



Atom Expo 2016 Conference

Future scenarios: nuclear and renewables in the energy mix evolution

Position Paper
May 2016

Five key messages to remember

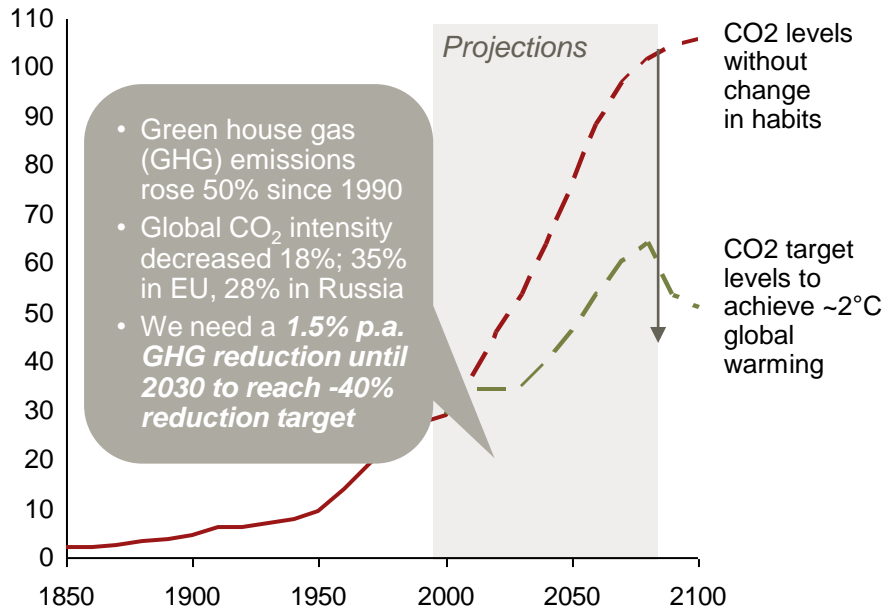
- Both **nuclear and renewables are critical** to reduce green house gas emissions and **reach CO₂ target** as well as ensure **security of supply and industrial and economic development**
- With a similar set of defining characteristics, **nuclear provides the energy backbone for nations in industrial transition**, while **renewables drive flexible decentralized solutions** for a diversified economy
- Nuclear faces a stiff competition: **renewables are becoming cheaper and attractive** to a broader investor pool. However, **‘non-market’ development** of renewables may lead to significant excess capacity and situations with "extreme prices" – **market out of balance**
- Going forward, **nuclear will remain a part of the energy mix ranging from 6 to 12% of global electricity supply**, depending on the energy demand and competitiveness of other technologies. The scenarios will **profoundly change the nuclear value chain**, posing new demands for OEMs, Operators and Investors
- To cope with the challenges **nuclear players must diversify their value proposition** to embrace an integrated solution for economic growth, of which **renewable energy is a primary component**

Contents

- **Context and challenges**
- Our perspective on energy mix development and scenario planning

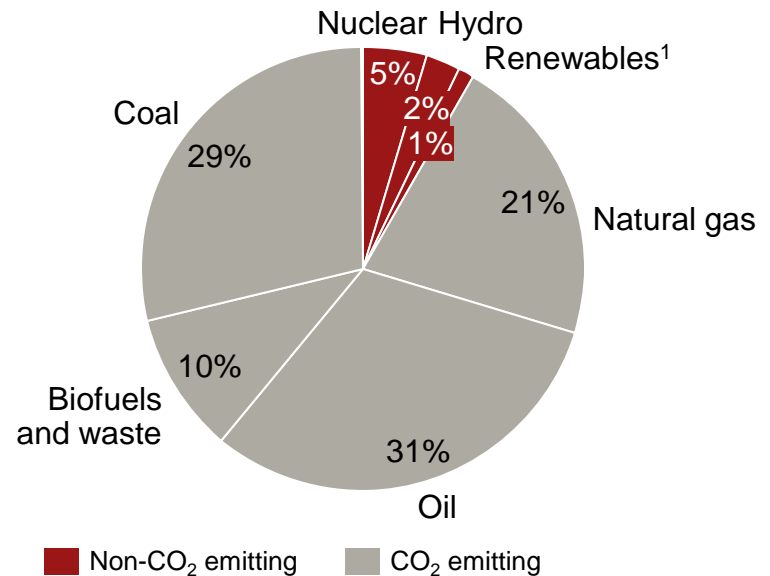
From a global perspective climate protection is an important argument for energy transition to non CO₂ emitting sources

CO₂ levels in the air 1850-2100p, Gt CO₂/year



- Decoupling of GHG emissions and economic growth is much needed to protect climate
- Levers to maintain CO₂ target levels
 - Innovation in low CO₂ emission/ CO₂ capture technology
 - Reduction of consumption and improved efficiency
 - **Switch to non-CO₂ emitting energy sources**

Primary energy consumption by fuel % of total world energy



- Historic growth of fossil fuels: increased 67% from 53% in 1990. Coal doubled it's usage in power generation
- With rising energy consumption current primary fuel mix will need to change if CO₂ targets are to be met
- Besides CO₂ capture technologies, **only greater use of renewables and nuclear can help achieve CO₂ targets**

¹. Includes solar, wind, heat, geothermal, etc.
Source: RCP database, AR5 Report, IEA, A.T. Kearney

Security of supply as well as industrial policy and economic development are the other motives for global energy transitions

