WORLD NUCLEAR UNIVERSITY

# The World Nuclear Industry Today
November 2020, Online, Brazil

MZConsulting

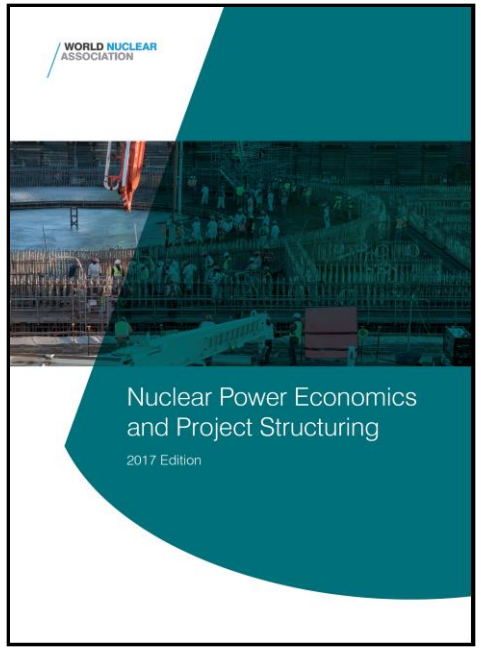
# Nuclear economics, project structuring and financing

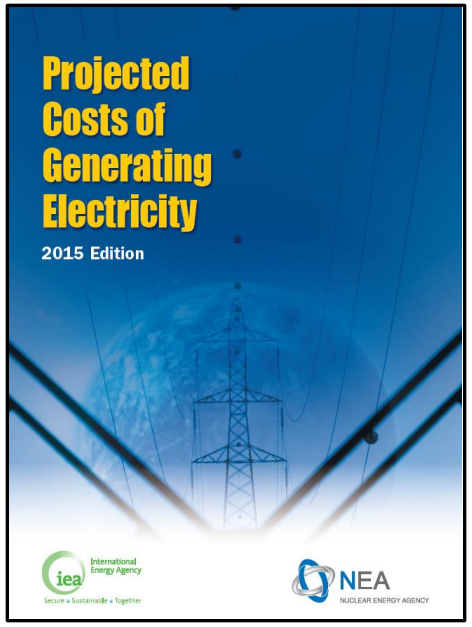
**Milton Caplan**
**President, MZConsulting Inc.**

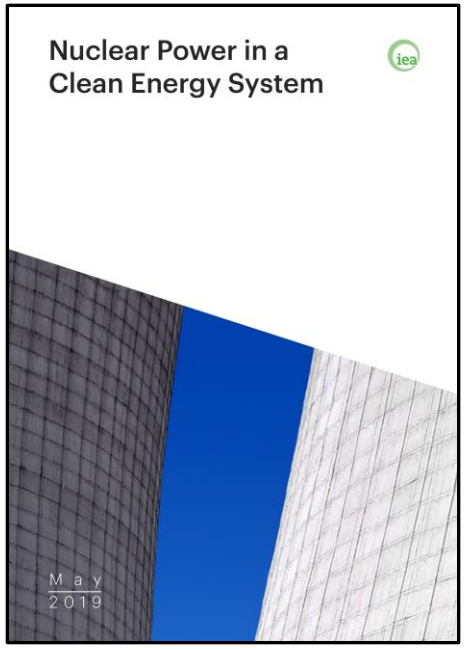
# Outline of today's presentation

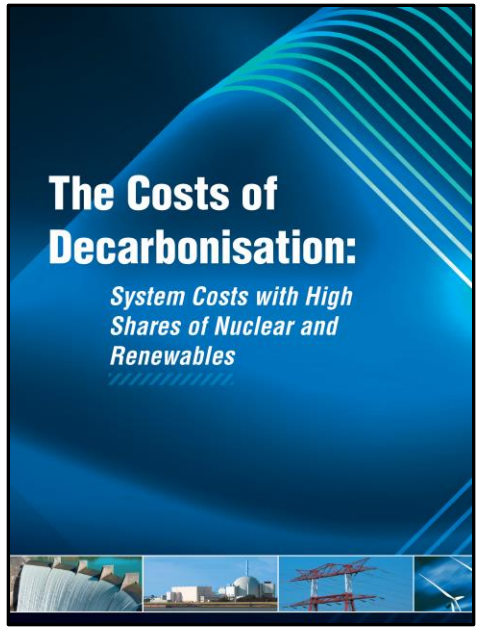
- Introduction
- Electricity and its importance to modern life
- Understanding the cost structure of nuclear plants
- A path forward to project success
- Summary and discussion points

