Renewables as a prospective cornerstone of the future energy mix

Key theses for the report at the round table "Energy mix optimization. Nuclear & RES"

Moscow, May 30, 2016

In the future RES will be capable of covering base load and/or semi-peak load demand by becoming more intelligent & more competitive

Key theses

1 **Significant installed capacities of renewables** globally, incl. specific countries where they are comparable with base load demand; expected **CAPEX of EUR 7.5 trillion in 2015-2040**

2 **Further decrease of LCoE[1] of renewables** due to massive scientific & technical progress (technologies, manufacturing processes, construction techniques)

3 **Further increase of technical availability and applicability of RES** due to advancements in electricity storage technologies, fleet footprint approaches, as well as large-scale introduction of Demand Side Management & energy efficiency instruments

4 **Further increase of investments into RES from non-energy players** due to the industry's decreasing dependency on state regulation / incentive schemes

5 **Possible shift in the energy system paradigm** – transition from "RES as a peak load capacity" to "RES as a basis of the energy mix"

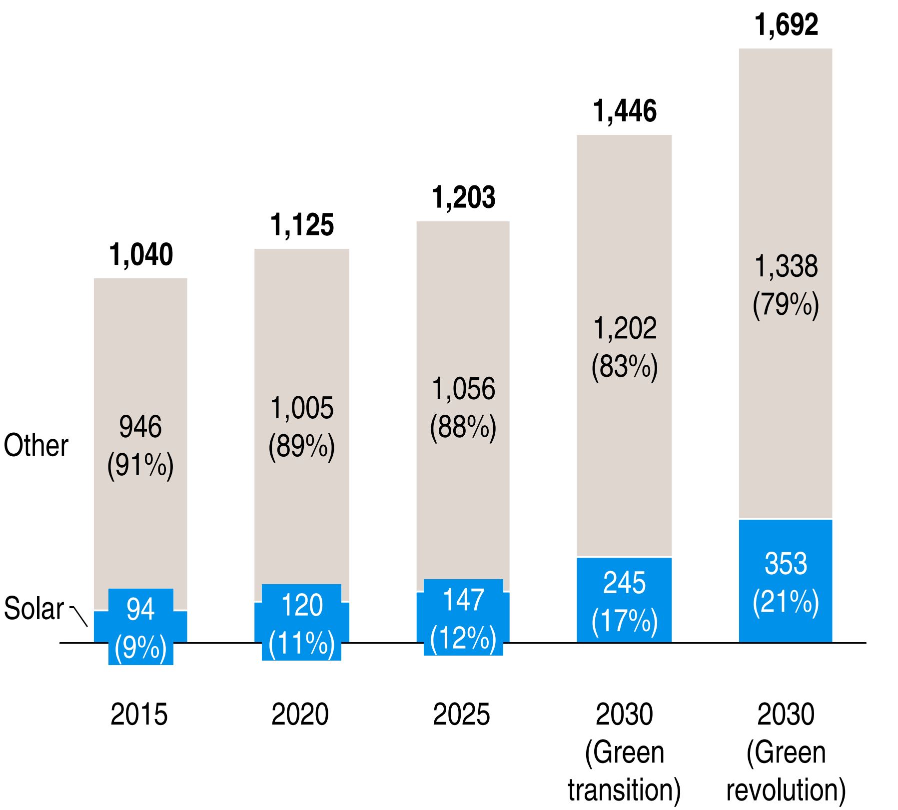
1) Levelized Cost Of Electricity

Source: Roland Berger

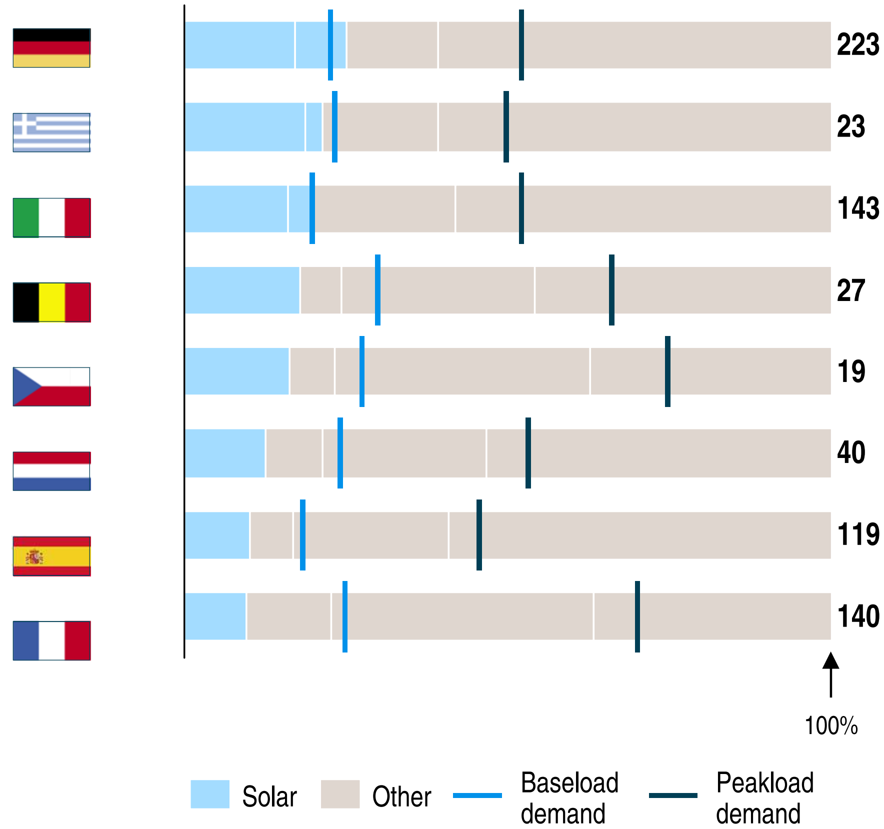
For example, solar PV can reach 12% of EU power-gen capacity by 2025, exceeding baseload demand in some European countries

Renewables share in Europe – Example of solar power

Generation capacity[1)] in ENTSOE area [GW]



Generation capacity and base and peakload demand in 2025 [GW]



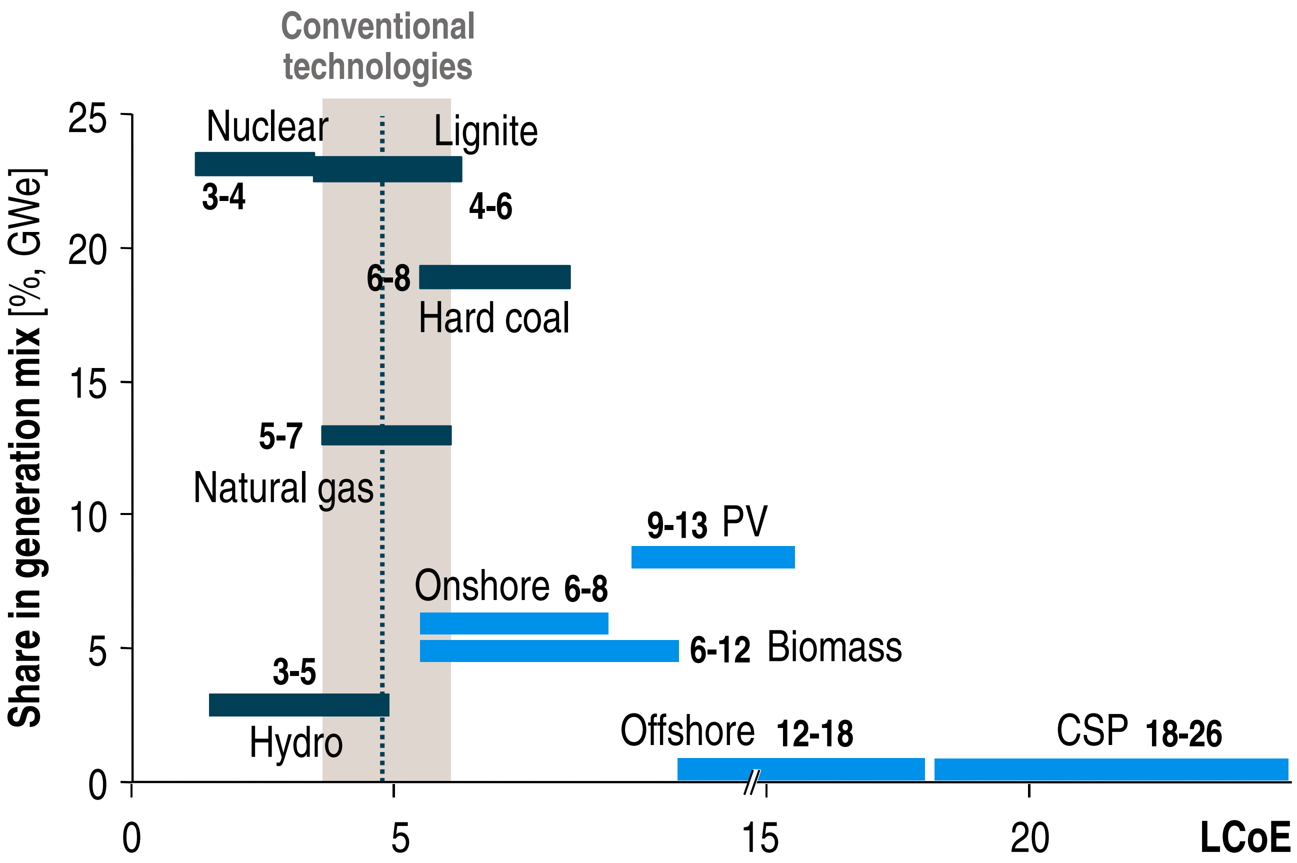
1) Scenario B of ENTSO system adequacy report; UK data taken from the slow progress scenario in the National Grid Future Energy report