Objectives of Energy-/Climate- Policy globally



Security of Supply

- Install new capacities and diversify the energy mix
- Reduce import dependency



Managing Growth of Energy Demand

- Expand supply to meet rising energy demand while keeping costs low
- Electrification of households in emerging countries



Cost Optimization of Energy Supply

- Substantially increased energy efficiency
- Increase competitiveness by using least-cost approaches for supply expansion



Reduction of CO₂ Emissions

- Low CO₂ power generation mix with global growth of conventional, nuclear and renewables in varying speeds
- Reduce local air pollution

Defining characteristics for nuclear and renewables:

- Limited access to traditional (fossil fuel) energy sources
- Security of supply in an isolated energy system (storage required for renewables)
- Leading regulatory role
- Innovation and “spillovers” to the other sectors of economy

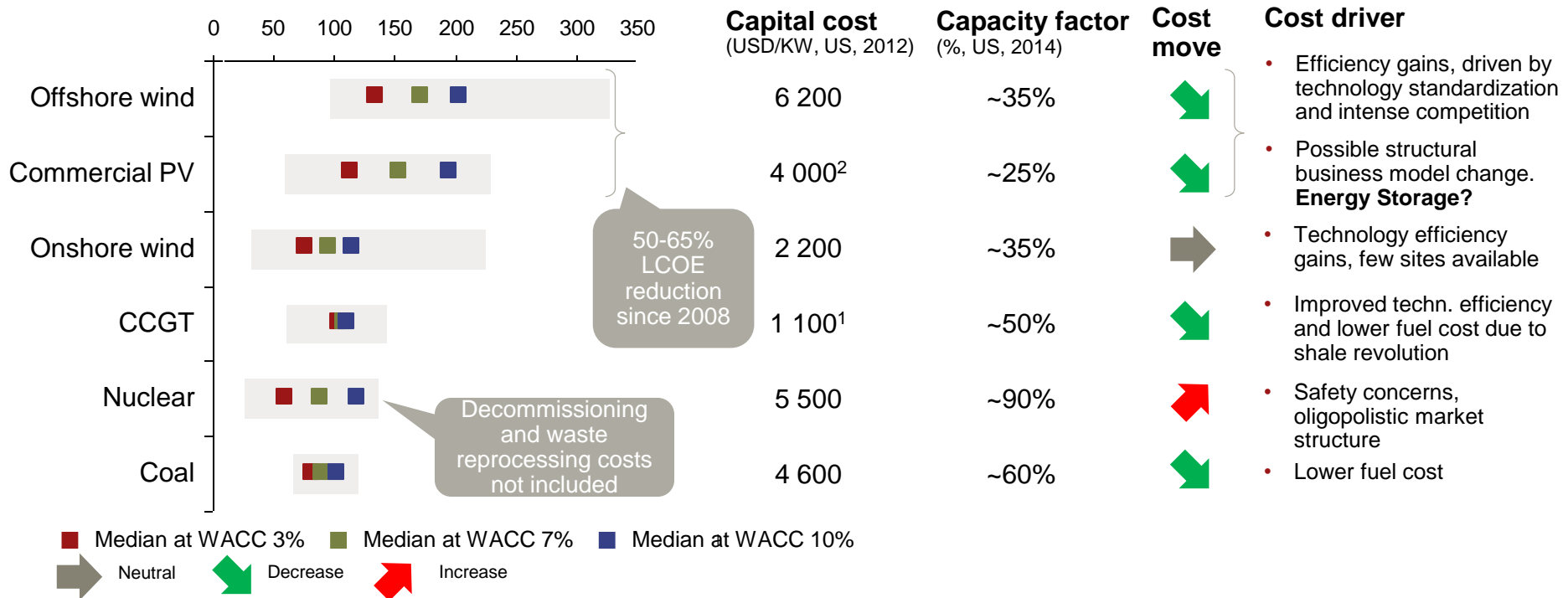
Nuclear provides the energy backbone for nations in industrial transition, while renewables drive flexible decentralized solutions for a diversified economy

Nuclear faces a stiff competition: fossil fuels are cheaper and renewables are “greener” and becoming cheaper too

Projected LCOE¹ by technology

Average 2013 USD/MWh for plants entering service in 2020

Selection



Nuclear is attractive to investors with low capital cost (such as governments); renewables appeal to a much broader pool due to size and guaranteed demand

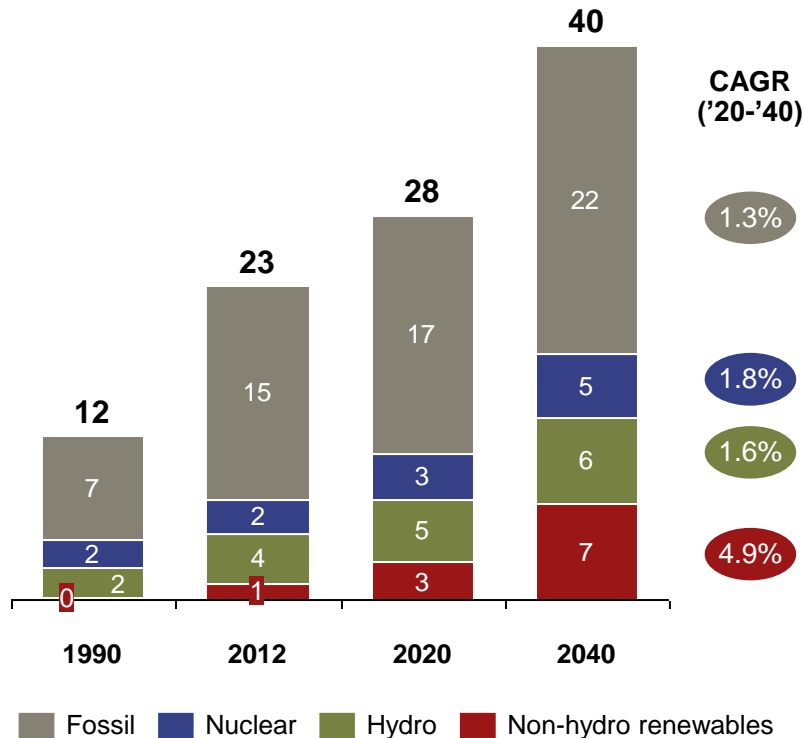
1. Levelized cost of energy
Source: IEA, A.T. Kearney