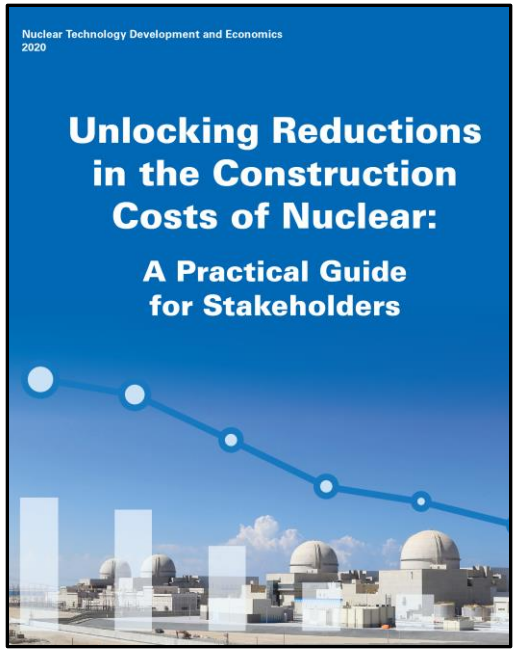
# Recent Reports



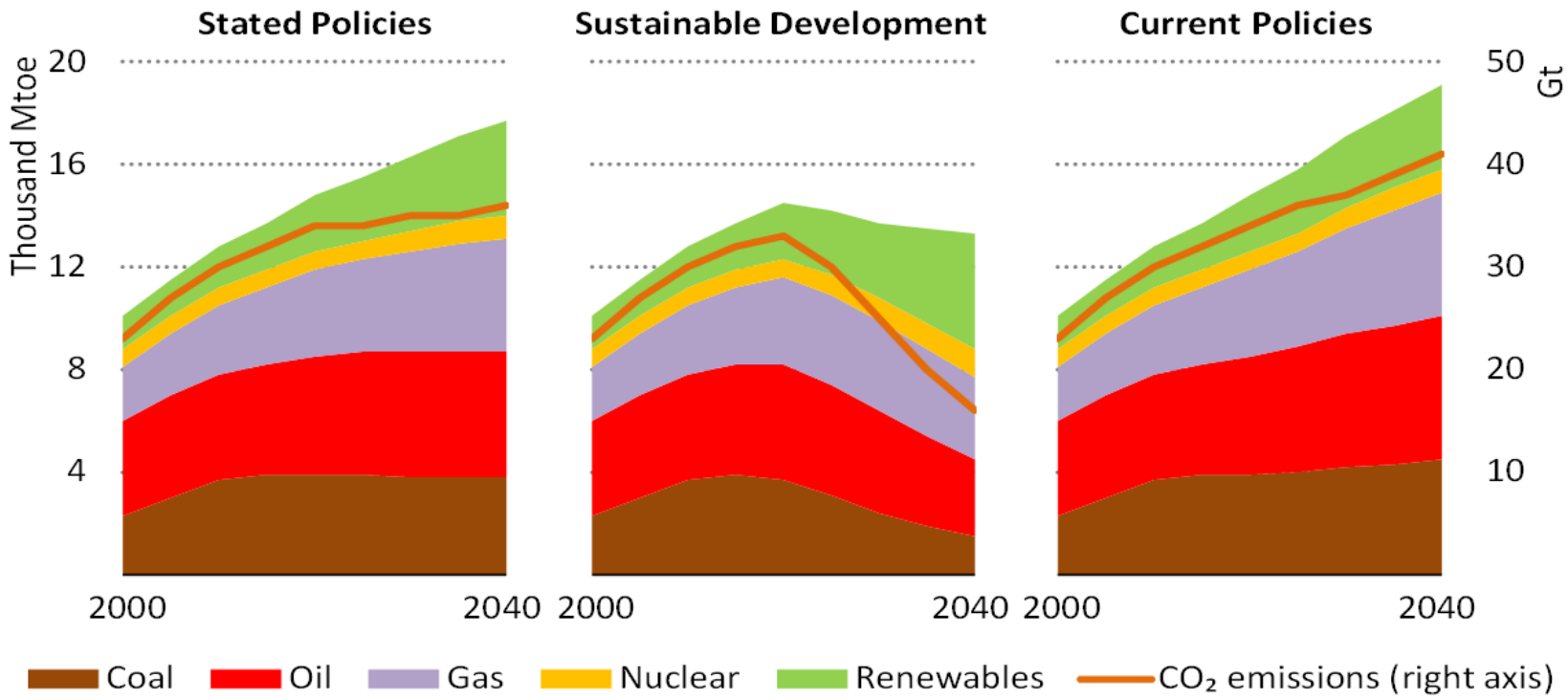



# Measuring Success

- For global success, nuclear must demonstrate that it is competitive in an economic sense. The industry can focus on improving public acceptance and demonstrating a need for low carbon generation, but only a cost competitive nuclear industry will really meet its full potential
- Nuclear has been and continues to be economic relative to the alternatives in most jurisdictions.
- As Nuclear is capital intensive with long project schedules and has low operating costs due to low cost of fuel, its cost of energy is very sensitive to both the capital cost and the cost of capital
- Rapidly increasing the share of variable renewables is driving up system costs and requiring large amounts of excess generation. As a system approaches full decarbonization, a system with nuclear is always lower cost than a system with renewables alone.
- Lower and predictable nuclear plant costs can be achieved by aggressively managing project risk with owners taking on a strong leadership role for project success

# ELECTRICITY AND ITS IMPORTANCE TO MODERN LIFE

# The World needs Energy



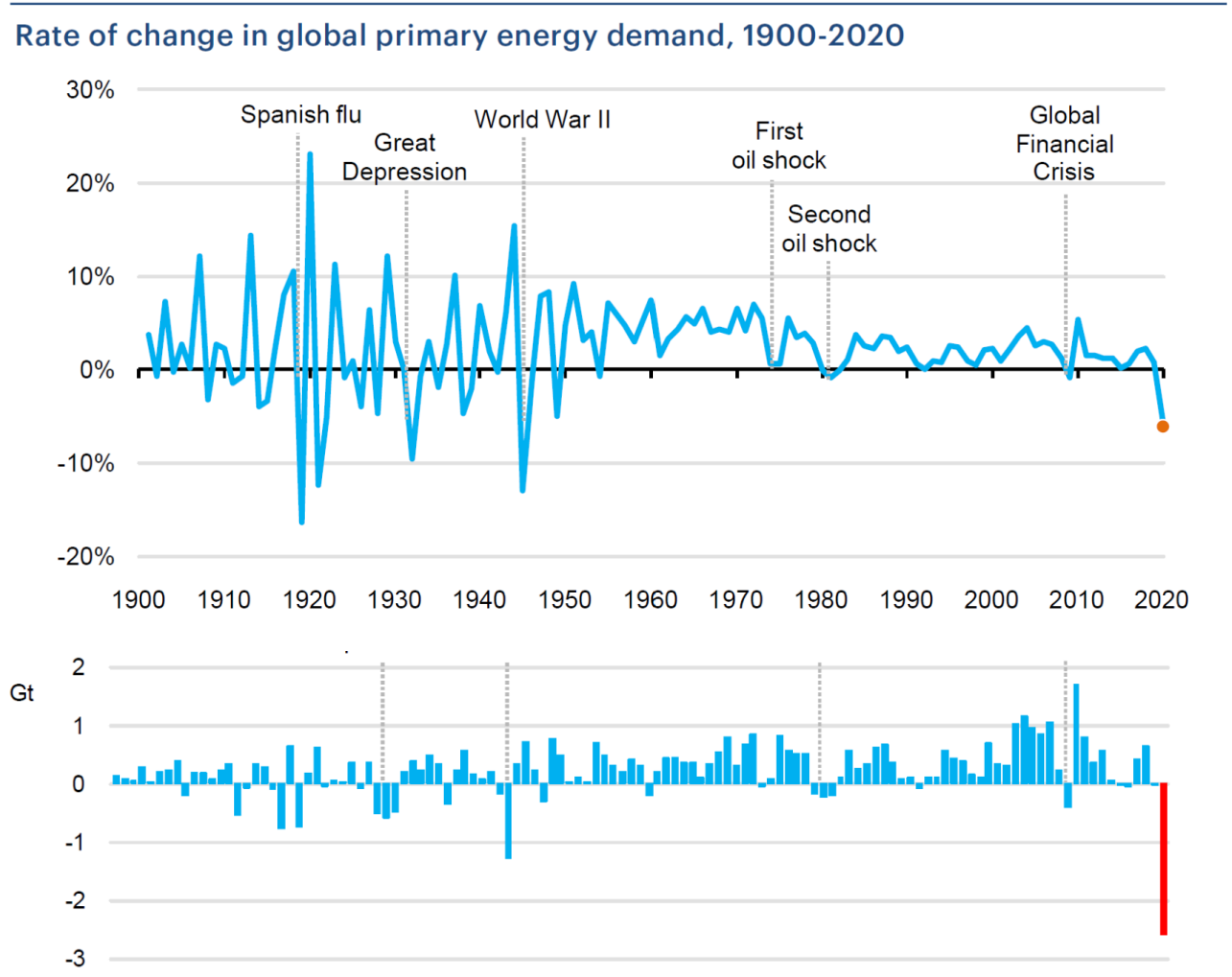

**World Primary Energy Demand by Fuel and Scenario**

Source IEA "World Energy Outlook 2019"

