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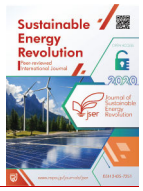

Renewable energy potential for sustainable development in Afghanistan

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ABSTRACT

Afghanistan is one of the developing countries in South Asia with an enormous renewable and nonrenewable energy resources. Since 1893, utilization of secondary (modern) form of energy in Afghanistan has been pursued. The trends of sustainable energy provision have been reinforced after the post-conflicts in Afghanistan. The Sustainable Development Goal-7 (affordable and clean energy access) encourages nations to assess their resource development of renewable, affordable, and accessible energy. Unlike many developing countries that struggle to identify domestic sources of clean, sustainable energy, Afghanistan has hydro, solar, wind, and geothermal resources as assets. This literature review analyzes Afghanistan's potential for renewable energy to identify obstacles and challenges like security, economics, and technology. Using surveys conducted by national and international organizations. This research evaluates Afghanistan's progress in meeting SDG-7, identifies the main barriers for renewable energy development, and offers recommended solutions. This study reveals the facts of energy sector development in Afghanistan to enable students, researchers, and practitioners with an overview of the current situation and future direction of the energy sector. Also, this study offers a concise outlook for energy sector investors and donors at the national and international stages.

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1. Introduction

A nation's sustainable socioeconomic development relies on managing secure sources of domestic energy. While renewable energy is available, most of the world's energy comes from non-renewable resources. Which directly contributes to climate change and causes environmental problems that detrimentally affect quality of life. Non-renewable energy sources are responsible for 50% of global air pollution and 60% of emitted global greenhouse gases [1]. Consequently, reducing reliance on non-renewable sources decreases global carbon dioxide and greenhouse emission concentration, and mitigates long-term climate change effects. Renewable energy sources, in contrast, can meet the increasing global energy demand and sustaining global development goals while maintaining the environment. Whereas, global energy demand increased by 2.1% in 2017, it is also expected to increase by 30% by 2035 [2]. In addition, 21% of the world's population lacks access to electricity and use biomass as their primary source of energy [3].

Afghanistan with a geopolitical privilege has the merit of energy hub between South and Central Asia. Afghanistan is a landlocked country borders with the Islamic Republic of Iran, Pakistan, China, Tajikistan, Uzbekistan, and Turkmenistan [4]. As of April 2020, the population of Afghanistan is reported about 39 million (38,722,255.0 with an average medium age of 18.4 years), ranked number 37 in the list of the world countries by population with a density of 60 per Km2 (25.4% urban residence) [5]. Afghanistan located between latitudes 29° N and 39° N and longitudes 60° E and 75° E that bestows plenty of solar and wind energy production potentials [6].

Reports indicate that only 30% of citizens of Afghanistan have access to electricity, and 80% of national electricity demands imports from neighboring countries [7]. While the rate of reliable electricity access is only between 10-15%, Afghanistan is listed among the lowest access countries in the world [8]. In 2013, consumption per capita was 178 kWh, and expected to increase national electricity demands from 3,531 GW (2011) to 18,409 GW (2032) [9]. Natural resources remain the primary source for approximately 85% of the population. Afghanistan like other developing countries, in addition to a low rate of modern energy accessibility challenge, has tried to overcome heavy reliance on import, deforestation and health issues due to excessive use of firewood and fossil fuel and etc. as a primary energy source and pollutant of air and environment [10]. Research has suggested that accessing and deployment of Afghanistan's renewable energy resources can meet the projected domestic energy needs.

To meet domestic demand, Afghanistan imports a tremendous amount of electricity from neighboring countries: Tajikistan (350 MW), Uzbekistan (320 MW),

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Turkmenistan (50 MW), and Iran (108 MW) [11]. Domestic sources come from hydro (263.4 MW), diesel-generator (93.3 MW), and thermal (247.9 MW) power plants [12]. Although it was planned to expand the electricity access rate to 100% in urban and 65% in rural by 2032, it remains a plan [13]. According to the Ministry of Rural Rehabilitation and Development of Afghanistan, at the present only 30% of Afghan communities have access to electricity, skewed more towards residents in urban rather than rural areas. Accessibility shares, 30% households use the national grid while 9% use solar power [14]. The rest (61%) are non-electrified or powered independently from other sources.

