What should the world’s nuclear sector do to deliver its full carbon avoidance contribution by 2050?

Dr. Sama Bilbao y Leon
Director General
Greenhouse gas emissions must decline rapidly

The share of fossil generation has not significantly reduced since 2000

Generation from fossil fuels in 2019 higher than total generation in 2000

CO₂ emissions must decline over next 30 years.

IEA: World Energy Outlook 2020
The expectations on nuclear energy are growing

Nuclear energy needs to grow rapidly if we are to satisfy energy demand, achieve climate targets and help the world meet the sustainable development goals.

The projections from the IPCC 1.5°C Report “middle of the road” scenario see nuclear energy grow six-fold by 2050, with 2243 GWe capacity, representing 25% of electricity generation.

Data Source: IPCC Special report on the impacts of global warming of 1.5 °C, 2018, IEA World Energy Outlook 2019, IAEA Electricity and Nuclear Power Estimates for the Period up to 2050, 2020
Nuclear energy is the only low-carbon source that can produce electricity and heat.
The global nuclear fleet continues to perform well

Global capacity: **393 GWe**
Operable reactors: **442**
Under construction: **53**

Global electricity generated (2019)
**2657 TWh**, up **95 TWh**

Average capacity factor (2019)
**82.5%**, up **2.7%**

**2019 Construction starts**
- Bushehr 2, Iran
- Hinkley Point C 2, UK
- Kursk II-2, Russia
- Shidaowan 1, China
- Taipingling 1, China
- Zhangzhou 1, China

**2020 Construction starts**
- Akkuyu 2, Turkey
- Shidaowan 2, China
- Taipingling 2, China
- Zhangzhou 2, China
- Xiapu 2, China
- San’oa 1, China
New reactor start-ups 2019/20: a few “firsts”

- **Akademik Lomonosov**
  - KLT-40S
  - Russia

- **Barakah 1**
  - APR-1400
  - UAE

- **Fuqing 5**
  - Hualong One
  - China

- **Leningrad II-2**
  - VVER V-491
  - Russia

- **Novovoronezh II-2**
  - VVER V-491
  - Russia

- **Ostrovets 1**
  - VVER V-491
  - Belarus

- **Shin Kori 4**
  - APR-1400
  - South Korea

- **Taishan 2**
  - EPR
  - China

- **Tianwan 5**
  - ACPR-1000
  - China

- **Yangjiang 6**
  - ACPR-1000
  - China
There is a lot of excitement about SMR development globally.

- **Carem 25, Argentina**
  - 25 MWe PWR
  - Under Construction

- **IMSR, Canada, US, UK**
  - 190 MWe Molten Salt
  - Under Development

- **HTR-PM, China**
  - 2x110 MWe HTGR
  - Under Commissioning

- **Yanlong DHR, China**
  - 400 MWth Pool
  - Under Development

- **Seaborg, Denmark**
  - 250 MWth MSR
  - Under Development

- **SMART, South Korea**
  - 100 MWe PWR
  - Design Licensed

- **BWRX300, US**
  - 300 MWe BWR
  - Under Review

- **NuScale, US**
  - 77 MWe PWR
  - Design Licensed
Nuclear LTO and new nuclear are competitive low-carbon solutions in OECD countries.

Source: IEA/NEA 2020 with cost of capital of 7% and CO2 price @ 30 USD/tCO2
Investment in nuclear will help rebuild the economy, generate jobs, and develop a cleaner energy system.

Nuclear projects provide many socio-economic benefits throughout the wider economy.

Nuclear sector pay is typically the highest for any energy technology.

Thousands of nuclear jobs from one power project.


Figure. Average US energy worker pay trends. Source: Oxford Economics, 2019, Nuclear Power Pays.

