Global Energy Transition and Challenges for Nuclear Players

ATMOEXPO Conference

19th of June 2017

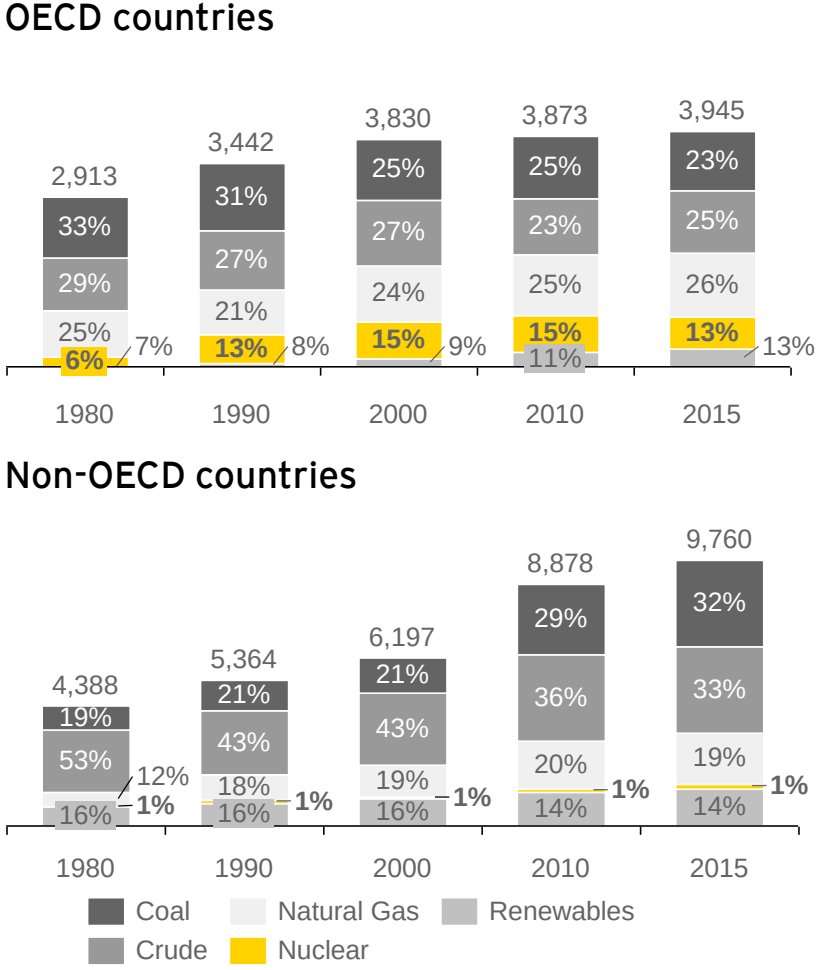
Anton Poriadine, Partner, CIS Strategy Leader

EY

Совершенствуя бизнес,
улучшаем мир

Global energy mix today is at it's turning point, opening up new opportunities for carbon free sources

