



An energy transition pathway for Turkey to achieve 100% renewable energy powered electricity, desalination and non-energetic industrial gas demand sectors by 2050



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ABSTRACT

In this research, Turkey's energy transition towards 100% renewable energy (RE) until 2050 is analysed by using an hourly resolved model. Turkey is structured into seven geographical regions and all assumptions and data are collected and applied separately for the regions. The energy transition is simulated for two scenarios: a power sector scenario and power sector plus desalination and non-energetic industrial gas demand (integrated) scenario. Turkey has an enormous solar energy potential, which leads to an installed solar PV capacity of 287 GW (71% of total installed capacity) in the power scenario and 387 GW (73% of total installed capacity) in the integrated scenario in 2050. Solar PV and other installed RE systems are balanced by storage systems to increase the flexibility of the system. Levelised cost of electricity increased slightly in the power scenario, from a fossil fuel based system with 63 €/MW h_{el} in 2015 to a fully RE-based system with 65.4 €/MW h_{el} in 2050. The capacity mix in the power scenario entirely built for the assumptions of the year 2050 led to a cost of 51 €/MW h_{el} , which can also be expected in the periods beyond 2050. In the integrated scenario, however, the costs decreased from 60.3 €/MW h_{el} to 57.3 €/MW h_{el} , mainly due to the benefit of sector coupling. A 100% RE system reduces energy import dependency and carbon emissions, while reducing the cost of energy supply.

1. Introduction

1.1. Motivation

Turkey is the second largest country in Eurasia, after Russia, and occupies a land area of 769,604 km². It is a central hub connecting Central Asia, the Middle East and Europe geographically and for the energy sector. The total population of Turkey is 78.6 million, the third highest population in Eurasia. Future population projections show that the population will grow to 87.7 million by 2030 and 95.8 million by 2050 (UN, 2015). The population tends to be concentrated in the industrialised cities and regions. Nearly 60% of all industry is located in the Marmara region, followed by the Aegean and Central Anatolia regions.

Turkey's annual electricity consumption was 209.2 TW h in the year 2013 and was recorded as the 5th highest electricity consumption in Europe (IEA, 2015). Between 2000 and 2015, annual electricity consumption in Turkey increased more than 170%, from 98.3 TW h to

268.8 TW h. Meanwhile, the annual electricity consumption per capita increased 90% from 1449 kW h to 2749 kW h (TEIAS, 2016). This electricity boom has driven an increase in expenditures for annual total fuel imports. These expenditures have risen from 10.4 b€¹ in 2000 to 41.2 b€ in 2014 and 33.9 b€ in 2015. According to the Turkish Statistical Institute, these amounts are equivalent to approximately 20% of all imported goods for the mentioned years (TUIK, 2016).

The European Union's average electricity consumption per capita in 2013 was 6036 kW h, approximately 120% higher than the corresponding value of Turkey (World Bank, 2016). However, Turkey's electricity demand is fast catching up and several factors are responsible for this surge. Ongoing economic development is increasing Gross Domestic Product (GDP), which has risen by 230% between 1990 and 2012. Meanwhile, there have been increases in population, urbanisation, industrialisation and demand for transportation. Simultaneously, the country has been weathering the effects of global warming, which affects household and commercial energy consumption and varies by region and season (Wilbanks et al., 2008). GDP and electricity

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¹ The data is provided by Turkish Statistical Institute database and the currency is automatically converted by base year currency rate.

Nomenclature

AC	alternating current
A-CAES	adiabatic compressed air energy storage
b€	billion euro
BAU	business as usual
BEPA	Biomass Energy Potential Atlas
capex	capital expenditures
CCGT	combined cycle gas turbines
COP21	21st yearly session of the Conference of the Parties/Paris Agreement
CSP	Concentrating solar thermal power
DBFZ	German Biomass Research Center
FLH	full load hours
GDP	gross domestic product
GT	gas turbine
GVA	gross value added
HHB	hot heat burner
HVDC	high voltage direct current
ICE	internal combustion engine
IEA	International Energy Agency
km ²	square kilometer
LCOC	levelised cost of curtailment
LCOE	levelised cost of electricity
LCOG	levelised cost of gas
LCOS	levelised cost of storage
LCOT	levelised cost of transmission
LCOW	levelised cost of water
m ³	cubic meter
MED	multi effect distillation

