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The Future Role of Renewables in Turkey's Electricity Supply Security

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ABSTRACT

As a fast-developing economy, Turkey's energy needs have also been growing rapidly for several decades. Its indigenous resources have been evaluated as insufficient to meet this rapidly increasing demand for energy, especially power. Therefore, it imports around half of its energy needs for power. Recently, it has newly started tapping into renewable sources, especially wind and solar. Considering these developments and official aims, this paper attempts to answer the question of which role this renewable developments can play in providing electricity supply security, which is a critical part of energy security. Whereas it seems clear that Renewables will certainly grow, whether this growth makes a significant difference from a reliability perspective is questionable. In other words, due to the problem of the intermittency, the requirement to provide backup power from thermal capacity seems obvious under today's technological conditions. Therefore, the official policy needs urgently to consider and encourage investments in technological solutions (especially energy storage).

Keywords: Renewable Energy, Energy Security, Reliable Power Supply
JEL Classifications: Q21, K32

1. INTRODUCTION

It is indisputable today that energy is a key issue and a vital resource for socio-economic development of all societies. Energy security is therefore a key priority for all countries. Its eminence has been visible in the economic and political agendas of national policies as well as international relations. As a concept, energy security is a complex and debatable issue with multiple dimensions.

The International Energy Agency (IEA) defined energy security as "the uninterrupted availability of energy sources at an affordable price" (IEA, 2016a). In their recent and rigorous literature review on the conceptualization of energy security, Biresselioğlu et al. (2017) point out that it currently includes the utilization of a variety of different sources (diversification), freedom from depending on a certain geographic region, self-sufficiency in energy, and ensuring the protection from external shocks. The European Commission (2000) defined energy security as the "uninterrupted physical availability of energy products on the market, at a price which is affordable for all consumers." In another brief definition, Cherp and Jewell (2014) proposed energy security as "low vulnerability of vital energy systems." Definitions may vary, but one of the key components of energy security is diversification (Yergin, 2006); the other is independence, which is basically understood as self-sufficiency (Yergin, 2011).

One crucial element in this context is supply security of electricity on which we will present a literature survey in the first section with an emphasis on intermittency problem. As a backbone of modern economies, electrical energy is produced and delivered practically in real time, and there is no convenient method to readily store it. This makes it necessary to maintain a continuous and almost instantaneous balance between production and consumption of electricity in power systems (Prada, 1999). It is therefore critical that adequate power capacity needs to be provided in a reliable way. What becomes interesting at this point is the problem of intermittency, which is currently a salient feature of Renewable Energy Resources (RES).

It is clear on the one hand, that RES rapidly increases (due to cost reductions and decarbonization policies) its share in the global energy mix (about 10%). By the end of 2015, 173 countries had set renewable energy targets (REN21, 2016), by implementing different incentive mechanisms. Feed-in Tariffs (FITs), for example, are in place in 75 countries (REN21, 2015). The EU has adopted a target of 27% share of RES in total energy consumption by 2030. Twelve out of 28 EU member states had already surpassed their 2020 targets by 2014 (Eurostat, 2016). It is also well established that through providing generation capacity with local resources, RES is expected to make a contribution to energy security (Ölz et al., 2007; IRENA, 2015a; IRENA, 2015b; Gözen, 2014; Paltsev, 2016; Larson, 2007; Sholten and Bosman, 2016; Ataseven and Baloğlu, 2015).

On the other hand, it is widely recognized that integrating growing RES portion to grid is a real challenge challenge (Caldwell, 2013; Robinson, 2013; Vital, 2016; Verzijbergh et al., 2017). While small penetrations of RES can be smoothly integrated, especially at levels of 20-30%, managing RES becomes challenging (Allen et al., 2013). It is therefore necessary to examine the issue as it affects the reliability (and security) of power supply.

As growing RES investments in Turkey certainly increase diversification and power generation capacity, the challenge of overcoming the intermittency (variability and unpredictability of RES) needs to be analyzed. Thus the following section sets out to present an overview of the literature review on electricity supply security and intermittency problem. In the third section of this paper, after outlining Turkish power generation profile, we will analyse official policy (including RES) targets and identify the need of backup power and finally point out some policy recommendations to deal with intermittency problem for a reliable power supply, present a detailed illustrative analysis of current and forecasted (target) power generation mix of Turkey with its larger and specific implications (arising from the intermittency problem) on power reliability.

2. ELECTRICITY SUPPLY SECURITY

2.1. Concept and Practice

Security of energy supply can be examined in two dimensions: External and internal. External dimensions are comprised of geopolitics (access to primary sources), safety and adequacy of infrastructures and resilience to changes in climate policy. Internal dimensions include adequacy of power generation capacity, regulation and operational reliability (OECD/Nuclear Energy Agency, 2010). Thus, one key component within the energy security concept is Electricity Supply Security; which is basically adequacy and reliability of power generation. According to Eurelectric (2006), security of electricity supply is the ability of the electrical power system to provide electricity to end-users with a specified level of continuity and quality in a sustainable manner, per existing standards and contracts at the points of delivery (Eurelectric, 2006). The concept of security of electric power supply can be subdivided depending on the time frame as follows (KU Leuven Energy Institute, 2013):

- Short-term: Operational security (also referred to as "operational reliability") is the ability of the system to withstand sudden disturbances.
- Long-term: Adequacy is the ability of the system to supply the aggregate electrical demand of customers at all times, taking into account scheduled and reasonably expected unscheduled outages. Long-term adequacy should include generation adequacy as well as network adequacy.