Global energy mix evolution, millions of toe



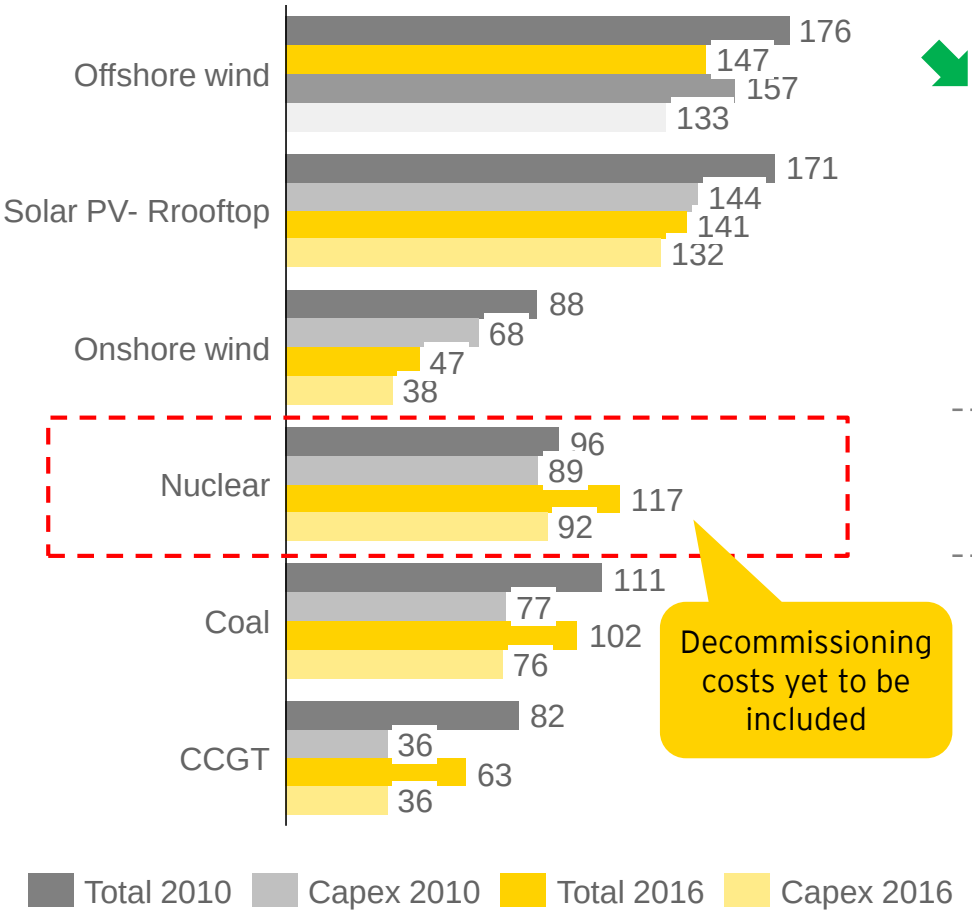
- ***Coal has been a major source for energy*** but its use has declined in OECD countries, while non OECD members (mainly China and India) have increased use of coal significantly
- ***COP21 agreement*** on NO additional net greenhouse gas by 2050 ***requires switch to non- CO2 emitting*** energy sources
- ***Nuclear*** has been regarded as clean, carbon free energy – ***key to achieve CO2 targets*** and a proven solution to fuel industrial growth or a backbone for isolated energy systems
- At the same time ***huge cost outlay and unresolved technology issues*** keep hindering widespread adoption of nuclear – "cheap energy for future generations" few can afford

How will nuclear evolve in the changing energy mix?

Source: IMF, EIA, EY analysis

Nuclear cost competitiveness is under serious threat – even "business as usual" requires a significant change

Projected LCOE by technology
LCOE 2016, USD/MWh



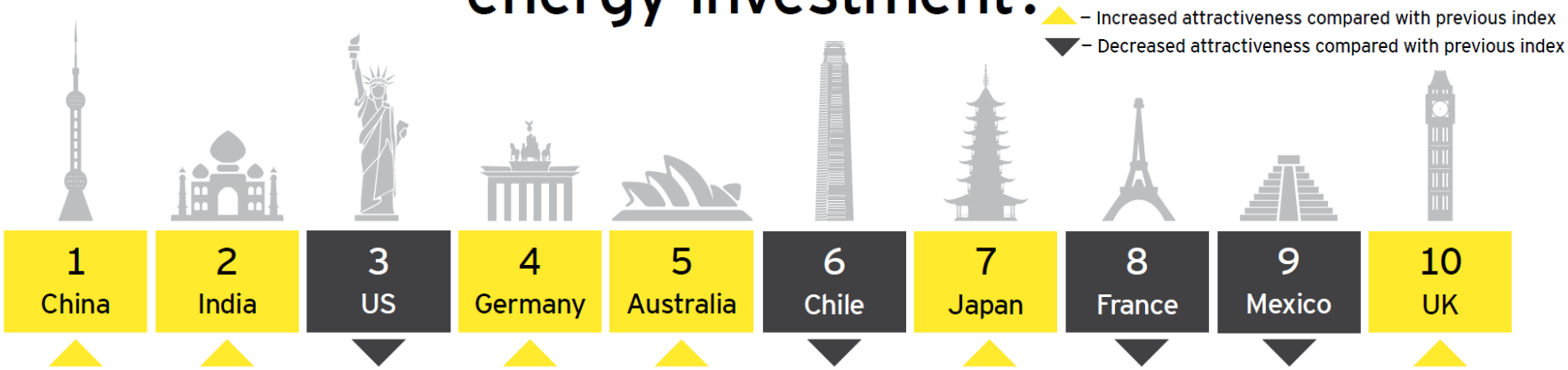
Drivers of LCOE change

- Efficiency gains, driven by technology standardization and economies of scale in installed capacity – already down to $120-125
- Further technology advancement for use in extreme conditions
- But(!) – decreasing investment attractiveness and continued issue of intermittent capacity to be factored in
- Increased CAPEX due to safety concerns
- No shifts in mature technology, LCOE follows commodity pricing
- Recent advancements in more flexible and efficient CCGT technologies

Source: Lazard, EIA, EY analysis
Assumptions: 60% Debt, WACC 10.5%

The growing competitiveness of renewables is offset by fast saturation and subsidies' cut in some key markets

Which countries are attracting the most renewable energy investment?