Renewables are expected to continue gaining importance in the global generation mix

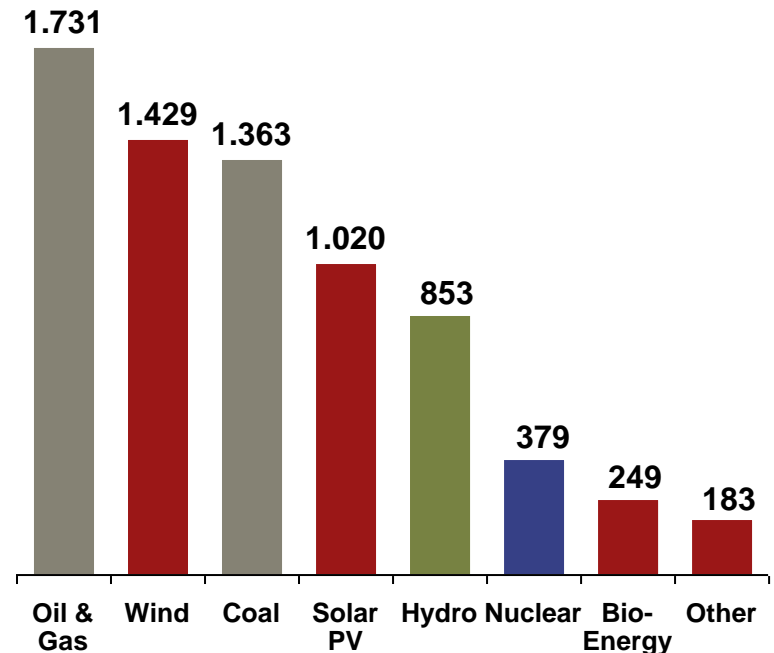
Global energy mix projections – reference scenario

IEA New policies

Production projections (10¹⁵Wh)

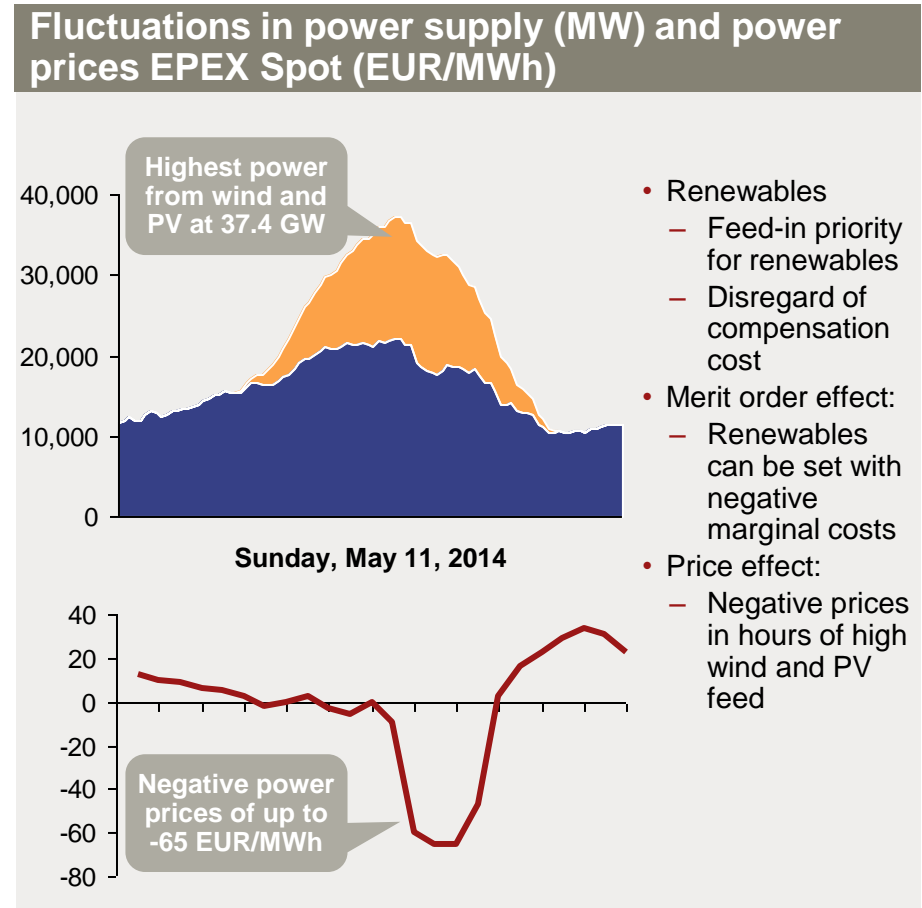
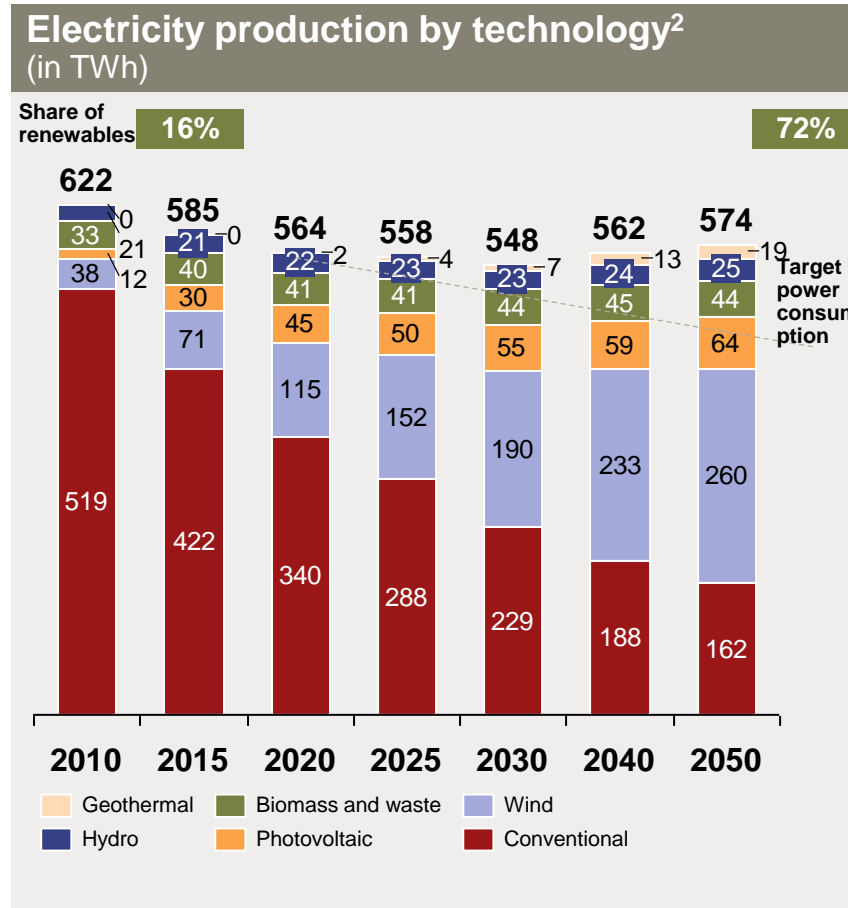