Challenges remain for the timely and cost-effective deployment of nuclear energy

- Streamlining the nuclear regulatory sector
- Level playing field with other low-carbon technologies
- Unlocking low-cost finance for nuclear projects

---

Note: Calculations based on OCC of USD 4 500 per kilowatt of electrical capacity (/kWe), a load factor of 85%, 60-year lifetime and 7-year construction time at a real discount rate of 9%.
World Nuclear Association calls upon policymakers to:

- Incentivize investment and facilitate the appropriate frameworks to unlock low-cost finance for nuclear projects: LTO and new build.
- Support nuclear LTO as a near-term cost-effective measure for decarbonization.
- Fast-track the deployment of large-scale reactors, to meet the increasing demand for clean and reliable electricity and fulfil climate change commitments.
- Prioritize the harmonization of international reactor design licensing.
- Accelerate the development and commercialization of SMRs.
- Actively explore the application of nuclear technologies in applications such as industrial heat and the production of green hydrogen.
- Work closely with multilateral banks in order to find ways to ensure that the growing need for electricity in developing countries can be met with nuclear solutions.
The Harmony programme is a global initiative of the nuclear industry coordinated by World Nuclear Association.

Sama.BilbaoyLeon@world-nuclear.org
The Changing Global Economics of Nuclear vs. other Energy Technologies amid the Growth of Low Carbon Energy Markets

Dr. Henri PAILLERE
Section Head
Planning and Economics Studies Section
International Atomic Energy Agency

Westminster Energy Forum
Annual Review of Nuclear Policy, Regulation & Markets
International Nuclear Power in the Context of COP26 Ambitions & Global Net Zero
10th February 2021
Nuclear generation hit record level in 2019: second highest after all-time high 2006, and share of 10.4%

2020: year of COVID19 pandemic. Electricity systems dominated by low C technologies, “postcard from the future”: Nuclear has proven resilient
2020: progress in several newcomer countries, UAE and Belarus have connected their first NPP units.
Energy, Electricity and Nuclear Power Estimates for the Period Up to 2050

- Electricity consumption expected to double
- Share of electricity in energy consumption increases by 8 pts
- High case: installed capacity increases by 80%, nuclear share of electricity generation 11%
- Low case: decrease by 7%, nuclear share ~6%

Released Sept. 2020
- Most scenario studies project nuclear capacity increases
- IPCC: four illustrative pathways in 2018 1.5°C report
- IAEA: low and high projections
  - High projection means that 500 GW are to be added in 30 years time
Low-carbon electricity systems


- Planning for the future:
  - Increasing shares of variable renewables (target or need?)
  - Necessary investments in grid technologies, storage technologies
  - Need for low-carbon dispatchable generation
  - Generation costs ≠ system costs ≠ value, how to balance economics and objectives resilience, security of supply and ambitious reduction in emissions

- Planning requires modelling of increasingly complex interactions of technologies, cost optimization and carbon constraints

- Specific issues for nuclear:
  - New nuclear: only slightly higher LCOE than solar or onshore wind, cheaper than offshore
  - Large investment projects with long payback periods, exposure to risks, cost of financing
  - Various mechanisms to secure revenues, de-risk investments
  - Importance of role of governments
Projected Costs of Generating Electricity (IEA/NEA, 2020) – median values, 7% discount rate

- **New Nuclear:** 69 USD/MWh
- **Wind onshore:** 50 USD/MWh
- **Wind offshore:** 88 USD/MWh
- **Solar PV:** 56 USD/MWh
- **LTO Nuclear:** 32 USD/MWh
Towards net-zero emissions

- Decarbonising the power sector will not be sufficient.
- Need to decarbonize other sectors, representing 60% of emissions today:
  - **Electrification** whenever possible (so increased demand for clean electricity)
  - Need **low C heat sources**
  - Need **low C fuels**, including hydrogen, produced from clean electricity
- IEA: “Almost half of the emissions reductions needed to reach net zero by 2050 will need to come from technologies that have not reached the market today”
Nuclear beyond electricity?