Source: ENTSOE; National Grid; Roland Berger

2

Expansion of renewables in Europe led to significant cost decreases over time – LCoE of onshore wind & PV close to cost competitiveness

Levelized cost of electricity in Europe, 2014 [EUR ct/kWh]



Renewables

> **Gap** between renewables and conventional generation technologies **is decreasing**

> **Wind onshore** already today **cost competitive** with hard coal and natural gas (although wind onshore LCoE highly dependent on location)

> Due to technological advance and increasing experience **further reduction in LCoE** particularly in **wind onshore and PV** expected

Source: Bloomberg New Energy Finance; IEA; EWEA; Roland Berger

Example of advancements in offshore wind – new foundation concepts, where the trend towards deeper water is shifting growth to jackets

Technological advancements – Example of offshore wind

WATER DEPTH

Foundation	Realized up to 2015	Outlook	Comments
Gravity based foundations (GBF)	20%	↘	Depth < 20 meters; less used recently, mostly in shallow water; new GBF concepts under development for depths of 20-40 meters
Monopile	75%	→	Depth 10-30 meters; remains most important foundation type, may lose some ground to other concepts, but new concepts likely to succeed
Tripile	1%	↘	Depth 25-50 meters; developed by BARD; large-scale further application unlikely due to high complexity and material needs
Tripod	< 1%	↘	Depth 25-50 meters; developed by Areva; large-scale further application unlikely due to high complexity and material needs
Jacket	2%	↗	Depth 20-60 meters; expected to gain market share due to great flexibility and low weight (40-50% less steel than monopiles); commercially viable at depths of > 30 meters
Floating	< 1%	?	Depth > 50 meters; currently at R&D stage; significant growth potential, especially for countries with steep shores; no large scale commercial application expected before 2020

Source: EWEA, Roland Berger

Example of advancements in solar PV – new technologies that increase the range of application and the conversion efficiency

Technological advancements – Example of solar power

Developments in solar cells/panels

Developments

- **Multi-junction cells**: organic, organometallic, inorganic mat.
- Perovskite combined with silicon
- **Dye-sensitized** solar cells (DSSCs)
- Photon **upconversion** or **downconversion**

Impact on installations

- For installation of panels, no material differences in the type of solar cells/modules is present
- Higher efficiency increases the range of application of solar PV