Decentralized renewable energy sources remain the best option to address the problems of increasing electricity demand and establishing a healthier environment especially in rural areas. Distributed Generation (DG), also called dispersed or embedded generation due to its flexibility, controllability, and dispatchability merits, has been widely attracted for reactive power compensation, renewable to grid integration, load control, and overall system stability and reliability improvement tool [15,16]. In addition, distributed generation can contribute a system instability and act as a preventive tool for voltage collapse by reactive power compensation, network loadability adjustment, and network re-configuration [17].

2. Afghanistan from the SDGs perspective

Balancing of essential dimensions (security of supply, climate and environmental impact, competitiveness) of energy resources in terms of primary sources (extracted or captured directly, i.e. fossil fuels: coal, crude oil, natural gas, nuclear fuel) and secondary sources (produced or converted from the primary energy sources) are known exigence [18]. Renewable energy resources and technologies deployment along with improvement of technical, and economic efficiencies can lead the Afghanistan energy sector towards self-sufficiency. That requires viable strategies and policies aligned with today's technologies [19].

Despite holding a high potential for renewable energy sources, Afghanistan has been addressing its energy needs by importing electricity from neighboring countries. In this paper we analyze the benefits of using these renewable energy sources for self-sustainable development. This analysis identifies available domestic renewable energy sources and the existing barriers restricting their development and deployment using surveys conducted by the World Bank and with personal interviews. The aim of this study evaluates Afghanistan's renewable energy potential for sustainable development and examines challenges for transition.

In 2015, the United Nations (UN) defined 17 goals and 169 targets with the vision of poverty reduction, planet protection, and global peace, for sustainable development of the world. These goals and targets are intended to improve the quality of life for the global population and not harm future generations [20]. SDG-7 ensures access to affordable, reliable, sustainable, and modern energy for all that focuses on three main areas: renewable energy, efficiency, and access that is identifying five targets [21]:

1- Universal access to clean and affordable energy services.
2- Increase the contribution of renewable energy to the global energy mix.
3- Double the global rate of improvement in energy efficiency.
4- Enhance international cooperation and investment in renewable energy technologies and growth.
5- Expand infrastructure and upgrade technology for supplying modern and sustainable energy services to all communities in emerging nations.

Because energy demand increases as population rises, energy production from non-renewable sources contributes to climate change and environmental damage. Investment in renewable energy sources – such as hydro, solar, biomass, wind, and thermal – can fulfill the demand through universal access to cheap and affordable electricity. To meet this goal by 2030, global residential and industrial electricity consumption needs to be reduced by 14% and cost-effective adoption of technology can help manage the demand. By encouraging developing countries to enhance their infrastructure and upgrade technologies to offer clean energy, they offer opportunities for environmental, socioeconomic, and political improvements. Moreover, investment in renewable energy is expected to create employment opportunities from 10.3 million in 2017 to 24 million in 2030 [22].

Afghanistan's strategy to address sustainable development goals occurs in three phases: nationalization, alignment, and implementation. Responsible for developing plans that meet the vision of the SDGs, the government coordinates the establishment of institutional processes for national planning, including security, education, health, social protection, infrastructure, agriculture, governance, and economy. The nationalization phase sets targets and defines metrics to monitor progress [23]. After goals are approved, alignment establishes tools, guidelines, and milestones to achieve the desired national targets. Approval of nationalized indicators and targets the phase of alignment is starting to state national strategies, policies and plans achieving the national targets and indicators [23]. The implementation process started in 2018 with progress reports occurring every three years until 2030.

Socioeconomic changes further underscore the urgency of these changes. Poverty increased in Kabul from 36% (2011-2012) to 39% (2013-2014) [24]. Improvements in maternal health metrics are beginning to slow down. Poor children are more likely to drop out of school [25]. If the Afghan government wants to make SDG-7 a priority,

commitment and investment to provide reliable, sustainable clean energy must be made in creating an efficient energy generation, delivery, and distribution infrastructure.

3. Renewable source assets in Afghanistan

Hydro, solar, and wind power are excellent renewable energy options for Afghanistan. Geothermal energy also holds potential value but has not been analyzed as completely. Biomass sources from agricultural waste are widely used for cooking and heating but can also serve as a source to generate renewable energy. In the following sections, each renewable energy source is discussed in detail.