Key pillars to define RECAI ranking:

- Is there a long-term need for ***additional/ replacement*** energy supply from ***renewable resources***?
- Is ***policy hindering or helping*** the ability to exploit renewables opportunities in a country?
- Are essential components in place ***to ensure project delivery***[1]?
- Does ***technology potential level, power offtake and incentive regimes*** prompt for renewables?
- Does the ***macro stability and investment climate*** enable or impede the ease of doing business?

At the current technology level the more renewable energy is deployed, the less attractive for investors next renewable project becomes – but this will change

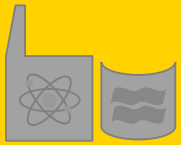
Source: EY RECAI® Index

[1] Such as long-term contracts, grid infrastructure and availability of finance

Forthcoming energy transition will further fundamentally change the energy markets

Energy transition drivers…

Technology



- ***E mobility***: electric cars are becoming reality
- ***Storage***: commercially viable both on industrial scale and on customer premises
- ***Digital***: big data, digital products and services, digitalization via sensors, robots and augmented reality

Regulation

- Energy markets' ***liberalization*** and greater support for ***carbon-free sources***
- Strong push for ***smart cities and smart grid*** projects
- Support for generation landscape ***decentralization*** in service based economies

Customers

- Generate their ***own energy*** ("prosumers")
- Demand for a ***greater choice*** (supply, services…)
- ***Connected and social***

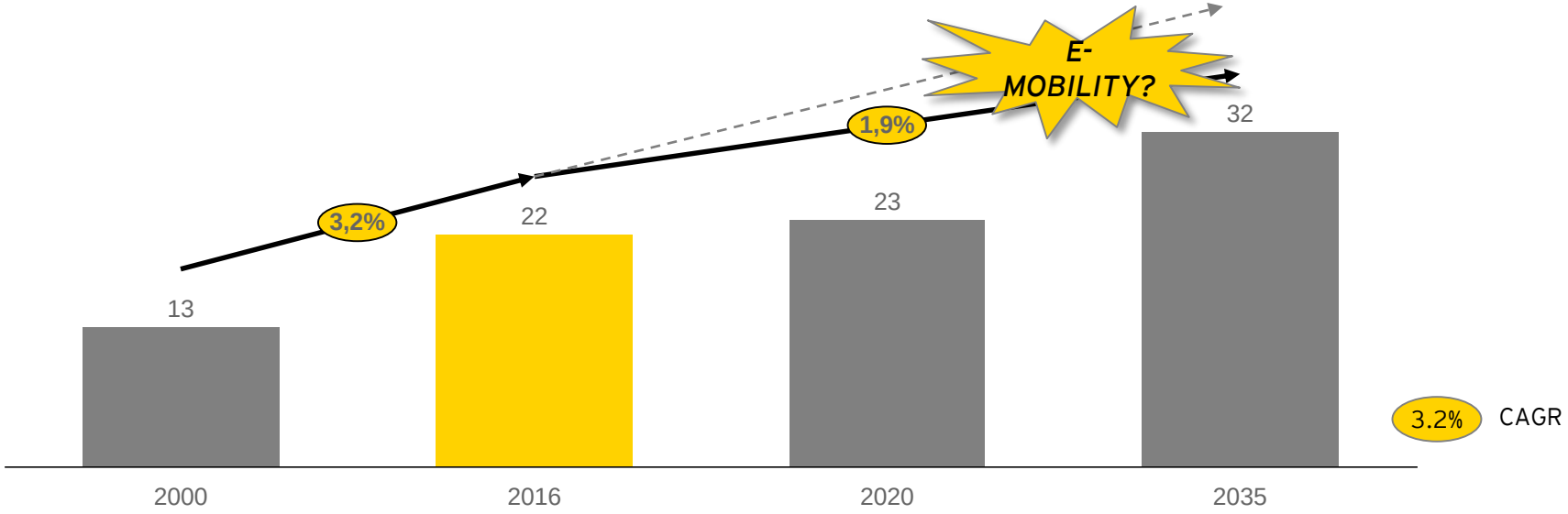
…and what it means

- Still greater demand for electricity
- Change in the energy system and generation mix
- Value shift from power plant to system management
- Entry of new players, disruption and convergence of value chain

Source: EY analysis

Electricity demand will grow largely driven by non-OECD countries and pace of e-mobility deployment

Global electricity demand (TWh '000)