In other studies, the concepts of electricity supply security and power system reliability have been used interchangeably (Heard et al., 2017; Cepin, 2011; Seymour and Horsley, 2005). The assessment of reliability considers diversity and volume of resources available to support power system adequacy (IEA, 2013; IEA, 2016b; Kocaslan, 2014). Reliable power supply therefore depends on providing sufficient and adequate capacity to the consumer. Besides, "for reliability of supply, not only do possible supply disruptions have to be bridged, but varying demand also has to be met" (OECD/IEA, 2004). For the system to be reliable, constant (i.e., available at all times) and/or fully dispatchable generation (able to be called-up or withdrawn at any time in response to demand changes) is deemed essential.

2.2. RES and the Problem of Intermittency

As the fast forward move towards RES is increasingly a global trend, there are assertions (EXAS, 2013; AWEA, 2013) that RES are able to meet all or nearly all of the power needs of future electricity systems. To analyze this issue, we need to consider some basic facts. First of all, it has been well established that a diverse mix of electricity is needed in order to ensure grid stability and reduce the overall risks of volatility. Secondly, integrating RES (especially wind and solar) into the power mix is not easy because RES, unlike baseload conventional, varies over time and as per weather conditions: Sources of electricity that exhibit uncontrolled increases and decreases in output are referred to as intermittent (The Parliamentary Office of Science and Technology, 2014). Baseload power is the minimum amount of power that is required to meet minimum demand based on reasonable expectations of customer requirements (Matek and Gawell, 2015).

Under current technological conditions, the intermittent nature of RES, makes it necessary to backup any new installation of RES with "reliable power." This is dubbed as amounting to a "shadow" system of conventional generation to backup intermittent RES (Jenkins and Thernstrom, 2017). Fast growth of RES has increased paradoxically the need for more installed capacity of thermal power (Flora, 2012; The Economist, 2017; APS Panels on Public Affairs, 2011). One side-effect of this is the overcapacity and idleness (too much reserve) as outlined by Robinson (2013) for Spanish case; Flora (2012) for EU-wide examples; and Martin (2016) and Sturm (2016) for German example. RES could provide more than half of the power demand in Germany. However, the variability of RES forces coal plants to keep running or to be ready to backup anytime. This has even caused an increase in emissions. The technological impact of fast RES integration had obviously not been fully anticipated. Therefore, huge investment might be needed for future safe connection of RES (Verzijbergh et al., 2016; Gerbert et al., 2014). Gillespie et al. (2015) point out that variation in wind and solar generation and electricity demand in the United Kingdom can lead to persistent power supply deficits lasting two to three weeks in a 100% renewable power system.

Examining Brazil (which is heavily dependent on hydro), Silva et al. (2016) clearly demonstrate the need of thermal backup for the system reliability.

It is clear from the foregoing that intermittency is currently a problem and in the absence of other to-be-developed technological solutions, provision of backup capacity is the essential part of any policy that gives renewables a large role (The Economist, 2015). The economics of the intermittency has also caught the attention of researchers. Studies have shown that dealing with intermittency problems increases the socio-economic cost of power supply (Ambec and Crampes, 2015; Gowrisonkaran, et al., 2016; Dailey, 2017; The Economist, 2017; Ueckerdt et al., 2013; Nikolakakis and Fthenakis, 2011; Hadelsblatt, 2015 and Fischer at al., 2016).

3. TURKEY'S ENERGY PROFILE AND POWER GENERATION

As of the end of 2015, the total primary energy supply of Turkey was 129.7 Mtoe: Natural gas (30.2%), oil (30.1%), coal (27.3%), hydropower (4.4%), and renewables (7.7%) (Figure 1). Turkey's energy mix is dominated by fossil fuels which represent 87.6% of total primary energy supply.

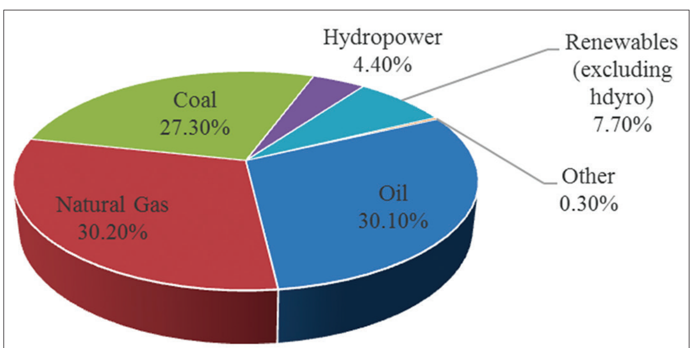
The dependence ratio is 75% of the total energy consumption. That is 99.2% of natural gas and 93.9% of crude oil consumption is met with imports (BP, 2016; EMRA, 2016). Turkey paid about \$38 billion in 2015 for energy imports, constituting about 18% of total imports (Turkish Statistical Institute, 2016).

On the other hand, Turkey has significant potential in terms of renewable energy. It is ranked 14th in the world with its geothermal energy capacity, 29th with its solar energy capacity and 16th with its wind energy capacity. For the wind, for example, the potential is estimated to be around 48 GW with a technically feasible capacity of 20-24 GW (Peker, 2015).