Cumulative gross capacity additions 2014-2040 (GW)



However, 'non-market' development of renewables may lead to significant excess capacity and situations with "extreme prices"

Forecast: electricity generation in Germany¹ and price impact



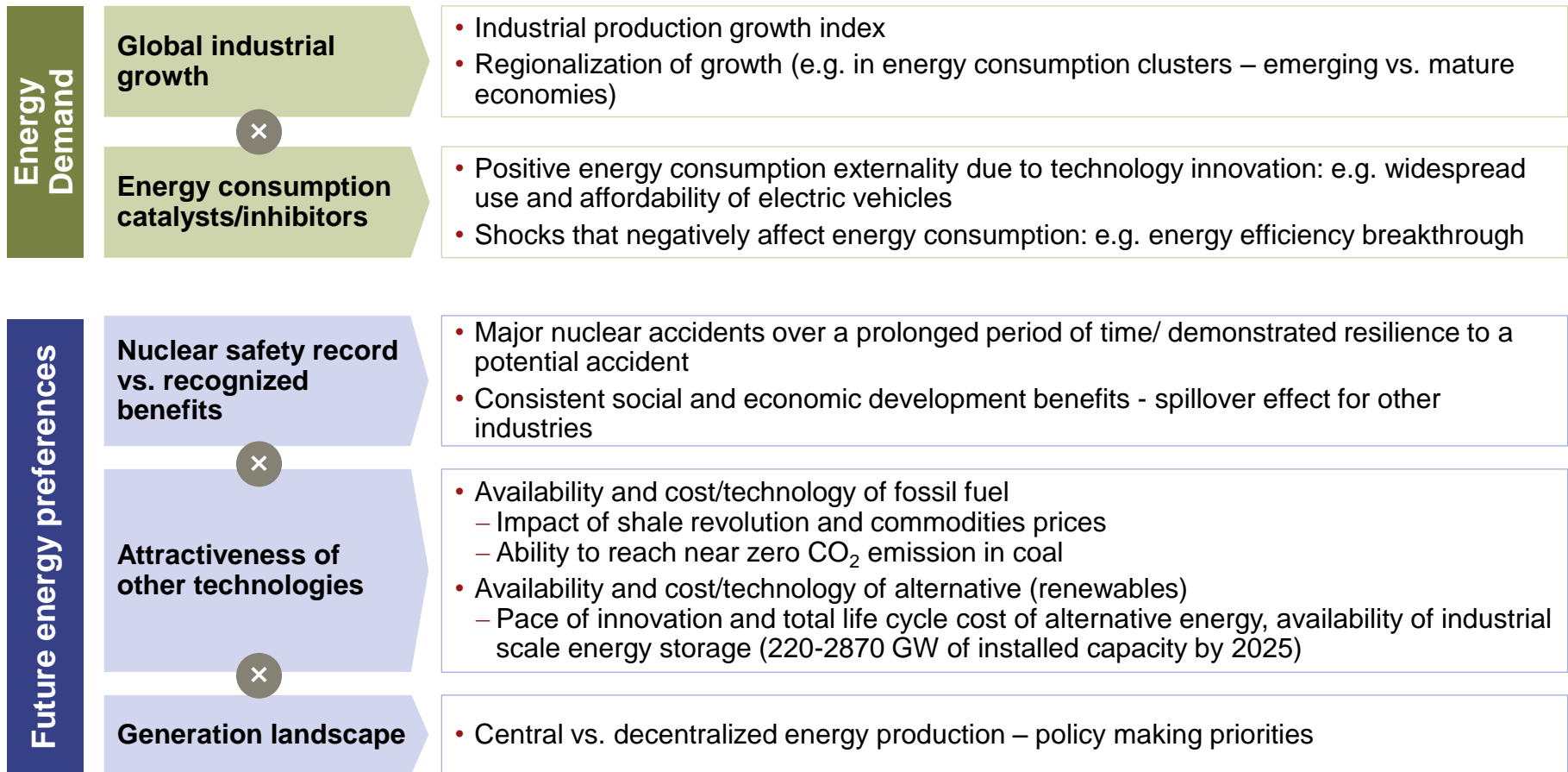
1. BMU Lead Study 2011 - 2011 Scenario A
 2. Figures exclude pumped storage and 'other'
 Source: BMU, AGEE Stat 2012; ENTSO-E; A.T. Kearney