3.1. Hydropower

Hydroelectric power is the most widely used source of renewable energy, contributing over 1000 GW (16%) of the world's net overall energy production [26]. China is the world's largest generator of hydroelectric power. In 1893, the first power generation was operated in Kabul; and the first commercialized hydropower plant (Jabal Seraj) constructed in 1916 on the Salange Revier at an altitude of 1600 m above the sea level; and has been operating since 1922 [27].

Hydropower from mountain sources is estimated to generate more than 23 GW of power [4]. Most of this energy (approximately 20 GW) can come from the north-eastern ranges (Amu Darya, Panj, and Kokcha). Mountains from the east of Kabul can provide 19 GW while Balkh and Jowzan regions in the north-west can provide 800 MW. Remaining hydropower supply (about 500 MW) can come from west-central part of Afghanistan.

Up until now, the full capability of hydroelectric energy has not been utilized. Total usage in March 2016 was 256 MW. The completion of the Salma dam renovation in mid-2016 provided 42 MW of additional power (total power 330 MW).

Table 1: Table 1: Some of hydro power plants in Afghanistan [28].

No.	Power Station	Capacity after Rehabilitation (MW)	System
1	Naghlu	100	Kabul
2	Salma	42	Herat
3	Sarobi	22	Kabul
4	Mahipar	66	Kabul
5	Durunta	11.5	Kabul
6	Assassab	0.7	Kunar
7	Charikar	2.4	Gorband
8	Jabul Seraj	2.5	Salang
9	Ghorban	0.3	Gorband
10	Kajaki	33	Helmand
11	Grishk	2.4	Helmand
12	Pul-e-Chomri	5.12	Pulikhumri
13	Pul-e-Chomri 2	8.79	Pulikhumri

Table 2: Afghanistan hydropower estimated capacity based on river region [29] .

No	Hydro System/Region	Capacity (MW)
1	Kabul	1,941
2	Panj-e-Amu	20,137
3	Shamali	760
4	Harirod	202
5	Pul-e-Chomri 2	8.79
	Total	23,310

Additional smaller hydropower plants are mostly located in rural areas which specifically generate electricity for community lighting purposes. The total hydro power available by system/region is listed:

Deliberate investment in hydropower will help realize the benefits of sustainable energy. With abundant hydropower, poverty could be mitigated or eliminated by creating employment opportunities, attracting tourists, increasing economic activity, and building effective governmental infrastructure. By constructing dams, the ground water supply could be replenished and greenhouse gas emissions reduced. Increasing hydropower capacity also supports increased biodiversity and better quality of life.

3.2. Wind energy

Wind energy provides 539.123 GW globally and is the second largest renewable energy resource with an annual growth of 12.6% [30]. China is the leading global producer of wind energy. Afghanistan has great potential as a producer of wind energy. It is estimated that with wind speeds exceeding 6.8 m/s, 150 GW can be produced, and the total amount of usable energy is 67 GW [31].

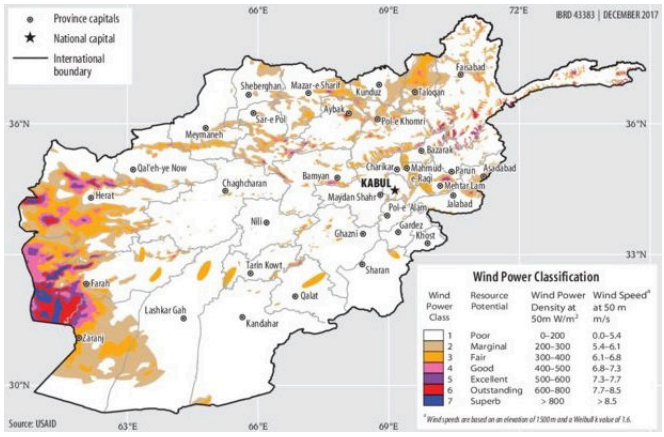

Figure 1. Afghanistan wind resources potential [32].

The table below provides the overall wind area, wind energy potential and capacity of wind energy in Afghanistan.

Table 3: Afghanistan wind resource per province [33].