3.1. RES Developments and Targets in Turkey

In Turkey, the Law on the Utilization of RES first came into force in 2005 (Law No. 5346). Initially, "investment in RES remained limited between 2005 and 2010 due to the lack of secondary legislation and relatively low FITs levels" (MENR, 2014). Later

Figure 1: Turkey's total primary energy supply (2015)



Source: Data aggregated from the IEA, Energy Policies of IEA Countries: Turkey (2016) (IEA, 2016c)

in 2010, with an amendment, a revised incentive mechanism with higher FITs rates was introduced, to the effect that it increased RES investments significantly.

In terms of installed capacity, Turkey has reached more than 73 GW (34 GW of it RES). In 2015, out of the 259 TWh of generated electricity, 67% is produced from fossil fuels, mainly natural gas (37%) and coal (28%). RES, with an upward trend since 2005, contributed about 32% (around 75% of that being hydro).

The Electricity Energy Market and Security of Supply Strategy Paper (2009) and Renewable Energy Action Plan "REAC" set targets for 2023 (DPT, 2009; Turkish Ministry of Energy and Natural Resources, 2015): Half of electricity generation capacity will come from RES (61 GW): 34 GW for hydro, 20 GW for wind, 5 GW for solar (PV and CSP) and 1 GW each for biomass and geothermal. Considering current installed wind capacity of around 5 GW and solar capacity of around 660 MW, this will require a four-fold increase in wind capacity and almost eight-fold increase in solar capacity by 2023.

In the context of climate change and the Paris Agreement Negotiations (COP 21), Turkey also has introduced its 2030 targets in the intended nationally determined contribution (Turkish Ministry of Environment and Urbanization, 2015): Solar 10 GW, Wind 16 GW and all hydro potential. There seems to be some contradiction between earlier announced targets in REAC and more recent INDC. To avoid any inconsistency, we will take REAC targets as the official targets for the basis of our analysis.

It is well established above that as a domestic natural resource, RES can make contribution to energy security. BNEF (2014) and Hill (2014) even proclaimed that RES could supply Turkey with full energy independence, on the other hand, for provision of reliable power supply, as outlined in the proceeding section, the question of overcoming intermittency needs to be addressed. Now, we turn to our analysis of current power generation pattern in Turkey to understand the problem of intermittency and its implications in the Turkish context.

3.2. Analysis of the Current Power Generation Status

To understand the current power structure and generation behavior, one needs to look at the relation of installed generation capacity of RES to its realized generation profile. In 2016, 33% of the total electricity was generated from RES, while the share of RES in total installed capacity was 43% (Table 1). This is related to the fact that most RES is not "baseload or available power." As illustrated in Table 2, based on realized operating hours, the capacity factor of RES is (on average) around half that of thermal power in Turkey. Wind power for example is calculated as 30%.

In other words, not all MWs are equal. That is, on average (under today's conditions) to replace or substitute 1 MW of conventional thermal capacity, around 1.8 MW RES is necessary in terms of generation potential. Additionally, there is the issue of fluctuation of RES. Figure 2 illustrates this situation on a monthly basis.

RES contributed highest as a share in the mix (by 51%, when the load was relatively low) in a single hour of only a single day,

Table 1: Capacity and generation projection for RES (2016-2023)

Sources	Capacity projection GW			Generation projection GWh		
	2016	2023 REAC scenario	Increase %	2016	2023 REAC scenario	Increase %
Hydro - Dam	19.40	24.82	28	48,896	67,014	37
Hydro - run of river	7.10	9.18	29	18,183	24,786	36
Wind	5.40	20.00	270	15,377	50,000	225
Solar (incl. unlicensed capacity)	0.86	5.00	479	1,145	8,000	599
Geothermal	0.80	1.20	50	4,214	5,914	40
Biomass	0.46	0.80	74	2,030	3,730	84
Total of RES	34.02	61.00	79	89,845	159,444	77
Total of conventionals	44.64	64.00	43	179,928	264556	47
Total of All Capacity	78.66	125.00	59	269,773	424,000	57
Share of RES	43%	49%	6	33%	38%	4

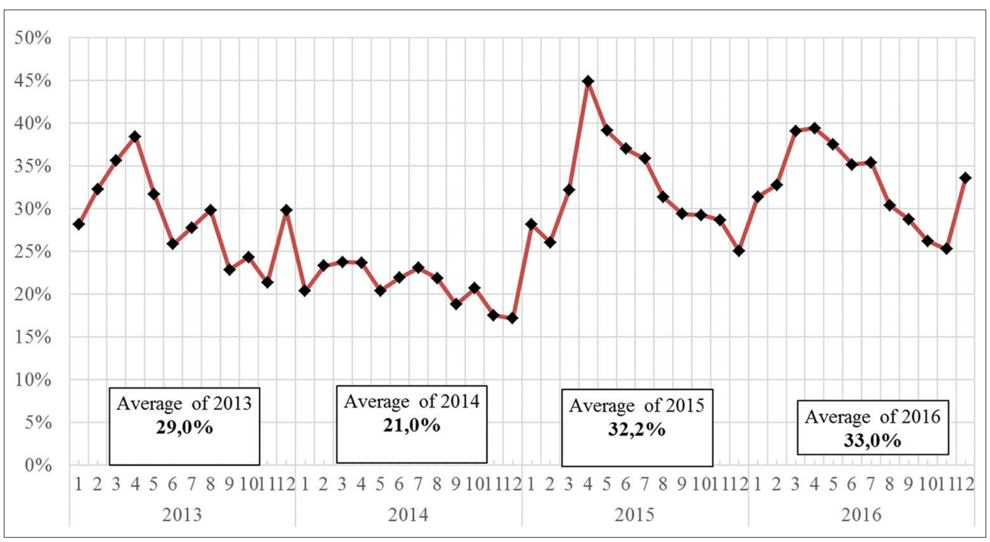
Source: The table is prepared based on data sources in the National Renewable Energy Action Plan – "REAC" (Ministry of Energy and Natural Sources, 2014) and EPİAŞ (2017). RES: Renewable Energy Resources