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- **Our perspective on energy mix development and scenario planning**

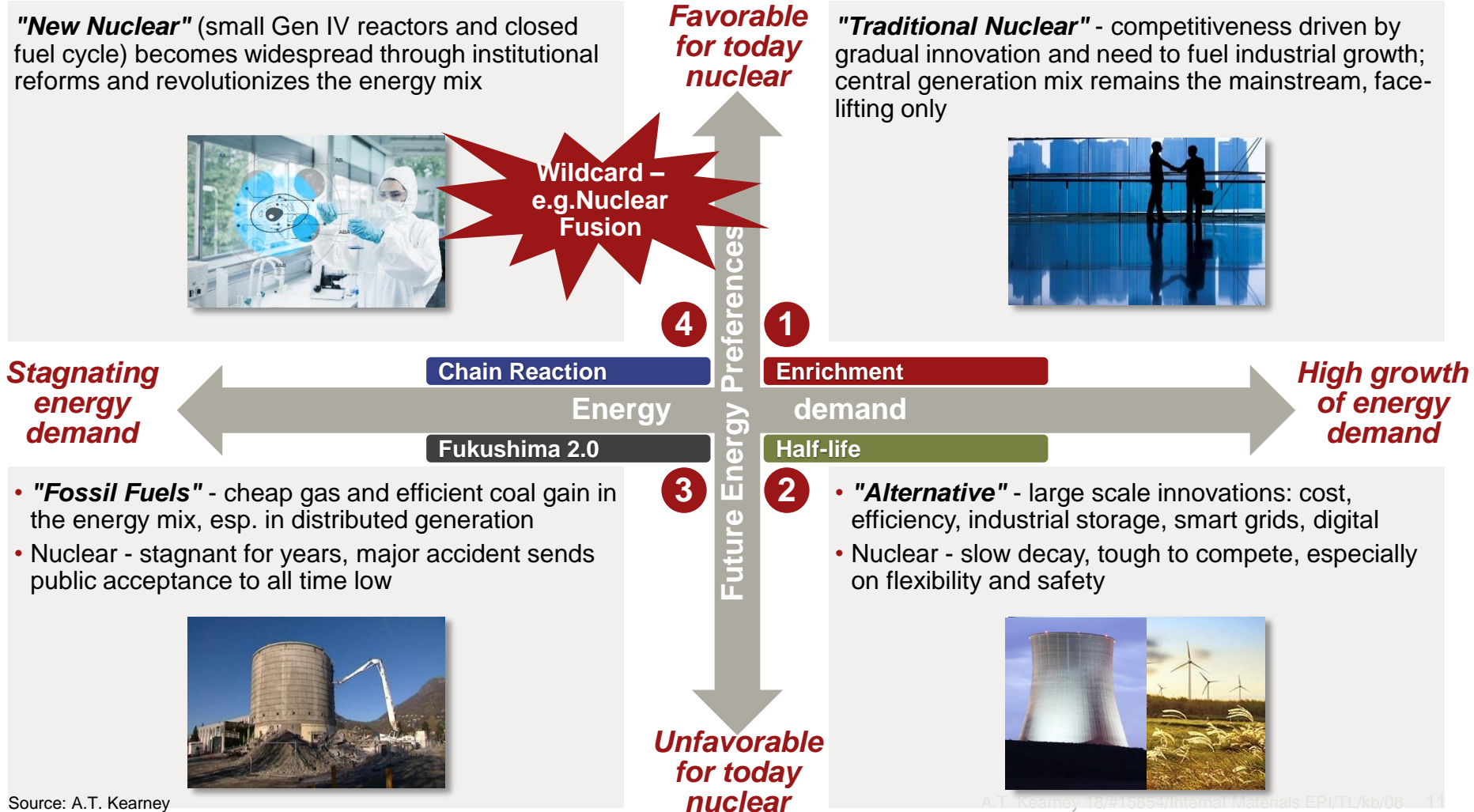
The nature of energy demand and future energy preferences will affect the energy mix going forward

Key macro factors for the energy mix evolution – focus on nuclear



Four nuclear scenarios emerge: the players will see significantly different challenges under each of the scenarios