- Most scenario projections: nuclear ONLY in the power sector.
  - Increased electrification will require more low carbon electricity (so potentially more nuclear)
- But there is also a need for lots of low carbon heat and low carbon fuels – and the technologies to produce them.
- Nuclear energy is also a source of low carbon heat, and can also be used to produce low carbon fuels such as hydrogen
  - Up to now, virtually untapped potential
- An opportunity for the nuclear energy sector?
  - Advanced reactors, SMRs, non-power applications
  - But requires a “level playing field” in terms of policies, support to innovation, and financing – as well as clear market signals to favour low C
  - Technology Readiness and Economics will be key
District Heating and Process Heat

- **District Heating**: decades of experience, in Russia, Hungary, Switzerland, etc
- In June 2020, the new **Floating Nuclear Power Plant** Akademic Lomonosov, powered by two SMR units, provided 1st heat to Pevesk district (1st grid connection in Dec 2019)
- In November 2020, **Haiyang NPP** (AP1000) started delivering commercial DH

- **Process Heat**: can be delivered by **High Temperature Reactors**
- Interest of Poland to replace coal-fired boilers
- In the past, projects were developed in US, Korea, etc, including for “clean steel” production
Nuclear production of hydrogen

- Decades of research on nuclear production of hydrogen, using (low temperature) electrolysis, High Temperature Steam Electrolysis or Thermo-chemical cycles

- Near term needs:
  - Low Carbon hydrogen can be produced by low-carbon electricity (renewables AND nuclear)
  - Electricity from nuclear LTO is “the cheapest source of low C power” (IEA/NEA Projected Costs of Electricity Generation, Dec. 2020) + Nuclear higher capacity factors than renewables

- Mid-term needs:
  - High temperature Steam Electrolysis or thermal-splitting may offer higher efficiencies / cost effectiveness – to be combined with advanced reactors
  - LCOE new nuclear likely higher than LCOE of wind/solar

- Demonstration projects and proposals are being considered in several countries

- IAEA developing a publication on “business opportunities” for nuclear production of hydrogen from existing reactors
Integrated Energy Systems (Hybrid Energy Systems)

• How to design low carbon energy systems using all possible low carbon technologies:
  - Renewables
  - Nuclear
  - Fossil with CCS

• Coupling of the power sector with the non-power sectors through 3 low carbon energy vectors:
  - Electricity
  - Heat
  - Hydrogen

• Economics of such systems requires sophisticated modelling approaches, able to inform on interactions between generation technologies, grid, energy storage and demand:
  - Optimize in terms of CO₂ emissions and overall costs
  - The value (economics) of a given technology depends on what is present in the system
Coupling via Electricity, Heat and and Hydrogen

NPPs: large Gen III reactors + Advanced reactors (incl. SMRs)

3 low-carbon energy vectors: electricity, heat, hydrogen
Take-aways

• Decarbonizing power:
  – Many options: nuclear, hydro, variable renewables, fossil with CCS
  – Nuclear can reduce overall cost of systems (dispatchability, cost of intermittency of variable renewables)
  – Market designs and role of governments to encourage investments in nuclear

• Decarbonizing other sectors: (towards ‘net zero’)
  – Use of low carbon heat (could be provided by nuclear – especially advanced reactors)
  – Use of low carbon H₂:
    • Produced from fossil with CCS, from renewables or from nuclear

• Complex energy system interactions – generation, grid and storage technologies.
• From an integrated system point of view, ability to provide all 3 low carbon energy vectors (electricity, heat and hydrogen) should prove beneficial to nuclear power
• Next March: joint IEA/IAEA webinar on long-term projections for nuclear power!
• Level playing field for all low-carbon technologies to reduce “policy risk” and increase chance of success.
The actual cost of electricity should reflect not only plant-level GENERATION costs but also grid-level SYSTEM costs and SOCIAL & ENVIRONMENTAL costs.
With the right **policy framework** new nuclear remains a **competitive** low carbon solution in OECD countries
The nuclear industry at a critical juncture with the completion of FOAK Gen-III reactors

Increase in cost estimates due to initially low Gen-III FOAK design maturity and adverse political context

Gradual cost reductions owing to greater design maturity and lessons learnt from FOAK projects

Recent trend in costs reflects increased design maturity and lessons learned for post-FOAK projects

Gap between two sets of projections has impacted overall perceived investment risks
Affordable financing key for the economic performance of nuclear: A range of government support can be envisaged

LCOE of a new nuclear power plant project according to the cost of capital

<table>
<thead>
<tr>
<th>Weighted average cost of capital</th>
<th>Levelised cost (USD/MWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0% 1% 2% 3% 4% 5% 6% 7% 8% 9% 10% 11% 12%</td>
<td>Fuel cycle costs</td>
</tr>
</tbody>
</table>

- **Equity, debt, ECAs, loan guarantee**
  - Equity stake can be transitional as additional sources of financing should become available once the plant is operational.