Lower demand growth in mature markets…

- Lower rates of ***economic growth***
- ***Efficiency improvement*** measures and declining share of energy-intensive industry
- ***High levels of appliance ownership*** with little scope for further increase
- Electrification of fossil fuel-based sources, e.g. ***e-mobility proliferation*** remains a ***wild card***

…Partially offset by acceleration in developing markets:

- ***Faster economic growth***
- ***Industrialization and urbanization***
- ***Expansion of electrification*** to remote areas
- Rapid ***uptake of appliances*** and cooling systems

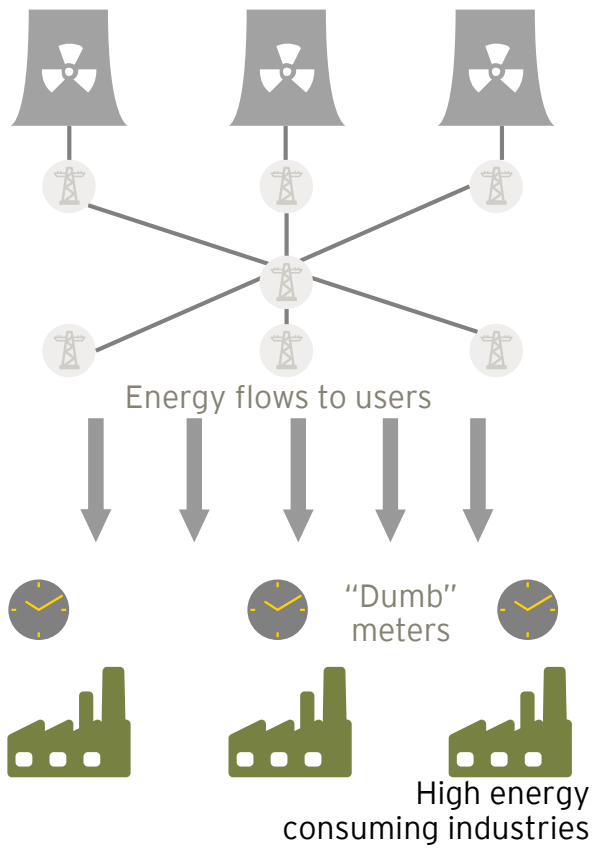
Developing markets contribute 87% of electricity demand growth to 2035, of which India and China to account for 48%

Source: International Energy Agency's World Energy Outlook 2016, EY analysis

Evolving energy system triggers the generation mix change

"Industrial" Age Energy System

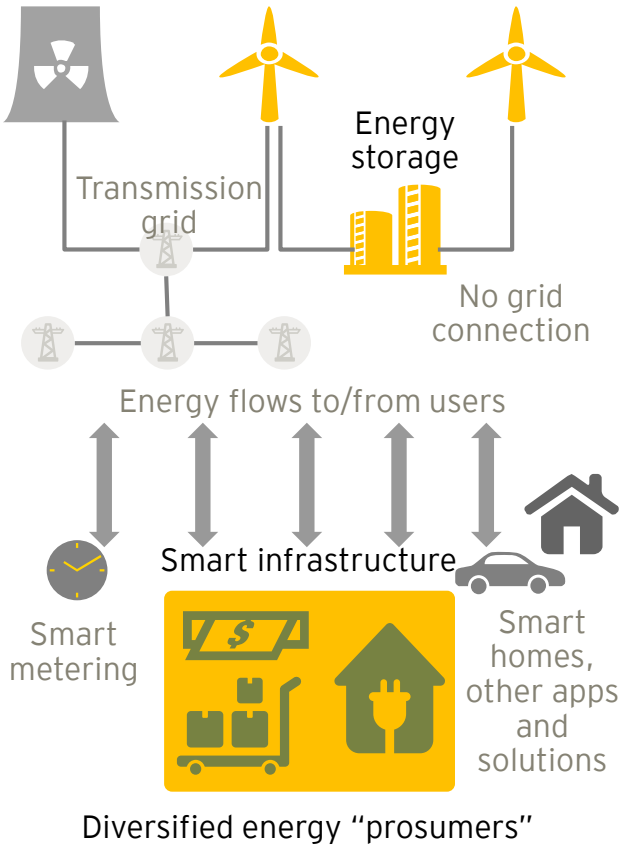
Large capacities:
0.5-2GW



"Smart" Age Energy System

Large capacities:
0.5-2GW

Small capacities -
Up to **20MW**



Key changes

- Rise of ***diversified distributed*** generation and ***energy storage***
- Energy "uberi-zation" in mid-term
- Flexible and fluid ***two way*** infrastructure
- Shift to ***smart cities*** and ***digital grid*** infrastructure
- New ***IoT based B2B and B2C services:*** smart home, e-health, e-marketplace

...And how does the nuclear fit?