**Need Energy to be:**

- **Affordable**
- **Reliable**
- **Secure**
- **Clean**

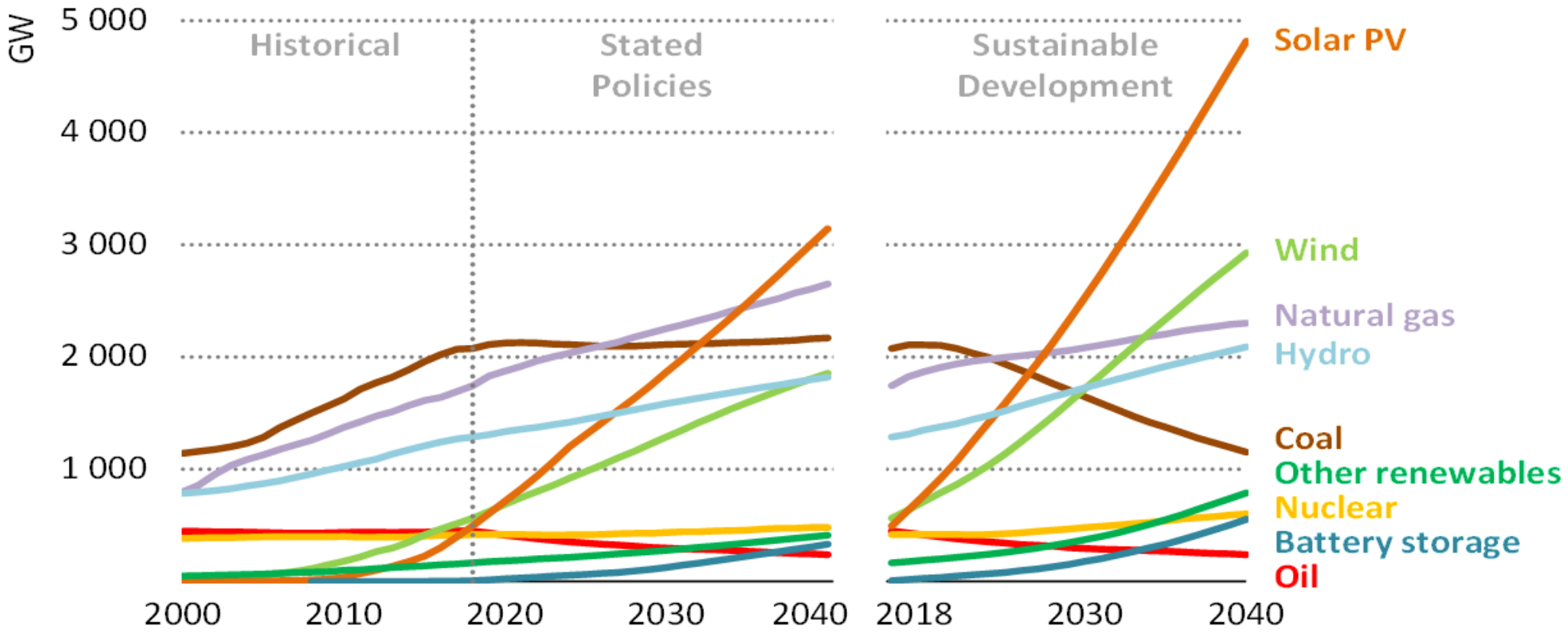
# The COVID pandemic has reduced demand – but not the need




- **Energy enabled people to work from home, stay warm and meet their needs**
- **Shutting down the economy is not the answer to decarbonizing**
- **We need abundant clean energy to secure our future**

Sources: IEA "Sustainable Recovery" 2020

# Electricity is the clean energy currency of the future

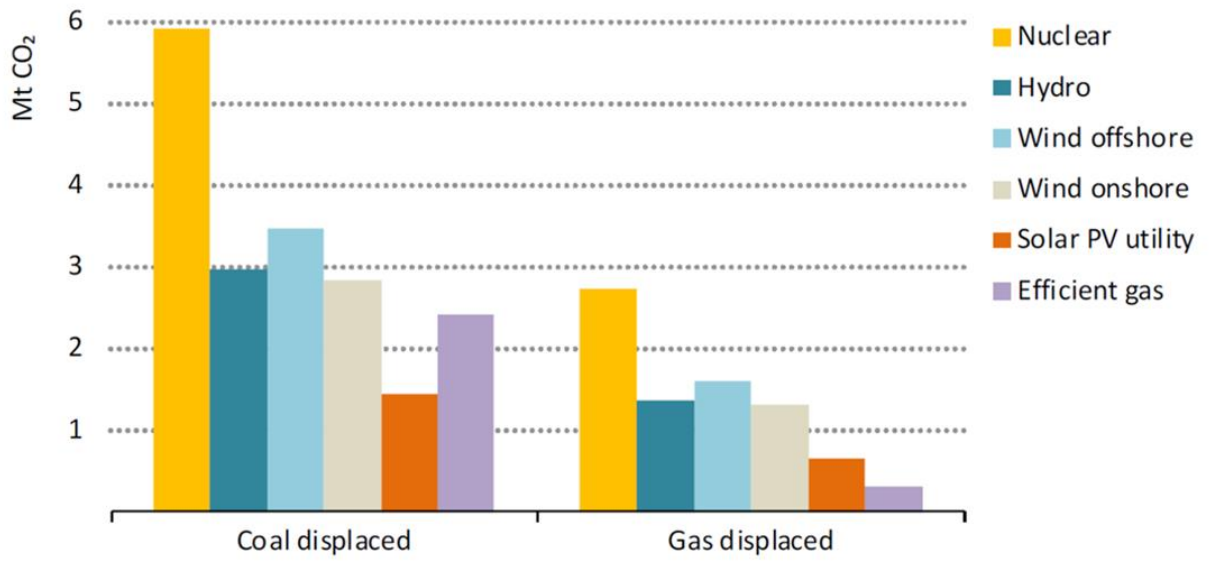



## Global Electricity Generation by Source

Source: IEA "World Energy Outlook 2019"

# Nuclear Power is low carbon generation

**Figure 2.8 ▷ Annual direct $CO_2$ emissions avoided per 1 GW of installed capacity by technology and displaced fuel**




*Nuclear power avoids more $CO_2$ emissions per GW of capacity than other fuels.*

Notes: Mt $CO_2$ = million tonnes of carbon dioxide. Efficient gas refers to combined-cycle gas turbines. Applied capacity factors are current global fleet averages for nuclear power, hydro and efficient gas, and global averages for new projects completed in 2019 for wind offshore, wind onshore and solar PV.

Sources: IEA “Sustainable Recovery” 2020

# Not all electricity generation is equal

- Cannot be easily stored – so supply and demand must always be in balance
- Reliability of generation is vital – customers do not accept the lights going out!
- Therefore need a stable grid – combination of reliable generation and a reliable delivery system (transmission and distribution)
- Huge variations in electricity demand according to time of day and year
  - Pattern is also country-specific – climate, industrial structure, etc.
  - Base load – that part of demand which is steady throughout the day and year
  - Peak load – the additional supply required to meet the additional demands during the day
- Different generation options are suited to either base or peak loads – due to technology and economics
- Intermittency of variable renewables adds complexity to meeting this demand

# Developing Energy Policy is Complex

- Energy policy is essential to address issues such as:
  - Market structures
  - Security of supply
  - Energy poverty
  - Resilience
  - Environment
  - International competitiveness

# UNDERSTANDING THE COST STRUCTURE OF NUCLEAR PLANTS

# Categories of generation costs

- Investment (capital) costs including financing costs
- Fuel costs
- Operations & Maintenance (O&M) costs - fixed and variable
  - For nuclear, fuel cost includes used fuel management/waste disposal.
  - Decommissioning of nuclear plants is an additional investment cost, but comes many years in the future

# Costs and their time schedule

- Hydro plants – high investment costs and very low marginal costs – no fuel cost
- Gas plants – low investment costs but high marginal costs (gas price)
- Nuclear close to hydro - but more significant marginal costs (O&M and fuel)
- Coal fits between nuclear and gas – average investment costs and average marginal costs
- Renewables such as wind and solar have high investment costs, low marginal costs but resource is intermittent (creating system costs)