Scenario overview

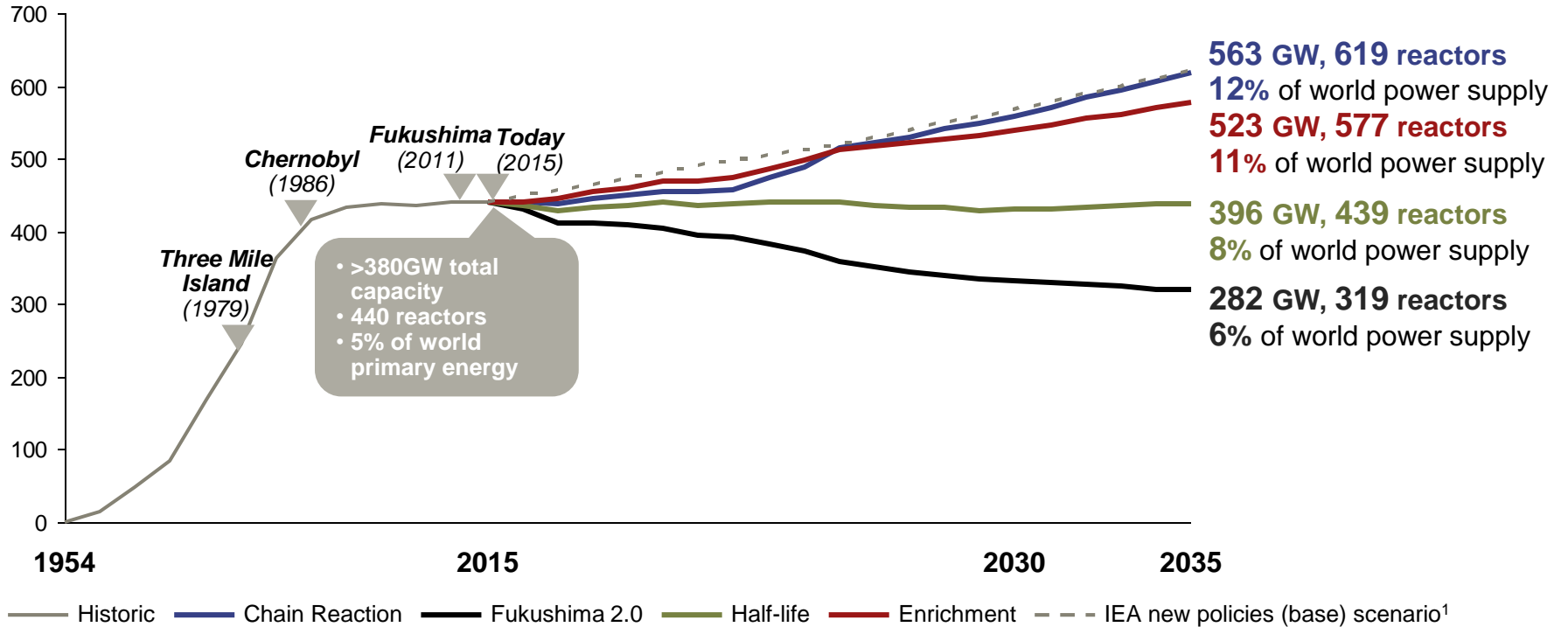


With chosen assumptions by 2035 nuclear will still be a part of the generation mix landing in the range of 6-12% of the total

Nuclear in the energy mix by scenario

(# in operation and GW installed globally)

of reactors



1. New policies scenario: here extrapolation based on 2040 forecast value of installed capacity, recalculated for # of NPPs in operation
 Source: World Nuclear Association, IEA, A.T. Kearney

Under uncertainty the players should balance managerial innovations of today with institutional innovations for the future

Implications for nuclear players

	1 Enrichment	2 Half-life	3 Fukushima 2.0	4 Chain Reaction
Nuclear OEMs	<ul style="list-style-type: none"> • Drive volumes globally via integrated approach (BOO financing, localization, waste management, new products); • Decrease costs 	<ul style="list-style-type: none"> • Standardize technology platform (VVER-TOI, EPR revised), reduce cost: Opex/Capex, improve serviceability • Diversify portfolio 	<ul style="list-style-type: none"> • Develop decommissioning and waste management • Use nuclear capabilities in new applications and industries, diversify product portfolio 	<ul style="list-style-type: none"> • Decrease costs/ improve time to market of new nuclear R&D projects
Operators	<ul style="list-style-type: none"> • Invest in efficient nuclear solutions and competitive kWt/h 	<ul style="list-style-type: none"> • Extend life of existing plants • Only targeted investments 	<ul style="list-style-type: none"> • Safety upgrade, conservation of existing plants • Rapid development of alternative sources 	<ul style="list-style-type: none"> • Invest in new nuclear projects
Investors (e.g. governments)	<ul style="list-style-type: none"> • Demand nuclear ecosystem and augmented solutions (e.g. desalinization) 	<ul style="list-style-type: none"> • Cut subsidies to nuclear • Promote alternative technologies – R&D support rather than subsidies! 	<ul style="list-style-type: none"> • Demand rapid phase out of the nuclear • Change institutional framework to favor alternatives 	<ul style="list-style-type: none"> • Develop institutional framework to make new nuclear commercially attractive • Build spent fuel market