MENA	Middle East and North Africa
MENR	Ministry of Energy and Natural Resources
MSF	multi stage flash
OCGT	open cycle gas turbines
opex	operational expenditures
PHS	pumped hydro energy storage
PP	power plants
PtG	power-to-gas
PtH	power-to-heat
PV	photovoltaic
RE	renewable energy
REPA	Turkish Wind Energy Potential Atlas
RoR	Run-of-River
SNG	synthetic natural gas
ST	steam turbine
SWRO	seawater reverse osmosis
TES	thermal energy storage
TRL	Turkish lira
UN	United Nations
USD	United States Dollar
USD¢	United States Dollar Cents
WACC	weighted average cost of capital
WRI	World Resources Institute
€	euro

Subscripts

el	electric units
th	THERMAL units
th, a	thermal units, annual

demand are highly correlated, as shown by historical data (Breyer, 2012). As GDP grows, so do the electricity demands for construction, manufacturing and transportation (Chen et al., 2007). Hence, Turkey will match the European Union’s per capita electricity consumption according to future developments and optimised policies.

Fig. 1 presents the breakdown of installed electricity capacity in Turkey at the end of 2015. Hydropower represents a major share of the installed electricity capacity, at 35.4% in 2015. However, another

major electricity capacity share is represented by natural gas, at 29%, due to higher full load hours than hydropower. All renewable energy (RE) resources made up to 49.2% of the total installed capacity at the end of 2015 (TEIAS, 2016b).

Turkey is a net natural gas importing country, with 99.2% of all consumption imported, thereof 55.3% from Russia, 16.2% from Iran (EPDK, 2016) and additional supply from Azerbaijan, Turkmenistan and Algeria. This consumption ranks Turkey as a major natural gas

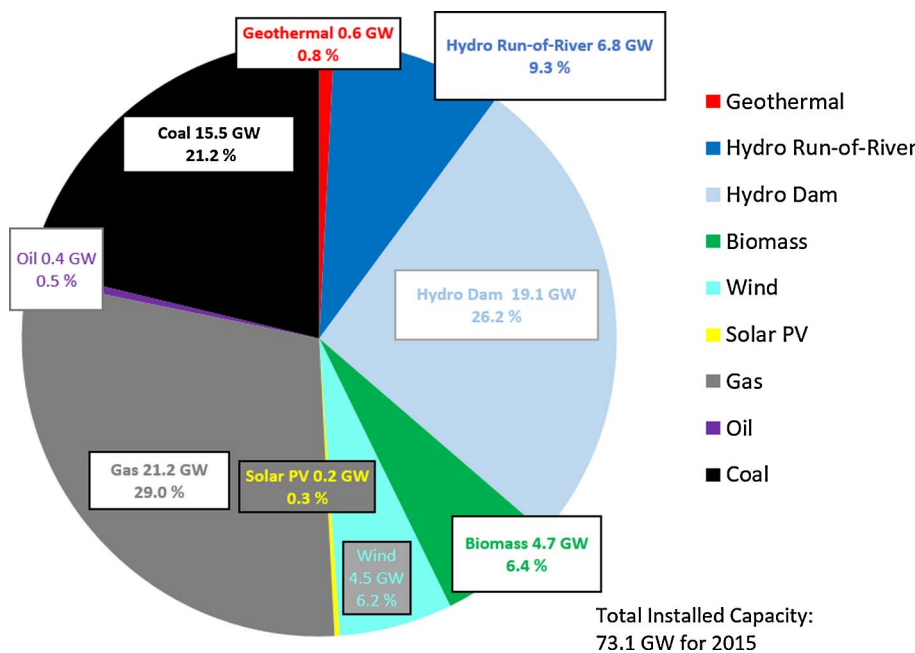


Fig. 1. Total installed electricity capacity of Turkey at the end of 2015 (TEIAS, 2016b).

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