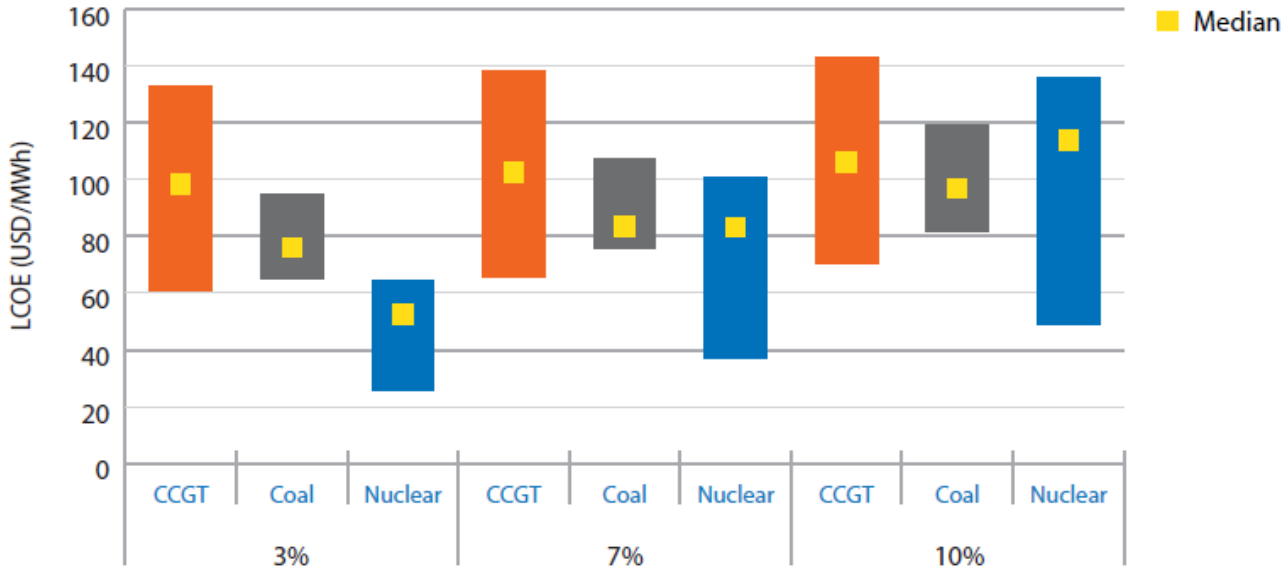
# Relative Cost Structure of Generation

- LCOE – Levelized Cost of Electricity
  - Defined as fixed price of electricity that will balance all of the costs over the plant lifetime on a discounted basis
- Nuclear projects are capital intensive and have long project schedules
- Gas plants are fuel intensive
- Coal plant are balanced

| General shares | Nuclear | Gas CCGT | Coal |
|---|---|---|---|
| Investment | 50-60% | 15-20% | 40-50% |
| O&M | 20-35% | 5-10% | 15-25% |
| Fuel | 15-20% | 70-80% | 35-40% |

# Economics of New Build Nuclear
# OECD Study (Baseload)

**Figure ES.1: LCOE ranges for baseload technologies** (at each discount rate)



# Competitiveness of Generation Options

- Nuclear has high investment costs, takes long time to come into operation, then has low and stable operating costs
- Gas plants have low investment costs, are built quickly and have high and variable operating costs
- Coal plants have moderate investment costs, are built relatively quickly and have moderate variable operating costs
- Which is the most economic depends heavily on:

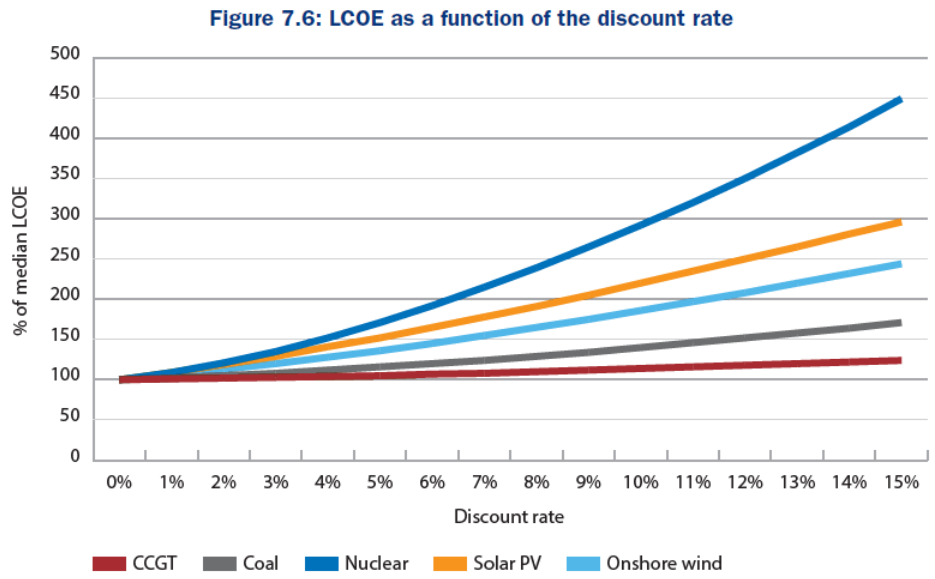
  (1) fossil fuel price and price for carbon, if any