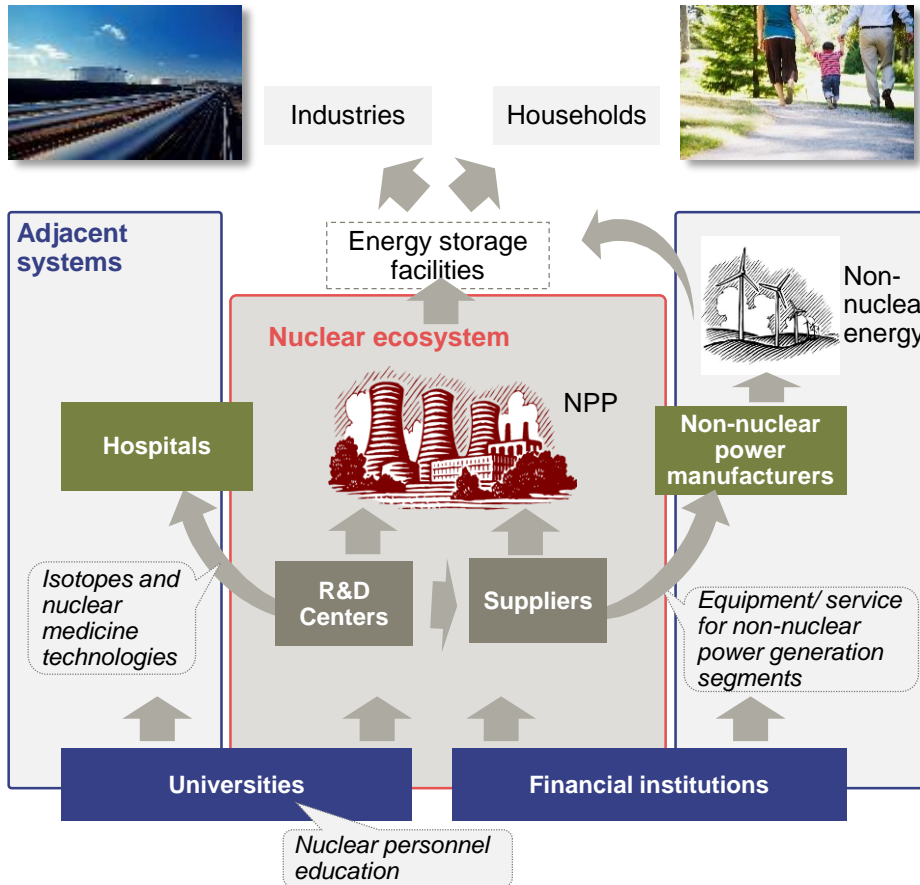
Managerial Innovation – “Do Better”

Institutional Innovation – “Do Differently”

Ensure safety and cost competitiveness while driving commercial attractiveness of technology innovations

Nuclear players must diversify their value proposition to embrace an integrated solution for economic growth

A model to develop within the ecosystem




Adjustment of value proposition - core offer beyond NPP


- Product range diversification:
 - Energy solutions beyond nuclear (desalination, renewables)
 - Nuclear solutions beyond energy (medicine)
- Financial solutions in partnership with local financial institutions or project finance provided by OEM
- Localization and supplier integration
- Augmented solutions in fuel, maintenance, service
- Spillover effect on adjacent industries (transport, education, banking, water, services, etc.) - increase of investment attractiveness

Integrated solution for economic growth


Large European utilities are already acknowledging the fact that the scenario is changing and building-up RES portfolios



- 9.8MW of RES
- EBITDA (14): €1.5bn RES Vs. €2.2bn conventional
- Conventional generation spin-off, focus on RES, grid & customer solution
- Next investments: on- off-shore wind
- Focus on distributed generation
- Fostering build & sell business
- Lobbying for capacity markets




- More than 14.5GW of RES, €1.3bn EBITDA (22% of group)
- Expanding capacity beyond Spain: UK, US, MX, BR. Mainly wind
- More than 22% of CAPEX dedicated to renewables in 2014-16
- Proactive regulatory fight against DG in Spain. Recent launch of DG products in Spain (Q3 2015)




- 1.8GW of wind & biomass, ex-hydro (11GW)
- Goal: Achieve greater growth in RES than market. Transform organization to achieve growth
- RES aligned with customer demand / integration into market
- Develop partnering models
- Search for cost leadership



- EDF Energies Nouvelles, 7.9GW (87% wind, 10% solar), + 1.9GW under construction. €650m EBITDA
- Further internationalization – stable countries
- Proactively looking for RES portfolios to acquire
- Thinking on build & sell business. All along value chain



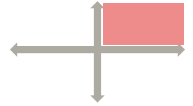
- EGP – 10GW, 744 plants, 17 countries and €1.9bn EBITDA. Integrating into ENEL Group
- Wind, solar, hydro, geothermal, biomass
- Current focus on N. America, LatAm (BR), South Africa, Turkey
- Commercially aggressive
- High focus on VAS in retail division. DG plans ready



- Renewable assets under Innogy – 3GW (inc. hydro)
- Current focus on efficiency - asset management perspective
- Focus on on- and offshore wind > ~ €1 bn in growth capex (2015-2017)-
- Partnerships to diversify risks and leverage project pipeline
- > Double digit revenue CAGR in next 3 years

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- **Annex: Scenarios' description**



Scenario 1 – Enrichment

Central Idea

Sustained global economic growth and high energy consumption by electric cars and other energy consuming sectors drive deficit in both developed and emerging nations. Alternative and fossil fuels also develop, but gradually without a step change. Public opinion turns to nuclear as a safe source to fuel growth. Nuclear players use this window of opportunity to further improve their offerings, which in turn fosters competitiveness