No.	Province	Wind Area (km2)	Estimated Potential (MW) (wind class 6.8->8.5)	Feasile Capacity
1	Badakhshan	1,428	3,314	331
2	Badghis	410	762	191
3	Baghlan	1,064	2,083	208
4	Balkh	1,698	3,145	766
5	Bamyan	100	240	24
6	Daikondi	-	-	-
7	Farah	19,270	61,353	30,677
8	Faryab	560	1008	552
9	Ghazni	93	191	48
10	Ghur	160	336	84
11	Helmand	1,040	1,872	936
12	Herat	14,694	36,947	18,473
13	Jozjan	95	171	43
14	Kabul	230	414	41
15	Kandahar	130	234	117
16	Kapisa	450	810	81
17	Khost	-	-	-
18	Kondoz	180	324	81
19	Kunr	40	72	7
20	Laghman	460	1,020	255
21	Logar	-	-	-
22	Nangrhar	300	582	146
23	Nemroz	10,130	21,450	10,725
24	Noristan	90	-	-
25	Paktia	-	-	-
26	Paktika	220	396	99
27	Panjshir	80	180	18
28	Parwan	705	1,269	127
29	Samangan	503	1,064	266
30	Sar-e-pol	385	729	182
31	Takhar	2,547	4,795	1,199
32	Uruzgan	650	990	495
33	Wardak	80	180	18
34	Zabul	860	1,632	816
	Total	58,543	147,563	66,726

Approximately 90% of the wind capacity is located in three western provinces Herat, Farah and Nimroz. However, there is no national electrical delivery network that connects these provinces to other parts of the country. It is imperative that these provinces will be connected to the national grid.

3.3. Solar energy

Producing and delivery of solar energy require different technologies to interface with conventional existing energy grids. By 2017, global solar energy production was 405 GW while concentrated solar-thermal energy production was 5.1 GW, with China, Germany, Italy, and the U.S. as the largest producers [34].

Afghanistan can also potentially produce 220,000 MW of solar power with 300 sunny days each year and can generate 6.5 kWh/m^2 [31]. The southern and western parts of Afghanistan receives even more direct sunlight and can potentially generate 1022 KW/m2/year or more with the installation of concentrating solar power (CSP) [35].

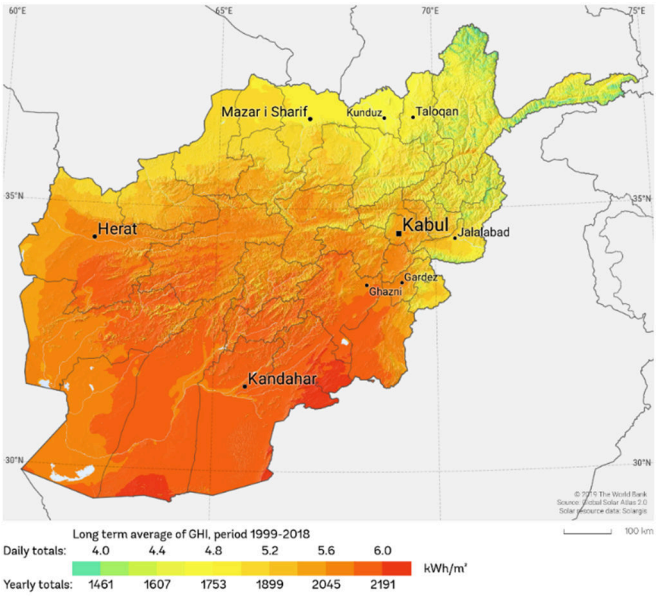

Figure 2. Afghanistan global horizontal irradiation [36].

The Afghanistan government along with other entities have been promoting development of solar energy integration with the existing electrical grid to help with rural electrification. Table 4 shows the solar potential energy capacity by province.

Table 4: Afghanistan solar resource per province [33].