  (2) interest/discount rate used

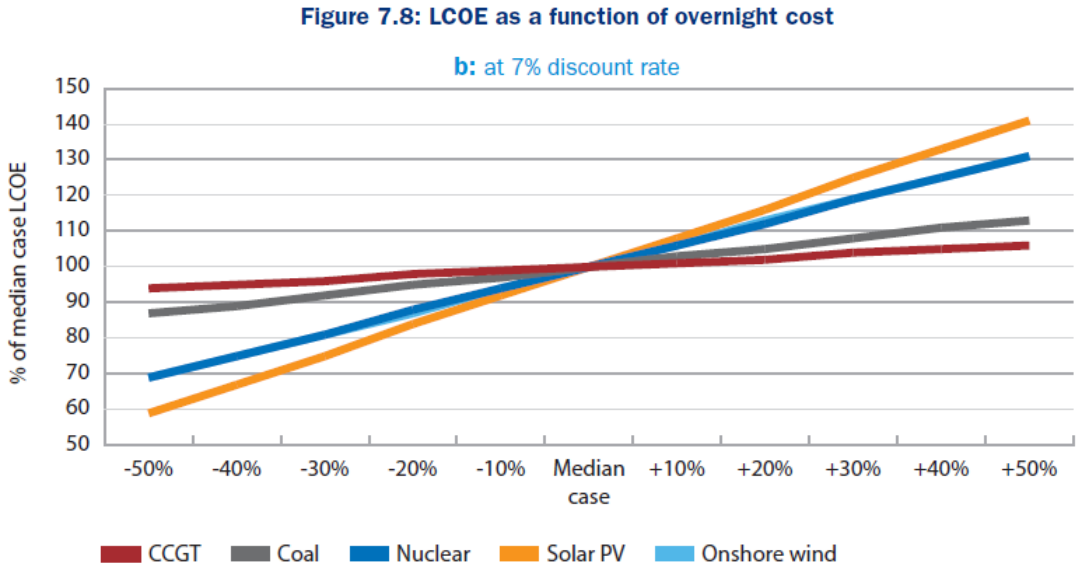
  (3) nuclear investment cost

# Energy cost sensitivity

## Cost of capital

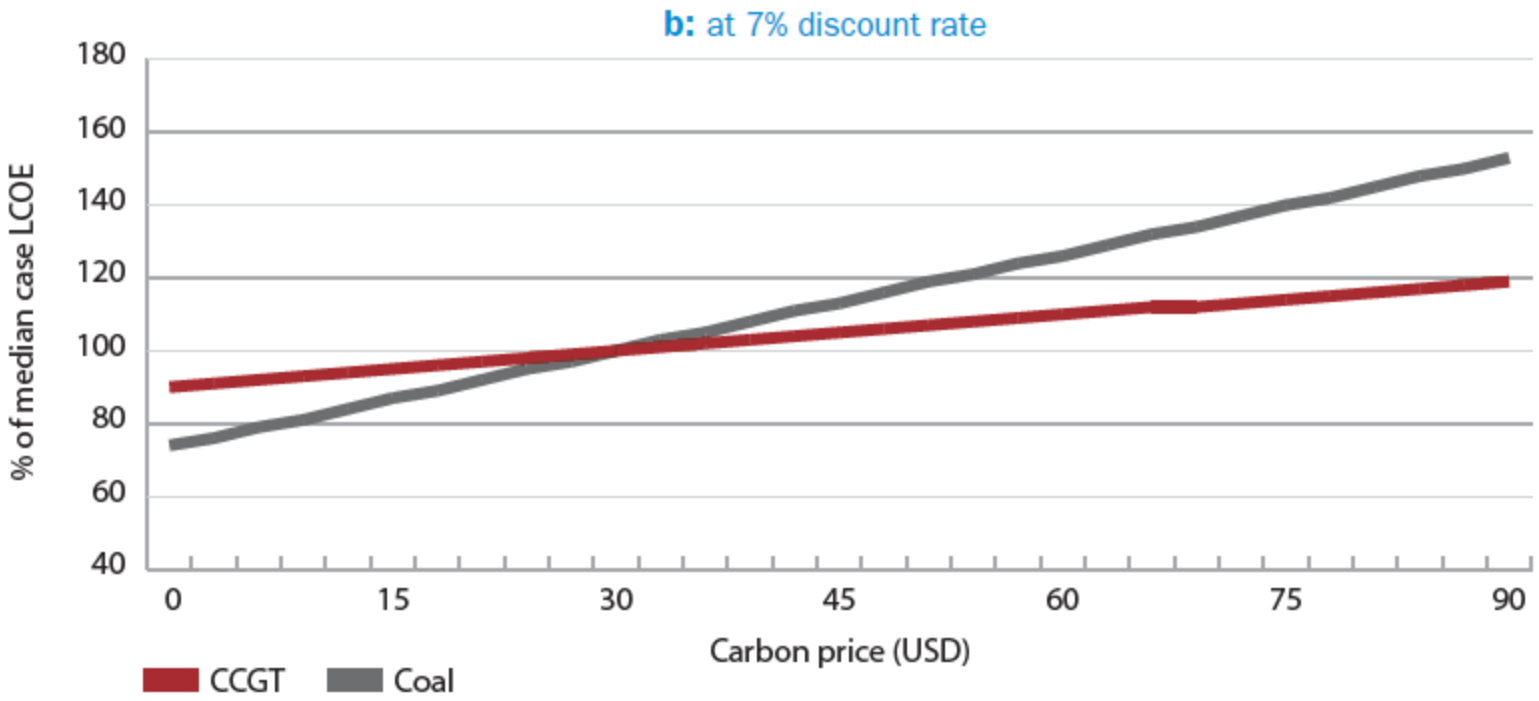



## Capital cost




Source: Projected Costs of Electricity, 2015 Edition, IEA and NEA

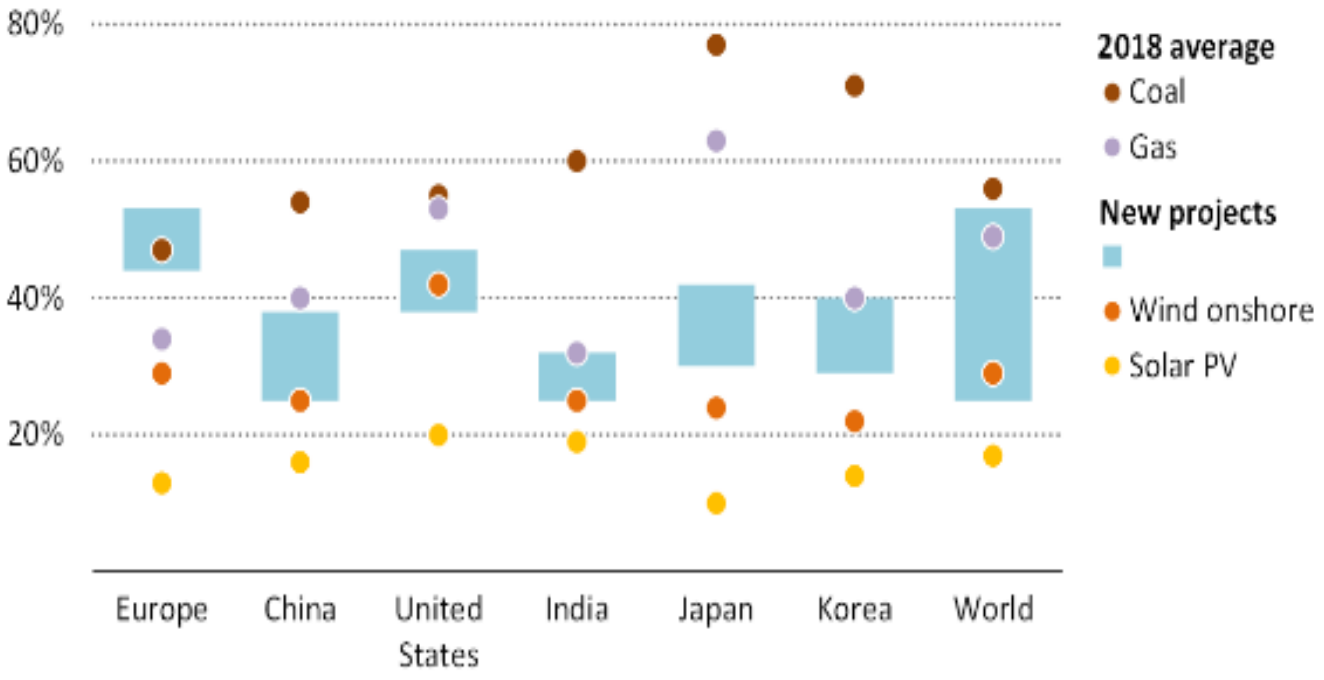
# Sensitivity to Carbon Price




Carbon prices impact the LCOE

Coal ~ $1 / tonne = $1 / MWh
Gas ~ $1 / tonne = $0.50 / MWh

# Adding Renewables Changes Everything

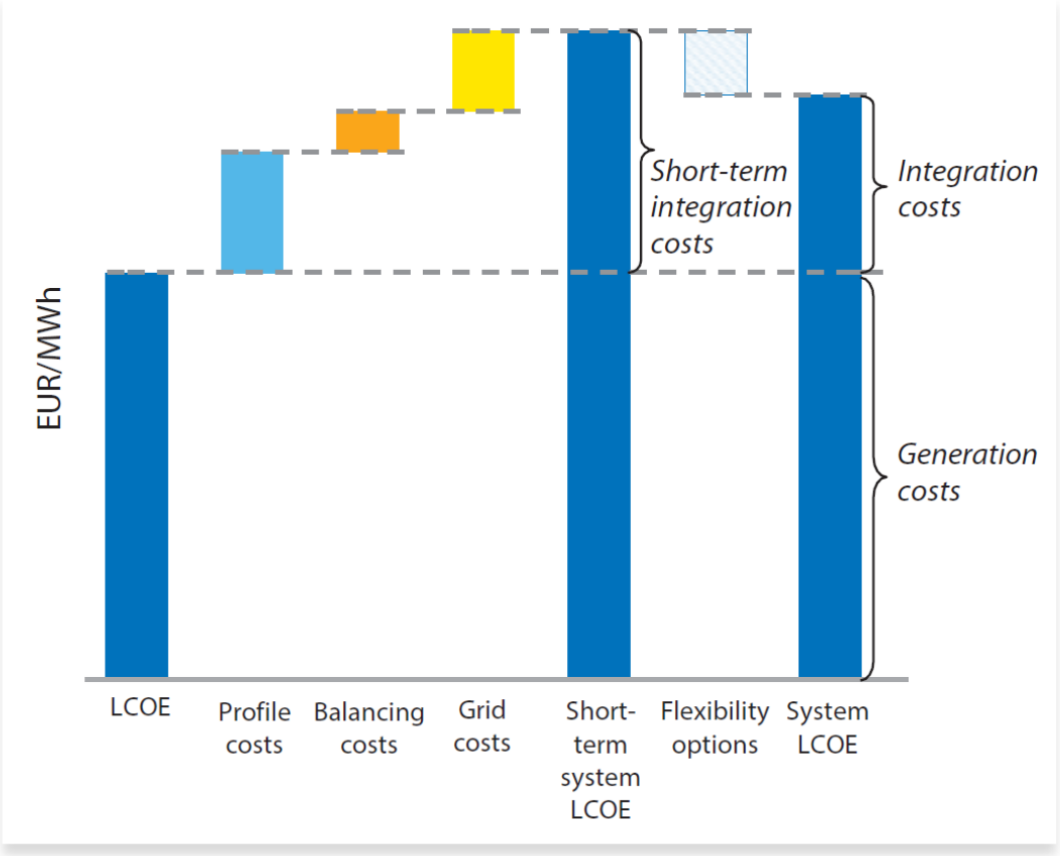



World Energy Outlook 2019, OECD/IEA, Paris'

- Renewables are variable and not dispatchable
- Low resource availability means low operating factors
  - Solar operates about 17% of the time
  - Wind operates about 29% of the time
- Contrast this with the 24/7 availability of nuclear power, which can operate at capacity factors of more than 90%.