New applications

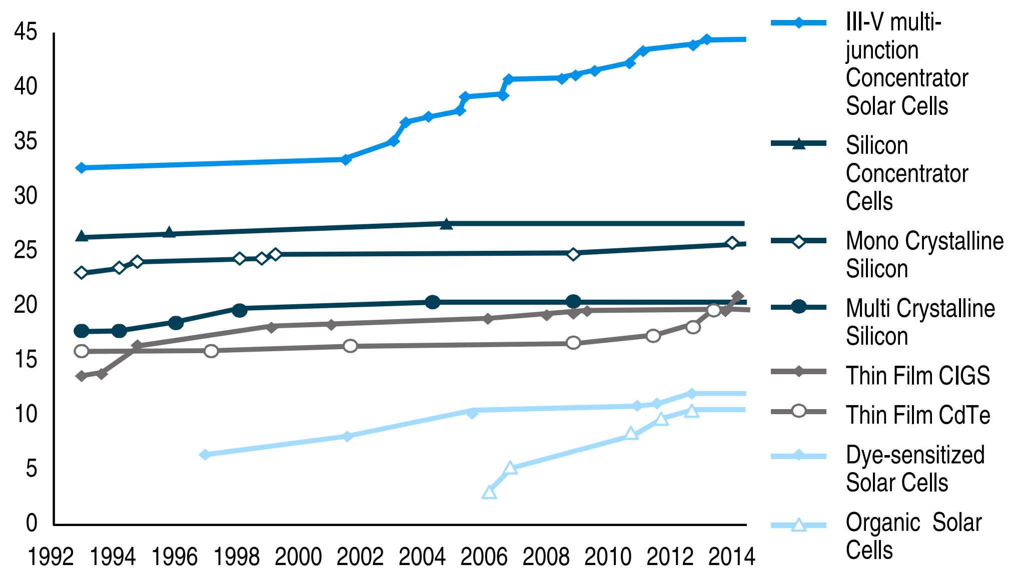
Developments

- **BIPV:** PV materials incorporated into the construction of new buildings
- Integration of solar installations with **battery storage**
- Solar **micro-inverters** attached to each solar panel
- **Demand-side management** by analysis of consumption profile

Impact on installations

- More complex installation of system and connection to the grid
- More complex operations of the solar PV systems
- Increased need for maintenance

Solar PV efficiency evolution with new materials



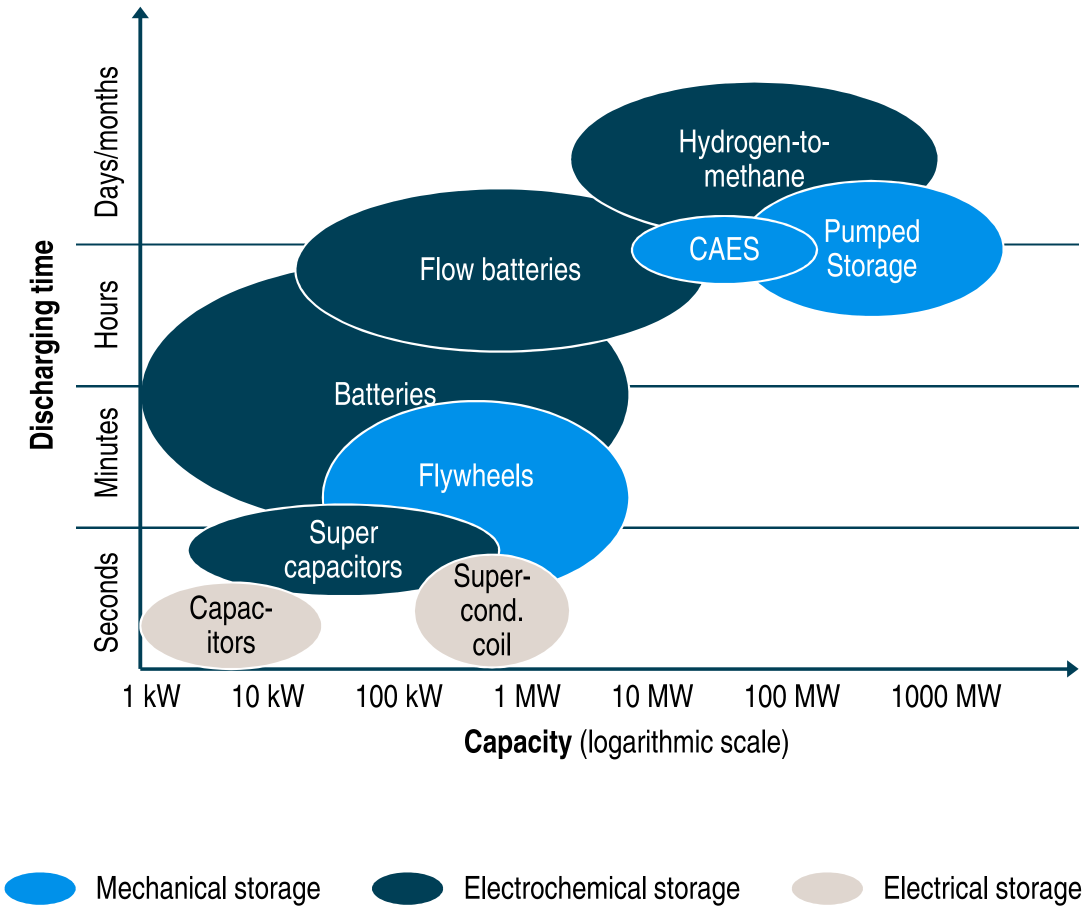
Solar cells materials evolution:

