it has been shown to be robust in countless other scenarios. The model used data from 2010-2015 to predict the period up to 2030. If predictions for the later periods of the 2010s were to be significantly awry, that would damage the belief in the model. There is aggregate data up to 2015, and the State Statistical Committee of Azerbaijan recently released data from 2016 and 2017 for CO2, N2O, CH4, and F-gases. Although this does not include all GHGs, it is close to the total. Data for these four substances are available from 2013-2017. Thus, the model can be tested for 2 of its modeling years against recently released data, and evaluated against three known years of historical data. Comparing the predictions of the model against what actually transpired can validate or disprove the model.

As seen in chart below, the gap between these 4 gases and total emissions is consistent for the years measured where full data is available with the predictions. The model's predicted years match the ratio expected from historical data, within a range of 93–97% of all greenhouse gases. Thus, the partial data available for 2016 and 2017 provides evidence of validation for the modeling technique when compared to the with existing measures scenario (WEM) (see Chart 1).

Of course, as Yogi Berra, the American baseball player and comedy legend noted, “It’s tough to make predictions, especially about the future.” In the area of climate change modeling, this is especially true, as models encapsulate a wide range of variables over long periods of time. However, for the data available, it appears the model has the appropriate
vector and magnitude expected. As time passes, entropy reigns, and more distant predictions may have more variance. But overall, it appears the model is sensitive and moves and the direction expected. Thus, there are real world predicted data to validate the model, with noted qualifications.

4. Discussion

Azerbaijan faces stark choices in combating climate change. On one hand, Azerbaijan is improving its oil and gas production in order to develop the country’s economy, and the population and GDP of Azerbaijan are continuously increasing, leading to increasing GHG emissions. On the other hand, the Republic pledged under the Paris Agreement to reduce GHG emissions.

This research inventoried GHG emissions from the energy sector for 2014–2015 using IPCC inventory software (version 2.54) describing Azerbaijan’s current circumstances. By applying the LEAP model, the study investigated the WOM scenario, which excluded all mitigation measures; and WEM scenario, which included currently planned mitigation measures. The result shows that in the WOM scenario, the amount of GHG emissions is much higher than the baseline year; however, it is insignificantly lower than 1990. In the WEM scenario, the amount of GHG emissions is a little bit lower than the baseline of research; however, it is significantly lower than 1990, which is the base year of UNFCCC.

The research revealed that current policies and mitigation measures are not enough to meet Azerbaijan’s target to the Paris Agreement. It implies a 20% increase of the share of renewable energy in total energy consumption and 20% improvement of energy efficiency would not be sufficient to achieve Azerbaijan’s commitment. Thus, more renewables and greater energy efficiencies are necessary.

Azerbaijan’s commitment to the Paris Agreement is a 35% reduction in GHG emissions by 2030 in comparison to 1990 levels. However, the modeling showed that considering currently planned climate-change-related policies, the Paris Agreement goals cannot be met. Existing policies will only bring about a reduction of 29.7%, meaning there is a 5.3% gap.

Now, the question is: what should Azerbaijan do to overcome this gap? First of all, Azerbaijan should prioritize energy efficiency and renewable energy. A 20% increase of the share of renewable energy in total energy consumption and 20% improvement of energy efficiency...
would not be sufficient to achieve the Paris target. Thus, renewable energy and energy efficiency goal should be greater than 20%. The EU Policy scenario can be a guide, if not a map.

Meanwhile, a thorough economic analysis must be done to define how much investment is required to attain new targets. Taking into account the assumption that electricity tariffs impact energy efficiency, it might be better to increase the current electricity tariff. Thus, the affordability of electricity tariffs for the population should be considered.

There will be substantial progress if Azerbaijan will apply market principles in the energy sector, taking advantage of international experience. For instance, CO2 and other emissions emitted by companies should be priced at their social cost, changing companies’ decisions in favor of reducing GHG emissions. A carbon tax could also be useful.

Additionally, Azerbaijan should think about diversification of its economy. As this paper has stated many times, since Azerbaijan is an oil and gas supplier its income depends on oil prices. Decreases in the oil price means a reduction in investment for climate change-related measures. Thus, Azerbaijan should consider serious reforms, decreasing dependence on oil revenues and increased investment in renewable energy resources and energy efficiency. These kinds of changes are not just helpful for GHG emissions but also for the wider economy.

The growth of your nation on the price of a few volatile commodities does not seem prudent for long term growth, especially as the cost of renewables continue their inexorable decline through dramatic pushes from governments all over the world. Finally, developed nations have committed to provide at least $100 billion annually in assistance for less developed nations to improve carbon efficiency. The current global situation may push nations to favor their own citizens and not sufficiently contribute to the problem of climate change.

What this research shows is the need for support in developing nations is and will continue to be great, so neglecting this commitment will quite possibly result in the inability of developing nations to meet their promises. The Paris Agreement was a package deal, and if one part is ignored or neglected, it could undermine the viability of the whole enterprise. Thus, if developing nations are to try to meet their commitments, they should receive the assistance that was promised.

5. Conclusion

This study modeled GHG emissions for Azerbaijan until 2030 under a business as usual scenario, a scenario with currently planned climate change mitigation measures, and a final scenario mirroring EU policy plans. This research finds Azerbaijan can reach its GHG target announced in the country’s pledge if the nation adopts EU policy, which is a 32% share of renewable energy in the total energy sector and a 32.5% improvement in energy efficiency. In order to implement this policy, considerable investment is required in modern renewable energy infrastructure, and current means are not adequate to improve renewable energy technologies. However, while this may be necessary to meet global commitments, the means are lacking. Almost certainly, to meet these commitments, development assistance from nations with more resources, as developed nations pledged in the Paris Agreement, must be forthcoming.

Future research should bring new data to these models. A cornerstone of the Paris Agreement is reporting. Ever more data will be available to show nations which policies have the greatest return on investment. Greater energy efficiency benefits the world community, and through this transparency, we can, and should, all learn from each other.

In conclusion, for Azerbaijan to meet its Paris Agreement commitments, Azerbaijan should embrace energy efficiency and increase the share of renewable energy sources in power and heat generation. The county should also strengthen cooperation with the private sector in renewable energy sectors. Finally, great flows of knowledge and capital from outside the nation should be invested to assist the country in its transition to a cleaner world.
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