# LCOE is not sufficient to compare costs

Figure ES2. **Illustration of system cost**



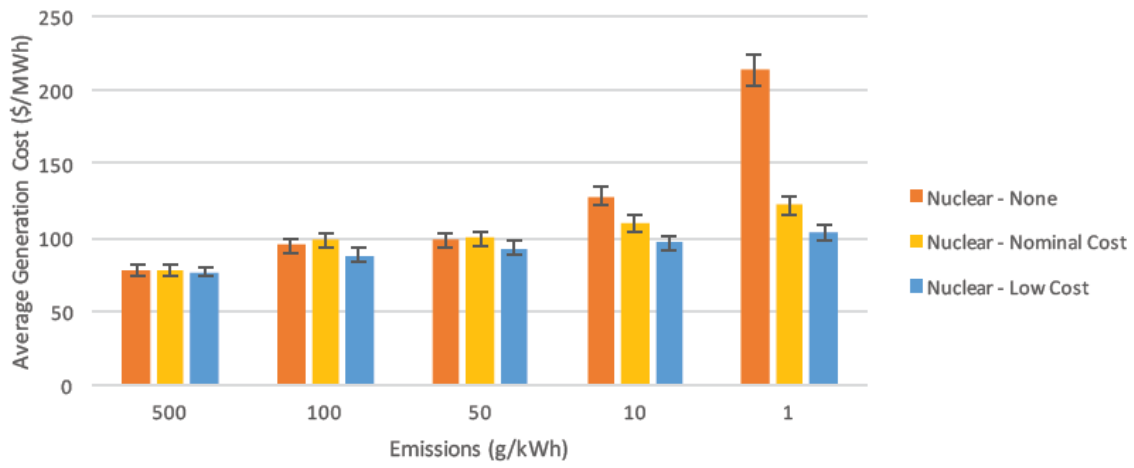

OECD NEA "The Costs of Decarbonization" 2019

**System Costs must be considered**

- **Profile costs (or utilisation costs) refer to the increase in the generation cost of the overall electricity system in response to the variability of VRE output.**
- **Balancing costs refer to the increasing requirements for ensuring the system stability due to the uncertainty in the power generation (unforeseen plant outages or forecasting errors of generation)**
- **Connection costs consist of the costs of connecting a power plant to the nearest connecting point of the transmission grid.**

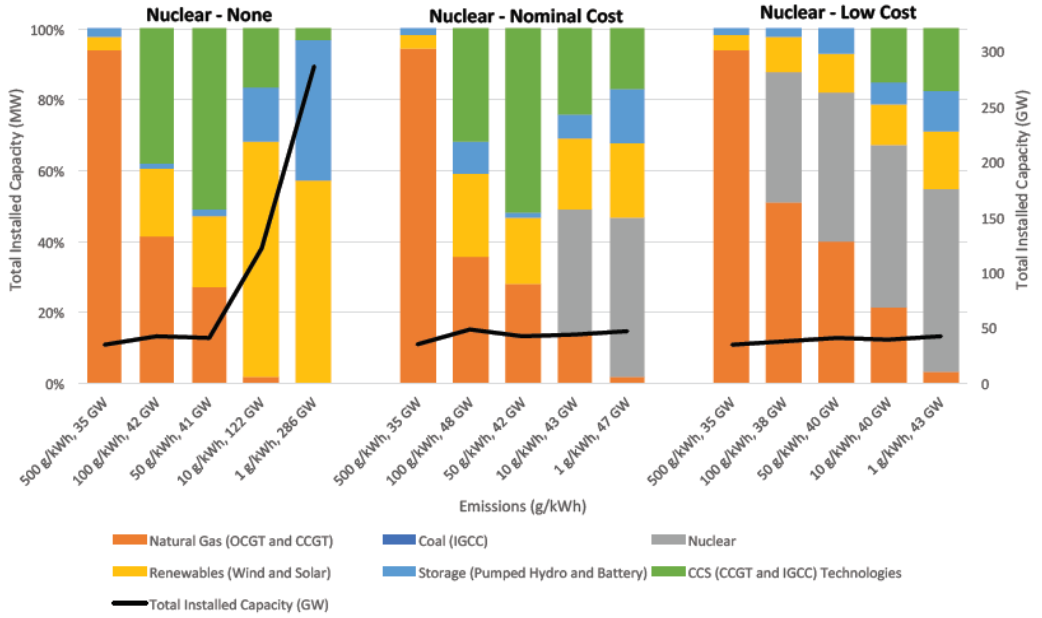
# As the share of renewables increase – so does system excess capacity