- 1[st] **gen.** : crystalline silicon, incl. polysilicon and monocrystalline silicon
- 2[nd] **gen.** : thin film solar cells, incl. amorphous silicon, CdTe and CIGS cells
- 3[rd] **gen.**: thin-film technologies, incl. organic materials, organometallic compounds as well as inorganic substances

Source: Fraunhofer, Roland Berger

Nowadays several proven electricity storage technologies exist with high capacity and long discharging times

Storage technologies – Discharging time / Capacity



> Pumped storage, CAES and hydrogen-to-methane storage represent the only technologies with **high capacity and long discharging times**

> Batteries already have storage capacities of several megawatts and are ideal for **backup power system support**

> Flow batteries have the potential to further **increase discharging times**

> Direct electrical storage with capacitors or superconducting coils can be realized only with small capacities and with very short discharging times

Source: BWK, Energiewirtschaftliche Tagesfragen, Pike Research, Roland Berger

Demand Side Management helps tackle utilities' real-time imbalances from intermittent renewables and reduce industrials' energy bills

Demand Side Management – Overview

Load optimization options

Illustrative

- Heating
- Ventilation
- Pumps
- Cooling
- On-site power generation
- Mills
- Com-pressors
- Specific process

Value chain steps	Competences required
1 Asset characteristics identifications & risk management choices	> Identify asset flexibilities > Define the risk management choices: return-risk preferences (target markets for valuation), risk policy, authorized products & levers for portfolio management > Set-up risk control infrastructure (limits, processes…)
2 Asset instrumentation	> Set-up **control & communication** instruments: – Install devices to remotely collect consumption information and control energy consuming equipment – Leverage smart objects / energy storage possibilities
3 Load & shaving forecast	> **Predict consumption** in order to monitor and adjust capacities
4 Market forecast	> **Understand market price dynamics** on the different markets: capacity market, TSO system services, intraday, spot and forward market > Estimate valuation and financial outcomes for the client
5 Portfolio Management	> **Optimize** flexibility: – Define hedging strategy (capacity market vs. TSO system services vs. intraday vs. spot and forward market) – Realize hedges (OTC or on organized markets)

Source: Energy Pool, Frontier Economics, Roland Berger

Roland Berger

Utilities are moving into new decentralized business models extending their portfolio vertically and beyond industry boundaries

Decentralized business models – Overview

Traditional approach → *High level of innovation*

	+ Auxiliary energy products	+ Vertical portfolio extension		+ New industries: Energy and IT integration	+ New industries: Multi-service
Power/ gas only	**Auxiliary energy products**	**Vertical portfolio extension**		Energy and IT integration	Multi-service
Selected examples	> **Sustainable energy products** – low-carbon, renewables > **Advanced customer info** – consumption reports, real-time load info > **Decentralized power generation**	> **Boiler and heating devices** – sale, installation, periodic revision, repair > **Home appliances** – in-house repairs > **Energy-saving products** (from light-bulbs to solar panels, >1000 SKUs)	> **Energy efficiency** – audit, home insulation, energy data management solutions	**Smart network solutions:** > Smart grid > Smart metering > Smart home (steering of electrical appliances, heating devices from distance)	> **Insurance** – from repairs to full home insurance > **Financial services** > **Automotive** - supplying & operating an e-mobility network

extraenergie | lekker Energie | Yello Strom Yello Shop. | VATTENFALL Energie-Shop | MVV Energie | HSE Das ganze sehen | British Gas | e.on | RWE The energy to lead

Source: Roland Berger

Renewables are no longer a CSR initiative, as they increasingly attract funds of non-energy players and oil & gas majors

Examples of corporate investments / initiatives in the area of wind & solar power

Wind

bp	Owns 16 onshore wind farms in US of 2.6 GWe capacity
Google	Signed power purchase agreements (PPAs) for > 2 GWe of wind power in US; 100% renewable energy goal by 2025 (from 37% now); Google X invests in wind energy kites (unit capacity of up to 600 KWe)
MARS	Partnered with Sumitomo on a 200 MWe wind farm, which covers 100% of its power needs in US (25% globally)
Audi	As part of its CO_2-neutral mobility strategy, co-financed an offshore wind farm in the North Sea which power its power-to-methane plant opened in 2013