Table 2: Installed capacity, generation and capacity usage factor

Sources	2016		Capacity usage factor (%)	Annual average operating hours
	Installed Capacity (MW)	Generated Amount (GWh)		
Hydro	26,508	67,274	26.3	2,303
Wind	5,374	15,360	30.0	2,631
Solar	888	1,413	15.8	1,381
Geothermal	814	4,474	63.6	5,568
Biomass	464	2,179	54.6	4,785
Total RES	34,048	90,700	27.8	2,433
Total thermal	44,616	182,688	50.0	4,381
General total	78,664	273,388	40.6	3,556

Source: Table is prepared based on data derived from EPİAŞ (2017) and National Load Dispatch Center Information System (YTBS, 2017). RES: Renewable Energy Resources

Figure 2: Share of Renewable Energy Resources generation on monthly basis over the years



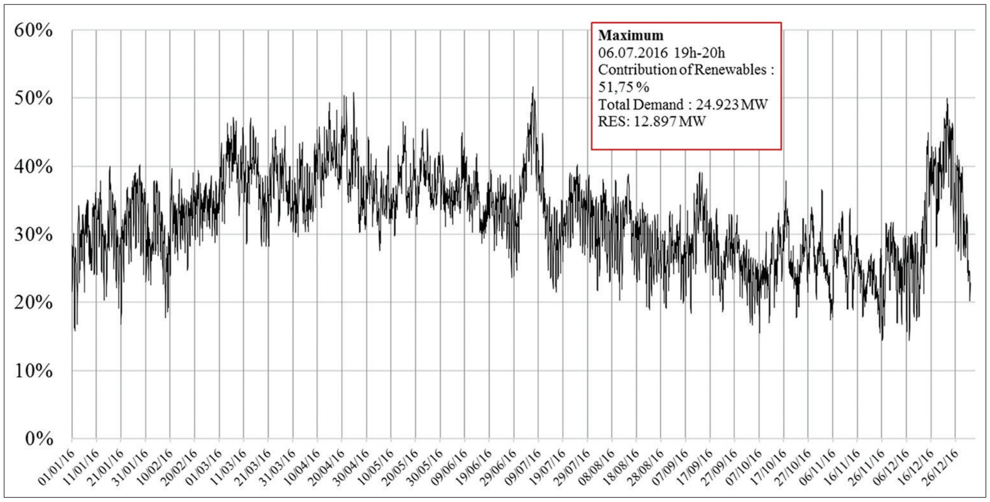
Source: EPİAŞ (2017)

06.07.2016 (Figure 3). It is observed (Figure 4) that, over time, RES (on an hourly basis) has swung from 3,706 MW to 20,845 MW (averaging around 10,200 MW), depending on the total power demand, which is swinging between 22 T MW and 44 T MW (averaging around 30 T MW).

It is understood from the above analysis that although in total on an annual basis, RES has a contribution share of 33% in generated power, momentarily however, this power has not been reliable. In other words, the share of contribution has ranged (even in very short time periods) from 9% to 51%.

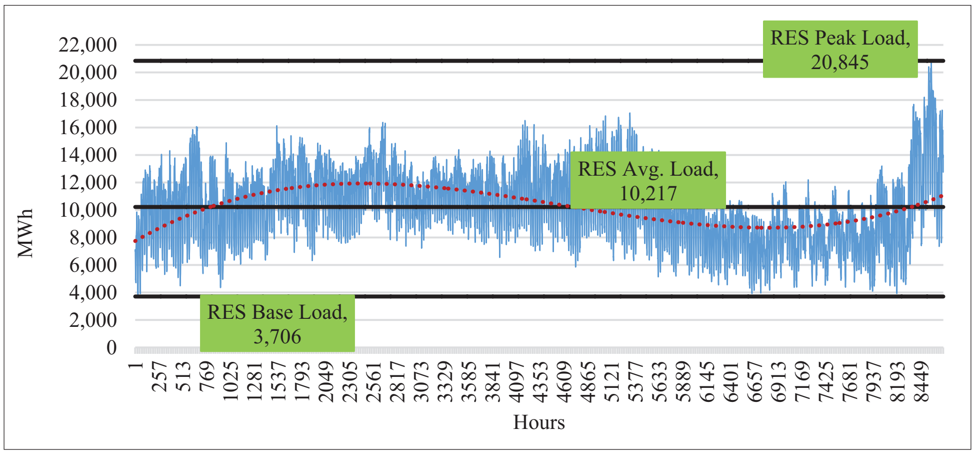
As established in the preceding section, with a sizeable RES installed system and for reliable power supply, the system needs additional backup capacity to make up for the times when power is lacking due to fluctuating generation from RES. In our analysis for 2016, as shown in Figure 5, that need was realized as 17 T MW

Figure 3: Maximum contribution of RES generation to power demand (as share %) on an hourly basis for 2016