Figure 1.5a: New England cost of electricity generation



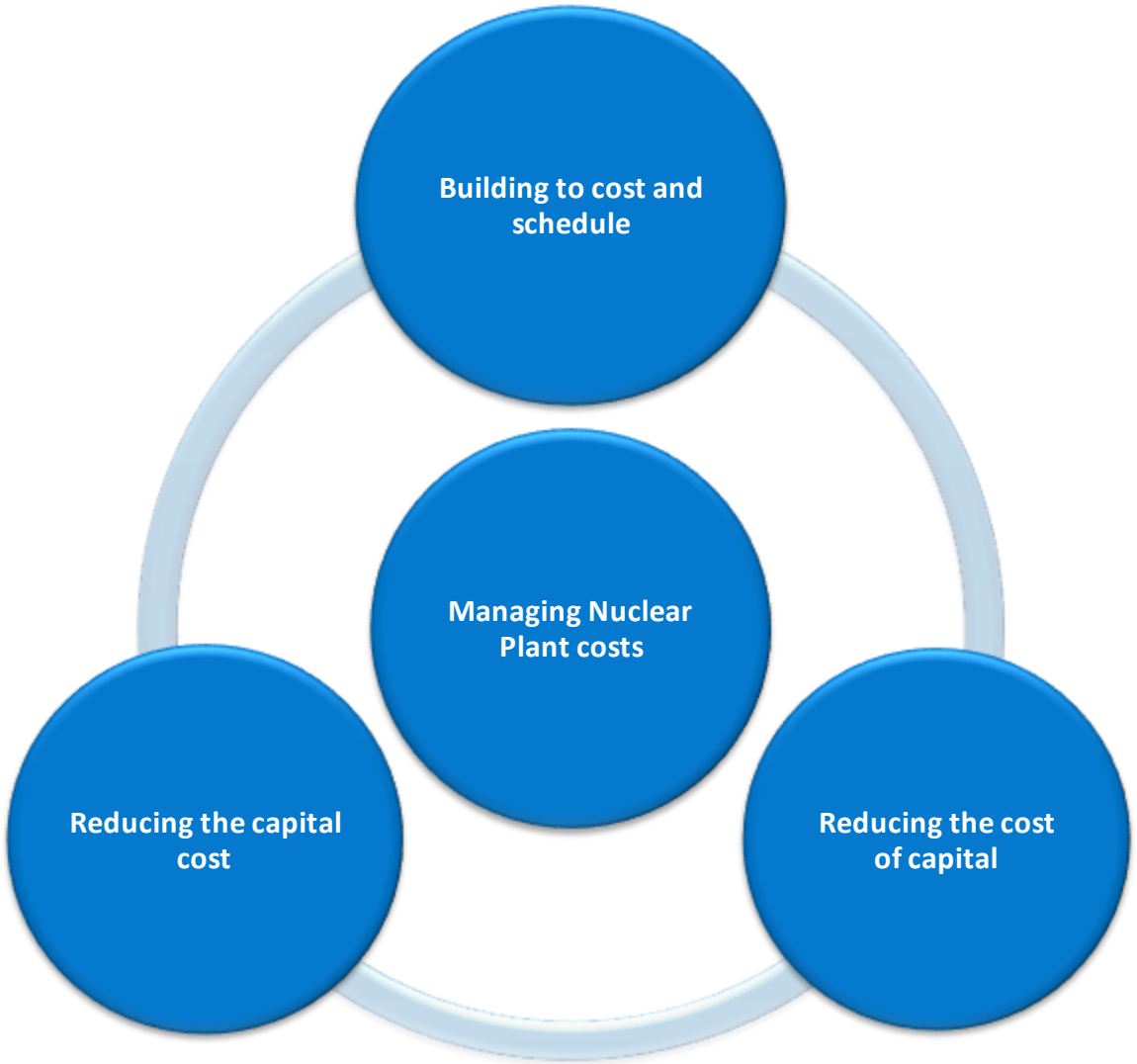

Source: The Future of Nuclear Energy in a Carbon-Constrained World
AN INTERDISCIPLINARY MIT STUDY

Figure 1.6: Optimal capacity mixes for New England



# A PATH FORWARD TO PROJECT SUCCESS

# Managing costs – planning for success



# Be prepared

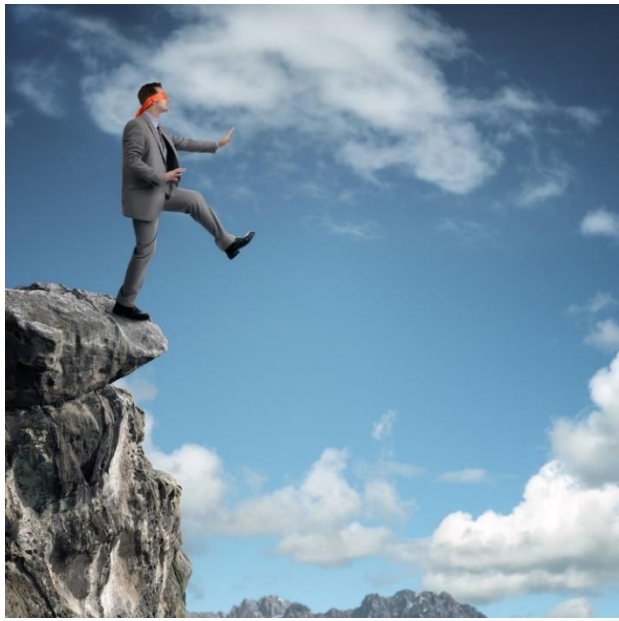
Building to cost and schedule

- Plan, plan and plan some more.
- Ensure adequate design completion before construction
- Ready your supply chain
- Create strong project metrics
- Develop and implement a robust risk management program. Use it as the basis for project contingencies
- Develop a project financial structure that supports preparation before final commitment
- Get the best possible people you can