`No.	Province	Estimated Capacity (MW)
1	Kabul	432
2	Kapisa	183
3	Parwan	548
4	Wardak	1,043
5	Logar	451
6	Ghazni	5,802
7	Paktia	5,042
8	Khost	364
9	Nangarhar	1,687
10	Kunar	447
11	Laghman	842
12	Nooristan	888
13	Badakhshan	3,736
14	Bamyan	1,863
15	Takhar	2,543
16	Baghlan	1,536
17	Kundoz	1,279
18	Samanagan	2,912
19	Balkh	2,900
20	Jozjan	2,230
21	Sar-e-pol	4,131
22	Faryab	4,679

23	Badghis	5,328
24	Herat	28,539
25	Farah	27,137
26	Ghur	10,539
27	Helmand	33,282
28	Nemroz	22,618
29	Kandahar	31,079
30	Zabul	9,464
21	Uruzgan	6,530
32	Daikondi	1,911
33	Panjshir	510
34	Paktika	374
	Total	222,849

3.4. Geothermal

Geothermal energy production relies on steam and hot water from active geothermal areas of the earth and can be used to heat houses or generate electricity. Additional research is needed to assess Afghanistan's geothermal energy potential. Geologically, Afghanistan lies on three tectonic plates whose motion and collision result in hot springs, hydrothermal minerals, volcanoes, and magma rocks. Consequently, the greatest opportunity to tap into geothermal energy may lie in the southern, eastern, and western parts of the country [37].

3.5. Biomass

A majority of Afghans work in agriculture and ranching, so biomass sources are plentiful and meet roughly 85% of their energy demand. Afghanistan's potential to produce clean energy from biomass is around 4GW. The Ministry of Energy and Water itemizes each province's potential for biomass clean energy production.

Table 5: Afghanistan biomass resources per province [33].

No.	Province	Biomass Capacity (MWh/year)		
		Municipal Solid Waste	Animal Dang	Agriculture Waste
1	Kabul	126,884	69,089	465,372
2	Kapisa	13,848	171,438	442,103
3	Parwan	20,287	16,028	565,369
4	Wardak	18,231	84,917	529,715
5	Logar	11,984	72,713	842,423
6	Ghazni	37,542	227,860	1,343,574
7	Paktia	13,291	144,569	475,755
8	Khost	17,563	367,769	376,509
9	Nangarhar	46,124	626,687	1,749,774
10	Kunar	13,773	313,913	449,026
11	Laghman	13,622	269,201	654,148
12	Nooristan	4,526	156,503	93,491
13	Badakhshan	29,029	452,658	598,604
14	Bamyan	13,667	143,149	286,562
15	Takhar	29,990	269,732	1,524,344
16	Baghlan	27,742	296,943	1,442,236
17	Kundoz	30,636	388,437	1,863,114
18	Samanagan	11,846	53,134	416,541
19	Balkh	39,993	196,478	1,731,926
20	Jozjan	16,449	75,809	906,725
21	Sar-e-pol	17,086	124,985	616,743
22	Faryab	30,450	182,730	1,350,830
23	Badghis	15,157	148,016	577,837
24	Herat	28,250	382,275	2,013,776
25	Farah	15,495	162,717	375,425
26	Ghur	21,109	232,387	406,450
27	Helmand	57,174	424,513	1,732,510
28	Nemroz	5,030	47,449	299,114
29	Kandahar	36,973	406,866	1,111,055
30	Zabul	9,292	70,405	261,469
21	Uruzgan	10,712	159,410	584,592
32	Daikondi	14,085	209,599	194,405
33	Panjshir	16,863	237,601	616,076
34	Paktika	4,693	37,076	185,815
	Total	819,396	7,367,282	27,083,408

With energy capacities from hydro (23 GW), wind (67 GW), solar (220 GW), and biomass (4 GW), Afghanistan can export energy to other southeast Asian nations and fulfill its own energy needs. Here are some of the challenges in developing renewable energy in Afghanistan.

4. Barriers for renewable energy development

4.1. Security and political barriers

Political instability undermines any data collecting efforts needed for proper planning. It is difficult to access reliable information about the Afghanistan energy sector due to lack of cooperation culture and modern data storing and sharing facilities. Alternatively, most of the available information is sketchy, anecdotal, piecemeal, and often conflicting [10]. Also, post-conflicts, provincial warlords, insurgent groups, and the weak central government challenges any diplomatic relationships that could help address the nation's energy demands.