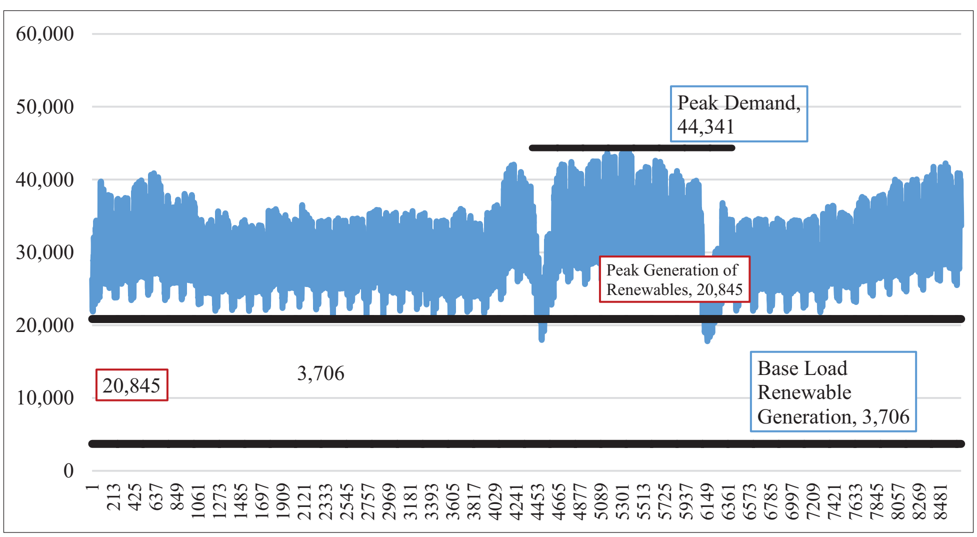
Source: EPİAŞ (2017)

Figure 4: Generation profile of (only) Renewable Energy Resources in 2016



Source: The figure is prepared based on data collected from EPİAŞ (2017)

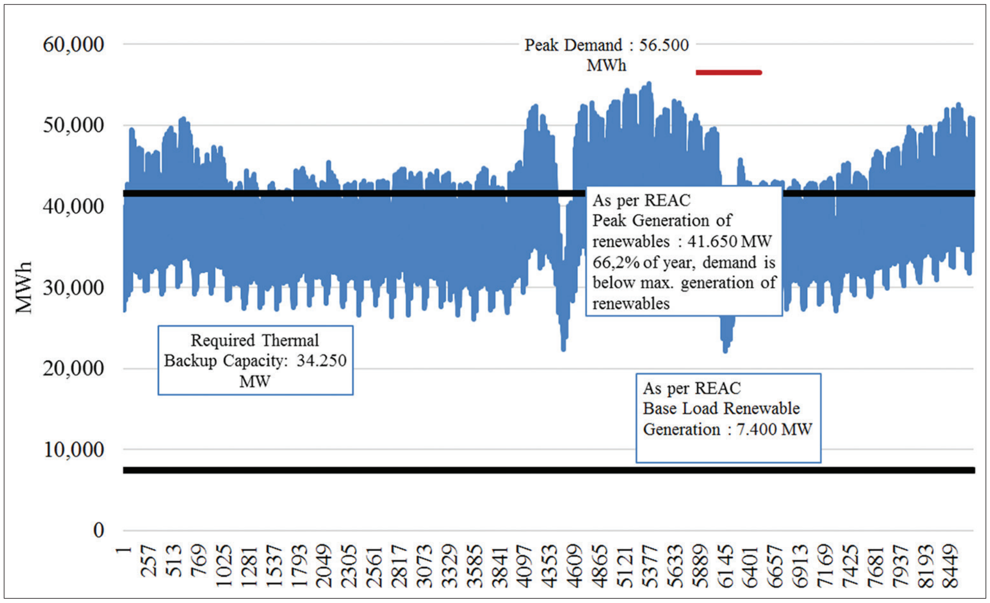
Figure 5: Power demand and peak Renewable Energy Resources generation in 2016



Source: The figure is prepared based on MENR (2014) and EPİAŞ (2017)

of thermal capacity (total thermal capacity is around 44 T MW). For clarification purposes this thermal capacity was needed just for backup to RES, so that RES could generate over the year 33% of the total demand.

Figure 6: Expected demand and peak RES generation in 2023



Source: The figure is prepared based on National Renewable Energy Action Plan – "REAC," MENR (2014)

3.3. Vision 2023: Analysis of the Future Power Generation

For the sake of analysis, to be able to calculate the contribution of RES to the power generation mix in 2023, we make two basic and reasonable assumptions: First, the officially set investment targets in REAC will have been met (both in installed capacity and generation terms). Second, availability and capacity usage patterns of all resources will be the same as the current year (2016).

Under these assumptions, as shown in Table 2, RES installed capacity (on average) increases by 79% (from 2016 to 2023) while the actual generation increases by 77% (as compared to thermal increases of respectively by 43% and 47%). The total peak demand will increase to 56.5 MW. It can be derived that 41,650 MW of that amount can be met by RES in its peak generation (Table 3). However, the fully reliable and stable power supply from RES will only be 7400 MW which is only about 1/6 of peak RES and 1/8 of total power peak and a mere 1/9 of installed future RES capacity of 61 GW (Figure 6).