Source: Open sources, EY analysis

The fit of nuclear in the energy transition will be determined by four scenarios and regional focus

2035 Nuclear scenario highlights

Center led

- ***Key idea:*** Long-term base load capacity required to fuel growth. Central plants prevail, de-central – countryside phenomenon

- ***Core technology***: fossil-fuel, "traditional nuclear"
- ***Typical countries****: Fast growing economies (Egypt, Indonesia,…)

11%
523 GW

- ***Key idea:*** Regulation and public support drive transition to diversified supply, nuclear solves its technology issues

- ***Core technology***: nuclear and renewable, some fossil fuel
- ***Typical countries***: Traditional nuclear, China, India, Middle East,…

13%
563 GW

Market led

- ***Key idea:*** Fossil-dominated world driven by cost considerations – "good enough" for low demand.

- ***Core technology***: fossil-fuel
- ***Typical countries***: Less developed emerging economies

6%
282 GW

- ***Key idea:*** De-central plants take big share in generation; central generation is required to ensure security of supply

- ***Core technology***: renewable, CCGT
- ***Typical countries***: EU, US, smaller developed nations,…

8%
396 GW

Industrial growth — *Service driven growth*

XX% Share of nuclear in the energy mix in 2035 (11%, 380 GW today)

Source: EY analysis
*) For new build only

As a result nuclear players of the future will be radically different in the next 5-10 years

Nuclear players of the future – key dimensions affecting the change

We humans lack imagination, to the point of not even knowing what tomorrow's important things will look like

Nassim Nicholas Taleb, Author of "The Black Swan" and "Antifragile"

Products	▸ ***Small price competitive reactors*** to fit for decentralized landscape ▸ Proliferation into ***renewables*** ▸ Proliferation into ***energy solutions***
Technology	▸ Commercially viable fuel ***reprocessing, fractionation and decommissioning*** ▸ Spillover ***beyond nuclear*** (superconductivity, supercomputing, new materials, medicine,…)
Embedded capabilities	▸ ***Flexibility to shift resources*** as change occurs ▸ ***People*** – IoT specialist will add more value than traditional nuclear engineer
Ecosystem	▸ Network of ***partnerships*** with key nuclear players, R&D institutions, co-investors ▸ Not just sell– ***act globally*** as producer, investor and R&D/technology player

Delivering zero carbon base load power from construction through operations to waste disposal and flexibility in product offering and resource configuration becomes a decisive factor

Source: EY analysis

Nuclear players should take use of partnerships in transforming the industry into "new nuclear"

	Value proposition/Offer elements	Status/Time to Market
Small reactors	▸ Flexibility, ease of access, greater safety ▸ Operation in the heating mode (cogeneration of heat and power) ▸ Operation in the desalination complex	▸ Many projects: CAR EM 25 (Argentina), ABV-6E, KLT-40S, RITM-200, SVBR-100, VBR-300 (Russia), HTR-PM (China), SMART (Korea), mPower (US) ▸ **Commercial use by 2030-2040 (!)**
Waste management	▸ Reprocessing ▸ Fractionation ▸ Long term integrated back end and storage solution	▸ AREVA – La Hague, deployment of technology in China ▸ BNFL – Thorp ▸ Rosatom – Mayak, GChC, SgChE ▸ JNFL – Rokkasho
Fuel efficiency – GEN IV	▸ Better fuel utilization (repeated recycling) ▸ Minimizing waste, e.g. through plutonium utilization ▸ Reinforced safety and reliability	▸ 7 technologies[1] selected for further R&D ▸ **Commercial deployment by 2030-2040 (!)**

Decommissioning	▸ End of life of ~300 GW in 2030-2050 (1/5 of 2016 fleet)
	▸ Increasing safety, decreasing costs, timing and socio-economic impact of decommissioning projects
		▸ Focus on ***project excellence in partnerships with specialized*** firms to address:
		  ▸ Decommissioning unit set up in compliance with legislation
		  ▸ Revenue stream for disposal
		  ▸ HR management
		  ▸ Professional large-scale-project management

Source: Open sources, EY analysis

1) Gas-cooled Fast Reactor (GFR), Lead-cooled Fast Reactor (LFR), Molten Salt Reactor (MSR), Supercritical Water-cooled Reactor (SCWR), Sodium-cooled Fast Reactor (SFR) and Very High Temperature Reactor (VHTR), SVBR-100 - Lead Bismuth Fast Reactor