523 GW of installed capacity by 2035 (11% of world power supply)

Scenario Highlights

- US accelerates industrial growth trajectory, moderate industrial growth in Europe (especially New EU) and even Russia lessens political confrontation and starts to attract investors and modernize its industries
- Globalization leads to growth spillover onto the developing countries, which, together with continued urbanization, gives them another boost. Even Sub-Saharan Africa achieves some stability and starts to grow.
- Advancements in energy storage make electric cars and data centers explode and emerging countries are hungry for energy (and other commodities, such as e.g. water). They also make central generation mix of nuclear more flexible.
- Alternative energy develops but gradual innovation is not enough to make it widely acceptable. Fossil fuel players enjoy high prices, which limits their propensity to innovate
- Public opinion welcomes nuclear that translates in significant new order backlog and a window of opportunity opens up.
- Players enjoy short term profits from volume increase and cost reduction due to platform standardization but balance investments into “business as usual” with driving management innovation in nuclear to be even more competitive



Scenario 2 – Half-Life

Central Idea

Global economy growth drives energy demand through structural changes: electric cars in the developed world and rapid urbanization of developing countries. However the other technologies benefit more from this growth: alternative sees major cost breakthrough, while gas and coal offer flexible (small) and efficient solutions. Nuclear is seen as “necessary evil” by the public as it struggles to adapt to a “greener” and more decentralized energy mix

396 GW of installed capacity by 2035 (8% of world power supply)

Scenario Highlights

- Fueled by strong demographics and productivity gains US keeps the industrial growth momentum, Europe finally overcomes challenges and returns to moderate growth
- China cools off softly, but its growth momentum is replaced by exploding MENA economies, Iran’s reemergence and more stable political regimes in Africa.
- Global growth drives energy demand despite efficiency gains:
 - Electric cars and data centers boom in developed countries
 - Rapid urbanization in developing countries drives infrastructure projects and megacities
- Large scale innovation in other power sources
 - Major efficiency gains in renewables and advances in battery technology, allowing to deal with peaks, see them proliferate
 - High commodities’ price limits innovation in coal and gas yet players excel in flexibility – e.g. in decentralized generation
- Nuclear technology proves “solid”, no accidents, some gradual advancements, e.g. in platform standardization, but public opinion criticizes it for the lack of flexibility (e.g. doesn’t fit the decentralized generation mix), high upfront investment and unsolved environmental issues
- Players compete to “do well what they’ve used to do”, adapt product offerings and adapt the value chain



Scenario 3 – Fukushima 2.0

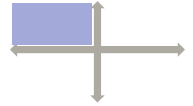
Central Idea

With global economy cooled off, advancements of shale and affordable oil and gas prices fossil fuels gain share in the energy mix. At the same time another nuclear accident even of a smaller scale than Fukushima triggers very negative public opinion. Developed nations exit nuclear: advanced scientific projects are scrapped, accelerated decommissioning becomes a norm.

282 GW of installed capacity by 2035 (6% of world power supply)

Scenario Highlights

- US and Europe display little or no industrial growth, Russia falls deep into recession and political crisis
- China's economy is hit by the "hard" landing, Middle East experiences some growth but cannot overcome religious and cultural divide, while Africa remains politically unstable. A positive power capacity surplus is created.
- New cheap coal and efficient gas generators achieve next to zero emissions at very competitive cost supported by low commodities prices and become the energy trend setter. Advancements in distributed generation cater to public demands for more flexible generation mix. Alternative looks too expensive to pursue under the economic constraints
- Nuclear technology stagnant for years, Russian, Chinese and Korean players still market 'time-proven' solutions to the third world countries. At the same time another nuclear accident even of a smaller scale than Fukushima triggers very negative public opinion and protests throughout the world
- Developed countries (US, UK) embark on rapid phase out among safety concerns, new reactor projects (Poland, Hungary) are scrapped, advanced scientific projects stopped and abandoned. Plants in France, Russia and China remain till the end of their life cycle but with low economies of scale cost rises and they remain subject for public scrutiny



Scenario 4 – Chain Reaction

Central Idea

Amidst little or no growth in energy demand when slow industrial growth is offset by energy efficiency gains, other generation technologies exhibit only gradual innovation. At the same time with a track of prolonged zero accidents, nuclear demonstrates proven potential to address core issues, which is made commercially attractive through the series of institutional reforms thus sparking a Chain Reaction

563 GW of installed capacity by 2035 (12% of world power supply)

Scenario Highlights

- Slowdown of industrial growth globally – a “semi-hard” landing in China has a profound impact on the industrialization in the emerging countries, India is unable to replace China as a source of growth, while Africa is hindered by political instability. ME (with Iran sanctions lifted) remains the source of growth but the deeply divided region can’t take full advantage of it. US industry growth slows down, while Europe struggles to reignite the growth engine and Russia is stuck in stagnation
- There is some growth in electric vehicles, but not explosive, while energy efficiency is on the rise to compensate for the little or no growth environment
- Growing resource scarcity, “green” CO₂ concerns negatively affect proliferation of fossil fuel, while cost of alternative energy remains prohibitive for a widespread unsubsidized use
- Nuclear demonstrates a track record of no major accidents with the conventional reactors. At the same time closing the fuel cycle, developing a safe fast neutron reactor and a long needed small reactor become technically sound solutions. Public opinion reacts positively and the institutions push forward set of reforms to promote “new nuclear” solutions
- This triggers a chain reaction...