In order for a reliable and secure power supply, the system will need to cover the fluctuation range (between 7,400 MW and 41,650 MW). Thus, 34,250 MW thermal backup capacity is needed to be ready and stand-by. This is obviously twice the current need of 17,100 MW. In a way, out of the increase of total thermal capacity by 20 GW (Table 2, i.e. from the 2016 level of 44,640 MW to 64,000 MW), 17 GW is necessary to back up RES for system reliability.

To recap from the tables and figures referred above, by 2023 RES installed capacity increases more than the increase in thermal/conventional sources and as generated amount the increase is nearly twice as compared to 2016 (from 89,845 GWh to 159,444 GWh), but increasing its share in total from 33% to 38%. On the other hand, due to reasons of intermittency, the contribution RES make to system reliability or security of power supply do not tangibly increase. An increase of only about 3% at the reliably-always available power and an increase of 22% at its peak load is achieved. In other words, by 2023, although considerably increasing their share in installed capacity (reaching nearly half of total) and annual generation of 38%, RES contribution to system reliability remains limited, requiring twice as much as today's need of thermal backup capacity. Thus, for a sound RES development, by the year 2023 Turkey will need thermal power plant investments as well.

Table 3: RES peak generation in 2023

Renewable sources	Expected ınstalled capacity in 2023 as per REAC (GW)	Expected peak generation in 2023 REAC target (GW)
Hydro	34,0	19,9
Wind	20,0	17,3
Geothermal	1,2	0,9
Biomass	0,8	0,5
Solar	5,0	3,0
Total	61,0	41,6

Source: The table is prepared based on data derived from EPİAŞ (2017) and National Load Dispatch Center Information System (YTBS, 2017). RES: Renewable Energy Resources

4. CONCLUSION

Turkey's energy policies are based on security of supply, diversification and utilization of indigenous resources. Therefore, in line with global trends and government support, investments in RES have started to accelerate. Nevertheless, despite increases, especially in wind and solar, there is still a long way to go to meet ambitious 2023 capacity targets.

In this study, the future role of RES in Electricity Supply Security is analyzed. The results show that although RES enhances adequacy of capacity and increases the energy supply diversity, it will have a limited contribution to reliable power supply due to its inherent deficiency related to intermittency. Thus, target RES developments will necessitate additional backup thermal power capacity. In addition, intermittency is a major hurdle to faster development of RES, not only in Turkey, but also globally.

It is understood that to increase the contribution of RES to a reliable power supply, the thermal backup capacity must be sufficiently present until the intermittency problem can be addressed (i.e., solutions as energy storage or smart grids). In the absence of such smart technological solutions, Turkey will need to build baseload thermal power plants (in the short and mid-term at least) to support the increasing fleet of RES in the system. This could then lead to overcapacity in the market as in many EU countries. Anticipating such results, the policy-makers should design policies and enable investments in energy storage that provides electricity supply security without causing undesired overcapacity in the market. In other words, thus, the focus should be on developing technological solutions (which does not necessitate additional thermal backup) to the intermittency problem to be able to fully utilize RES potential and, consequently, to reach expected results for climate policies.

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REFERENCES

Allen, P., Blake, L., Harper, P., Hooker-Stroud, A., James, P., Kellner, T. (2013), Zero Carbon Britain Rethinking the Future. Mechynlleth: Centre for Alternative Technology.

Ambec, S., Crampes, C. (2015), Decarbonizing Electricity Generation with Intermittent Sources of energy. No. 15-603. Toulouse School of Economics (TSE).

APS Panels on Public Affairs (POPA). (2011), Integrating Renewable Electricity on the Grid. Washington DC: American Physical Society.

Ataseven, M.S., Baloğlu, H.B. (2015), Türkiye Rüzgar Enerjisi Potansiyeli ve Mevcut Yatırımların Türkiye Enerji Güvenliğine Katkısı. In: Biresselioğlu, M.E., editors. Enerji Hukuku Araştırma Enstitüsü. p72-77.

AWEA. (2013), Wind and Reliability: Base Load Power. American Wind Energy Association. Available from: http://www.awea.org/Issues/Content.aspx?ItemNumber=5453. [Last accessed on 2015 Jan 13].

Biresselioğlu, M.E., Yıldırım, C., Demir, M.H., Tokcaer, S. (2017), Establishing and energy security framework for a fast-growing economy: Industry perspectives from Turkey. Energy Research and Social Science, 27, 151-162.

BNEF. (2014), Turkey's Changing Power Markets, Bloomberg New Energy Finance. Available from: https://www.about.bnef.com/blog/turkeys-changing-power-markets/. [Last accessed on 2012 Feb 12].

BP. (2016), Statistical Review of World Energy, 9, British Petroleum, BP P.L.C., London

Caldwell, D. (2013), Intermittent Nature of Green Power Is Challenge for Utilities. The New York Times. Available from: http://www.nytimes.com/2013/08/15/business/energy-environment/intermittent-nature-of-green-power-is-challenge-for-utilities.html. [Last accessed on 2017 Jan 13].

Cepin, M. (2011), Assessment of Power System Reliability: Methods and Applications. London: Springer.

Cherp, A., Jewell, J. (2014), The concept of energy security: Beyond the four as. Energy Policy, 75, 415-421.

Dailey, M. (2017), The Cost of Progress in Solar Power. Energy and Capital. Available from: https://www.energyandcapital.com/articles/the-cost-of-progress-in-solar-power/5730. [Last accessed on2017Jan 31].