4.2. Technical barriers and shortage of field professionals

While a national electric grid exists, it does not cover all parts of the country. Most southern and central areas of the country do not have access to the grid. Other sections of the grid have limited capacities, making meeting voltage and frequency mismatches challenging to integrate new renewable resources. However, there is no update and inclusive information about energy sector technical and financial losses, the power networks losses reported near to 40% with an average annual loss of 2 million (USD) [38]. The lack of a central data monitoring system to measure national demand prevents any investment in sustainable energy projects. Afghanistan also lacks technical experts and energy workers experienced in clean energy. The country still suffers from high unemployment while foreign-born workers are involved in large energy projects across the country.

4.3. Economic barrier

Though there are improvements in life expectancy, literacy, and per capita income since 2001, the country suffers from poverty and is dependent on foreign aid. Most citizens lack access to electricity, clean water, health care, and jobs. Political instability, corruption, and subjective legal enforcement hinders future economic growth and does not promote a commitment to invest in the high initial costs for addressing these issues. Investments are made in dollars as tax revenue is collected in the more unstable Afghani. The Afghanistan Land Authority oversees land development only has 30% of urban and 10% of rural property registered [39]. Furthermore, the domestic banking and investment infrastructure remains focused in the big cities. Investment in renewable energy projects carries the financial risk that few investors are eager to accept. Microfinancing processes also prevent investment in small projects.

4.4. Legal and regulatory framework

Policies and regulations for rural electrification, renewable energy, and developing agreements for international power purchasing have been developed, but the World Bank reports there lacks a realistic process or timeline for implementation. The Renewable Energy Policy encourages DABS but does not mandate a purchasing scheme. Private-sector development is encouraged to support building and expansion of mini-grids and off-grid projects, but a central strategic plan is still needed.

4.5. Poor community awareness

Educating the public on the benefits of renewable energy – such as its potential socioeconomic impact – is ineffective in developing counties, including Afghanistan.

5. Conclusions and recommendations

Afghanistan can benefit from its high renewable energy resources of hydro, solar, wind, geothermal, and biomass to make progress towards the Sustainable Development Goals and SDG-7. To maximize these assets, Afghanistan must overcome significant barriers as identified in this research. The following are suggestions.

- *Build training and employment opportunities:* Investing in education and training should build a domestic community of technical professionals who can build and manage the integration of renewable energy sources, develop new technologies, and upgrade the existing power supply network. The current number of vocational training facilities needs to be increased and improved.
- *Provide risk insurance for renewable energy projects:* The government should provide risk insurance to promote renewable energy projects throughout the country. This should motivate banks, investors, and microcreditors to engage the public's interest in construction of these infrastructural improvements towards sustainable energy goals.
- *Improve existing policies and enforce regulations*: Making a fitting decision for deployment cost-effective renewable energy technologies, which requires viable polices and a profound technical, managerial, and interdisciplinary knowledge and expertise to lead Afghanistan toward self-sufficiency. This objective can be achieved by conducting exhaustive research to provide a market-based energy development framework and involves innovative measures, tools, and techniques in terms of a strategic planning and policy development [40].
- *Offer incentives favoring renewable energy:* However, renewable energy technologies' deployment cost is steadily decreased (i.e., the average price of solar panels dropped about 60% since 2011 [18]), still high initial investment is a challenge. Because the overall cost of energy from renewable sources is higher than current non-renewable sources, market incentives should be offered to encourage switching to renewable energy. Therefore, well-management of payback, cash flow, tax-in-tariffs and other financial initiatives to encourage public and private sectors for an active engagement are necessary.
- *Increase public awareness:* Educating the importance of sustainable energy should encourage the public increase its awareness and use within the energy grid. Lack of stakeholders and beneficiaries of energy projects' awareness from potential benefits of the investment lifecycle in the long-term is reported [41]. This problem along with many others linked with improper decision-making and inadequate policy development. In which, missing decision-making standard process and procedure (on time, and budget and risks), external and internal factors' evaluation (economic, political, behavioral, and cultural), interest to control wholesale markets, etc. leads to instant responses instead of sustainable solutions [42]. Using Information and Communications Technology (ICT) for public awareness, information broadcasting, and more importantly for local engagement is recommended [43].
- At last, renewable energy resources in Afghanistan estimates 330 GW, sufficient to meet it domestic energy demand. However, deployment and integration of these resources are challenging and requires political commitment, academic and technical studies, and a strong economy.

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