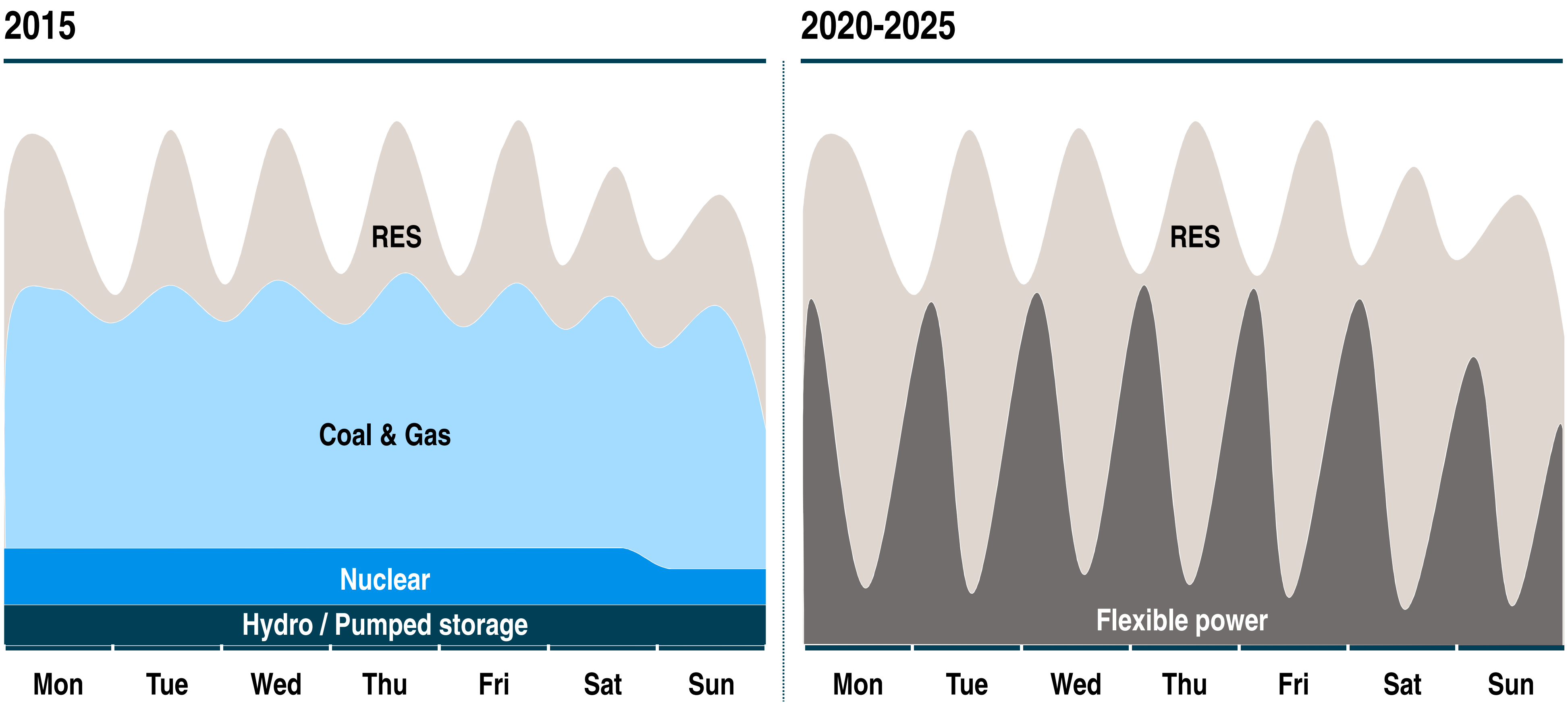
Solar

TOTAL	Agreed in May 2016 on the acquisition of a battery producer Saft worth USD 1.1 bn, following the '2011 acquisition of a PV producer SunPower
Walmart	Installed > 100 MWe of solar panels on roofs of > 300 its stores and distribution centers (6% of the company's locations), with a plan to double the capacity by 2020
IKEA	Started selling solar panels in its UK shops (in partnership with SolarCentury)

Source: Roland Berger

Future energy systems may have no baseload, with solar & wind covering major demand, and (CC)GTs flexibly covering the remainder

Future shift in the energy system's paradigm – Example of Germany



Source: German Energy Transition, Roland Berger

Thank you!

Denis Borisov

Project Manager

Competence Centers
"Energy & Chemicals" and
"Infrastructure"

Tel. +7 495 225 76 45
Mob. +7 967 268 10 92
Denis.Borisov@rolandberger.com
127051, Moscow, Tsvetnoy Bulvar, 2

Source: Roland Berger

Roland Berger