DPT. (2009), Elektrik Enerjisi Piyasası ve Arz Güvenliği Strateji Belgesi, Devlet Planlama Teşkilatı. Available from: http://www.oib.gov.tr/2011/dosyalar/Elektrik_Enerjisi_P_A_G_Stratejisi.pdf. [Last accessed on 2016 Dec 23]

EMRA. (2016), Elektrik Piyasası 2015 Yılı Piyasa Gelişim Raporu. Energy Market Regulatory Authority.

EPİAŞ. (2017), Transparency Platform. Availalbe from: https://www.seffaflik.epias.com.tr/transparency/. [Last accessed on 2017 Jan 16].

Eurelectric. (2006), Security of Electricity Supply-Roles, Responsibilities and Experiences With in the EU. Brussels.

Eurostat. (2016), Share of Renewable Energy in Gross Final Energy Consumption. Available from: http://www.ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=t2020_31&plugin=1. [Last accessed on 2016 Dec 23].

Exas Consulting. (2013), The Economics have Changed, New Base Load Power is Likely Dead. Available from: http://www.exasconsulting.com/blog/the-economics-have-changed-new-baseload-power-is-likely-dead/. [Last accessed on 2015 Jan 13].

Fischer, W., Kuckshinrichs, W., Hake, J.F. (2016), Reflections on the German Energiewende. Institute of Energy and Climate Research. Istanbul: Paper Presented to 23rd World Energy Congress.

Flora, R.M.C. (2012), Intermittency, Backup and Overcapacity in Wind Energy: Evidence from Europe Countries. Covilhã, Spain: Dissertation, Universidade da Beira Interior.

Gerbert, P., Rubner, H., Herhold, P., Steffen, B. (2014), Germany's Energiewende: The End of Power Market Liberalization? Available from: https://www.bcgperspectives.com/content/articles/sustainability_energy_environment_germany_energiewende_end_power_market_liberalization. [Last accessed on 2016 May 05].

Gillespie, A., Grieve, D., Sorell, R. (2015), Managing Flexibility Whilst Decarbonising the GB Electricity System the Energy Research Partnership. London. Available from: http://www.erpuk.org/wp-content/uploads/2015/08/ERP-Flex-Man-Full-Report.pdf). [Last accessed 2017 Mar 03].

Gowrisonkaran, G., Reynolds, S., Samano, M. (2016), Intermittency and the value of renewable energy. Journal of Political Economy, 124, 1187-1234.

Gözen, M. (2014), Renewable energy supports mechanism in turkey: Financial analysis and recommendations to policymakers. International Journal of Energy Economics and Policy, 4(2), 274-287.

Hadelsblatt. (2015), Die grüne Rechnung. Available from: http://www.handelsblatt.com/my/politik/deutschland/kosten-der-energiewende-die-gruene-rechnung/12224460.html?ticket=ST-5333950-IkEgpS0M5EcGWqiBfE5c-ap2. [Last accessed on 2015 Aug 25].

Heard, B.P., Brook, B.W., Wigley, T.M.L., Bradshaw, C.J.A. (2017), Burden of proof: A comprehensive review of the feasibility of 100% renewable-electricity systems. Renewable and Sustainable Energy Reviews, 76, 1122-1133.

Hill, J.S. (2014), Renewables Could Supply Turkey with Energy Independence, Continues Trend. Available from: http://www.cleantechnica.com/2014/11/19/renewables-supply-turkey-energy-independence. [Last accessed on 2017 Feb 02].

IEA. (2013), Secure and Efficient Electricity Supply: During the Transition to Low Carbon Power Systems. Paris: International Energy Agency.

IEA. (2016a), International Energy Agency. Available from: http://www.