# Project structures are about managing risk

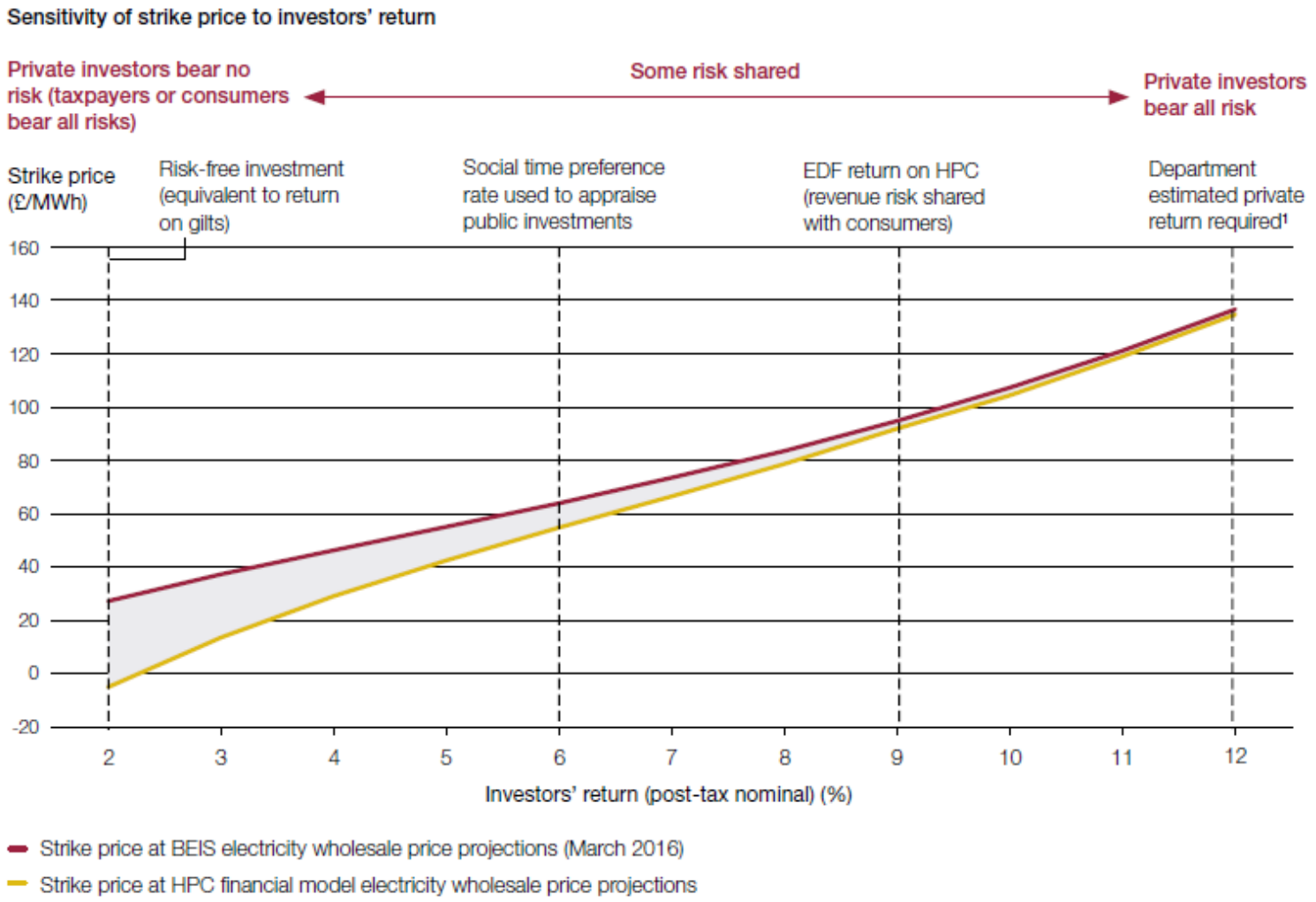
Reducing the cost of capital

- As the project owner, the total risk resides with you
  - Transferring all risk to contractors is an illusion
  - Allocating risk is a form of risk management, it does not disappear
  - There is no scenario where your contractor fails and you succeed
- Complete transparency through to the contractor is essential so that actions can be taken when the problem arises and the costs to correct are manageable
- Ensure adequate oversight



# UK analysis of options based on HPC

**Reducing the cost of capital**




The chart presents the strike price necessary for investors to achieve different levels of return based on two sets of electricity wholesale price projections. The higher level of risk private investors bear; the higher the strike price. In summary table *Figure 19), we show three different scenarios:

- '100% private risk' assumes private investors carry all risks. The Department has estimated that the hurdle rate for nuclear projects is about 12% (post-tax nominal). To achieve this return, the price they receive would need to be between £135 and £137 per MWh during the first 35 years of generation;
- 'HPC' scenario replicates the current deal. By removing the electricity price risk for 35 years as well as other risks, it reduces the investors' required return to 9% which results in a strike price between £91 and £95 depending on the forecasts for market prices after the CfD period; and
- '100% public risk' assumes all risks are transferred to the public sector and the tax payer would have to pay the full project cost (£19 billion). In this case the strike price for 35 years would range from -£6 to £28 depending on the electricity price forecasts. The combination of low discount rate and high future electricity prices makes the present value of the cash flows post CfD so high that it compensates for the negative strike price during the CfD period to achieve an overall investor return of 2%. Such a strike price is a theoretical price based on a comparison with the 35-year structure used in HPC.

Source: UK National Audit Office, "Hinkley Point C", June 23, 2017

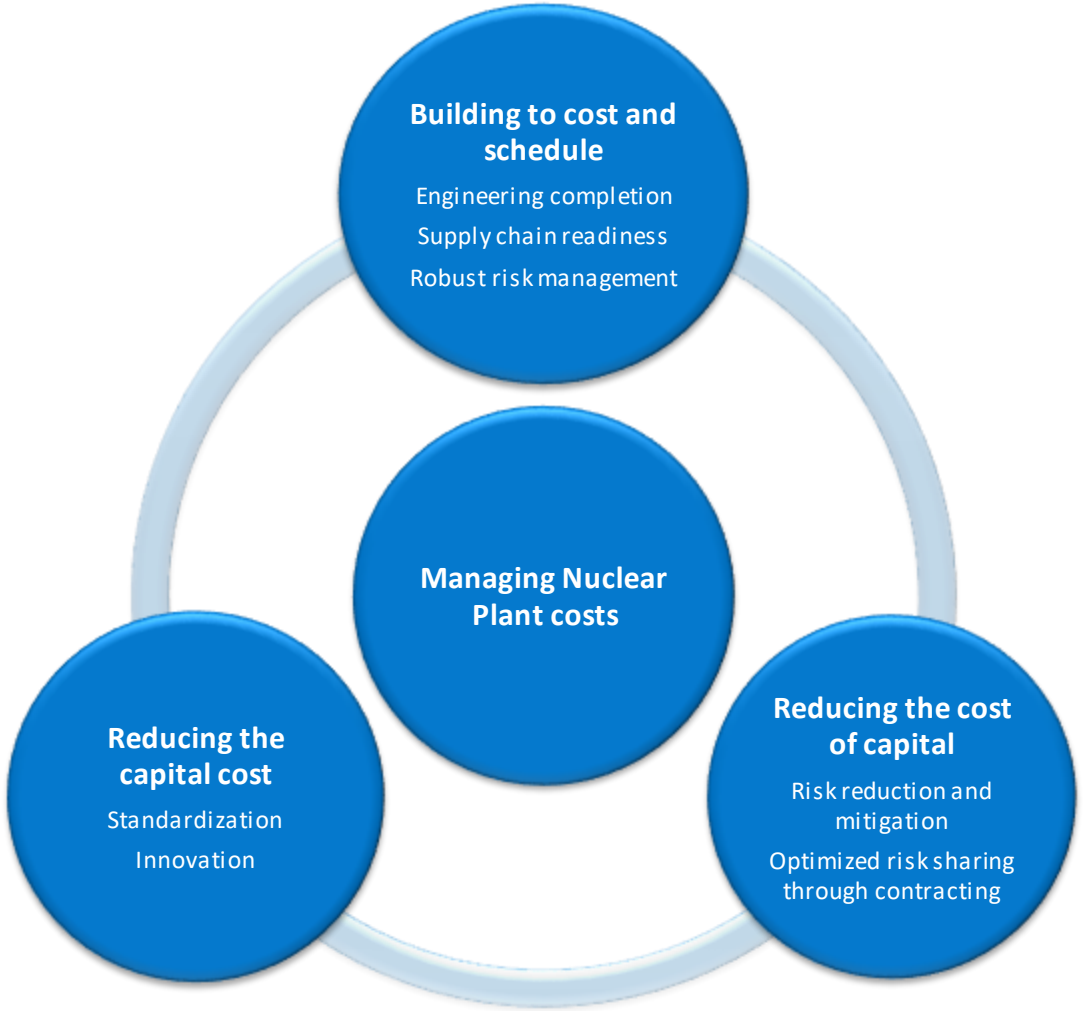
# Build and repeat

Reducing the capital cost

- Standardization – there is no doubt we get better as we repeat the same activities over and over
  - Goes beyond design. Includes site, supply chain, project model right down to individual workers
  - Recent example at Barakah in UAE, four unit site with the 4th unit cost about 40% less than the site average
- Innovation – replicating also allows for ideas on where there can be improvements that save both cost and schedule

# Lower and predictable nuclear plant costs can be achieved

- Be ready
- Manage risk
- Build and repeat
- Innovate



# Takeaways

- In most industrialised countries today, new nuclear power plants are an economic option to generate base load electricity – even without consideration of additional geopolitical and environmental advantages that nuclear power confers
- Adding renewables to electricity systems changes everything due to their intermittency. Fully decarbonized systems are always lower cost when they include nuclear
- Successful nuclear projects result from investing in managing risk

# Thank You!

Milt Caplan President MZConsulting Inc.

milt.caplan@mzconsultinginc.com

+1.647.271.4442