iea.org/topics/energysecurity. [Last accessed on 2017 Mar 13].
IEA. (2016b), IEA Note on Electricity Security for the G7. Available from: https://www.iea.org/media/topics/engagementworldwide/g7/IEANoteonElectricitySecurityfortheG7.pdf. [Last accessed on 2017 Oct 03].
IEA. (2016c), Energy Policies of IEA Countries: Turkey. International Energy Agency. p21. Available from: https://www.iea.org/publications/freepublications/publication/EnergyPoliciesofIEACountriesTurkey.pdf. [Last accessed on 2017 Mar 10].
IRENA, (2015b), Renewable Energy Prospects: Germany, Remap 2030 Analysis. International Renewable Energy Agency.
IRENA. (2015a), The Role of Renewable Energy in Energy Security. International Renewable Energy Agency, Fifth session of the Assembly.
Jenkins, J.D., Thernstrom, S. (2017), Deep Decarbonization of the Electric Power Sector Insights from Recent Literature. Energy Innovation Reform Project.
Kocaslan, G. (2014), International energy security indicators and Turkey's energy security risk score. International Journal of Energy Economics and Policy, 4(4), 735-743.
Larson, A. (2007), Oil. The geopolitics of oil and natural gas. New England Journal of Public Policy, 21(2), 215-219.
Martin, R. (2016), Germany Runs Up Against the Limits of Renewables. Available from: https://www.technologyreview.com/s/601514/germany-runs-up-against-the-limits-of-renewables/. [Last accessed on 2017 Feb 22].
Matek, B., Gawell K., (2015), The Benefits of baseload renewables: A misunderstood energy technology. The Electricity Journal, 28(2), 101-112.
MENR. (2014), National Renewable Energy Action Plan for Turkey. Turkish Ministry of Energy and Natural Resources. Available from: http://www.eie.gov.tr/duyurular_haberler/document/National_Renewable_Energy_Action_For_Turkey.PDF. [Last accessed on 2016 Dec 25].
Nikolakakis, T., Fthenakis, V. (2011), The optimum mix of electricity from wind-and solar–sources in conventional power systems: Evaluating the case for New York State. Energy Policy, 39, 6972-6980.
OECD/IEA. (2004), Security of Gas Supply in Open Markets: LNG and Power at a Turning Point. Paris: OECD/IEA.
OECD/Nuclear Energy Agency. (2010), The Security of Energy Supply and the Contribution of Nuclear Energy. Organization for Economic Co-Operation and Development Nuclear Energy Agency, Nuclear Development.
Ölz, S., Sims, R., Kirchner, N. (2007), Contribution of Renewables to Energy Security. IEA Information Paper.
Paltsev, S. (2016), The complicated geopolitics of renewable energy. Bulletin of the Atomic Scientists, 72(6), 390-395.
Peker, H.S. (2015), Yenilenebilir Enerjide Teknik Kapasite, Teknik Yapılabilir Kapasite ve Ekonomik Yapılabilir Kapasite. Available from: http://www.hasansencerpeker.blogspot.com.tr/2015/04/yenilenebilir-enerjide-teknik-kapasite.html. [Last accessed on 2016 Dec 25]
Prada, J.F. (1999), The Value of Reliability in Power Systems: Pricing Operating Reserves. Massachusetts Institute of Technology.
REN21. (2015), Renewables 2015 Global Status Report, Renewable Energy Policy Network for the 21st Century. Available from: http://www.ren21.net/wp-content/uploads/2015/07/REN12-GSR2015_Onlinebook_low1.pdf. [Last accessed on 2016 Dec 25].
REN21. (2016), Renewables 2016 Global Status Report, Renewable Energy Policy Network for the 21st Century. Available from: http://www.ren21.net/wp-content/uploads/2016/06/GSR_2016_Full_Report.pdf. [Last accessed on 2016 Dec 10].
Robinson, D. (2013), Living with Intermittent Renewable Power: Challenges for Spain and EU. Oxford Energy Comment.
Seymour, J., Horsley, T. (2005), The Seven Types of Power Problems, APC White Paper.
Sholten, D., Bosman, R. (2016), The Geopolitics of renewables; Exploring the political implications of renewable energy systems. Technological Forecasting and Social Change, 103, 273-283.
Silva, R.C.R., Neto, I.M., Seifert, S.S. (2016), Electricity supply security and the future role of renewable energy sources in Brazil. Renewable and Sustainable Energy Reviews, 59, 328-341.
Sturm, C. (2016), Germany's Energiewende: The Intermittency Problem Remains. Bulletin of the Atomic Scientist. Available from: http://www.thebulletin.org/germany%E2%80%99s-energiewende-intermittency-problem-remains9469. [Last accessed on 2016 Jun 21].
The Economist. (2015), Renewable energy: Puffs of Hope. Available from: http://www.economist.com/node/21660124/print. [Last accessed on 2016 Sep 22].
The Economist. (2017), Clean Energy's Dirty Secret. Available from: http://www.economist.com/news/leaders/21717371-thats-no-reason-governments-stop-supporting-them-wind-and-solar-power-are-disrupting. [Last accessed on 2017 Mar 13].
The European Commission. (2000), Green Paper towards a European Strategy for the Security of Energy Supply. Available from: http://www.iet.jrc.ec.europa.eu/remea/sites/remea/files/green_paper_energy_supply_en.pdf. [Last accessed on 2017 Mar 13].
The Parliamentary Office of Science and Technology. (2014), Intermittent Electricity Generation. Post note. p464.
Turkish Ministry of Energy and Natural Resources. (2015), Renewable Energy Action Plan Reac. Available from: http://www.eie.gov.tr/duyurular_haberler/document/National_Renewable_Energy_Action_For_Turkey.PDF. [Last accessed 2016 Dec 23].
Turkish Ministry of Environment and Urbanization. (2015), Intended Nationally Determined Contribution. Available from: http://www.4.unfccc.int/submissions/INDC/Published%20Documents/Turkey/1/The_INDC_of_TURKEY_v.15.19.30.pdf, 2015. [Last accessed 2017 Feb 02].
Turkish Statistical Institute. (2015), Fasıllara Göre İthalat. Available from: http://www.tuik.gov.tr/PreTablo.do?alt_id=1046. [Last accessed on 2016 May 24].
Ueckerdt, F., Hirth, L., Luderer, G., Edenhofer, O. (2013), System LCOE: What are the costs of variable renewables? Energy 63, 61-75.
Verzijlbergh, R.A., De Vries, L.J., Dijkema, G.P.J., Herder, P.M. (2017), Institutional challenges caused by the integration of renewable energy sources in the European electricity sector. Renewable and Sustainable Energy Reviews, 75, 660-667.
Vital, V. (2016), The Impact of Renewable Sources on the Performance and Reliability of the Electricity Grid. Bridge on the Electricity Grid.
Yergin, D. (2006), Ensuring energy security. Foreign Affairs, 85(2), 69-82.
Yergin, D. (2011), The Quest: Energy Security and the Remaking of the Modern World. New York: Pengiun Press.
YTBS. (2017), National Load Dispatch Center Information System. Available from: https://www.ytbs.teias.gov.tr. [Last accessed on 2017 Jan 28].