- **Contract-for-difference (UK), Mankala model (Finland)**
  - PPAs focus on market risks but often do not address explicitly construction risks, which impact risk premium.

- **Rate-of-return (US), Regulated Asset Base (UK)**
  - Specific conditions can be specified for the allocation of certain risks (e.g. cost sharing and cap with hybrid RAB model).

Note: Overnight cost of 4500 USD/kWe, a load factor 85%, 60-year lifetime and 7-year construction time.
Assessing the System Costs of Electricity

• Total system costs are the sum of plant-level generation costs and grid-level system costs
• System costs are mainly due to characteristics intrinsic to variable generation

System costs depend on:
  – Local & regional factors and the existing mix
  – VRE penetration and load profiles
  – Flexibility resources (hydro, storage, interconnections)

Additional impacts on load factors of dispatchable generators and prices.

Profile costs (Changing mix)
Balancing costs (Short-term variations)
Transmission and distribution costs

VREs are not always available
VREs are difficult to predict
Good VRE sites are distant from load centers

Source: L. Hirth

© 2020 Organisation for Economic Co-operation and Development
High VRE Shares Result in Large Inefficiencies

10% Variable Renewables

75% Variable Renewables

- High VRE penetration result in challenges for system management.
- Residual demand (BLUE line) – the available market for dispatchable generation becomes volatile and unpredictable.
As VRE Share Increases System Costs Grow Quickly

- System costs are large and increase with VRE generation share - Profile costs are the dominant component.
Decreased load and volatile electricity prices discourage investment

• Increase of hours with zero price (over 3750 hours p.a. at 75% VRE), compensated by greater number of high-price hours (>100 USD/MWh).
• Price volatility increases uncertainty, investment costs and risks to capacity adequacy.
Recent NEA Work: 
**Broad Conclusions**

- To meet global energy and environmental requirements, all low-carbon technologies must be optimally applied—with all costs accurately allocated.
- The electricity markets must be modernized. Existing market structures make investment in any unsubsidised low-carbon technology very difficult.
- Large deployment of VRE will occur around the world – but the contribution of VRE in each country will depend on the cost of available resources.
- To the degree dispatchable capacity is needed, nuclear can serve a large role—if it is economically compatible with evolving markets.
Thank you for your attention

More information @ www.oecd-nea.org
All NEA reports are available for download free of charge.
Follow us: Facebook, Twitter, LinkedIn
The role of Nuclear in the UK market

Vicky Parker
Global Utilities Strategy Lead
Accenture

Westminster Energy Forum
10th February 2021
AN EVOLVING PORTFOLIO OF ENERGY
Nuclear has remained an important part of the mix

2019 ANNUAL UK ELECTRICITY GENERATION (1)

- Renewables: 37.1%
- Gas: 40.6%
- Nuclear: 17.3%
- Other Fuels

HOW HAS THIS CHANGED SINCE 2013? (1)(2)

- **RENEWABLES:**
  - 2013: 15%
  - 2019: 38%
  - Increase: +23%

- **NUCLEAR:**
  - 2013: 20%
  - 2019: 17%
  - Decrease: -3%

- **GAS:**
  - 2013: 27%
  - 2019: 41%
  - Increase: +14%

- **COAL:**
  - 2013: 36%
  - 2019: 1%
  - Decrease: -35%

Sources:
(1) BEIS DUKE 2020 Operational Data, (2) BEIS 2013 Energy Statistics

Copyright © 2021 Accenture. All rights reserved.
“AND-AND” RATHER THAN “AND-OR”
And an evolving portfolio needs low-carbon firm power

BEIS ENERGY TRENDS (DEC 2020) (1)

TWO UK ENERGY RECORDS

“THERE HAVE BEEN LONG COAL-FREE PERIODS IN GREAT BRITAIN THIS YEAR, INCLUDING A RECORD-BREAKING 67-DAY PERIOD BETWEEN MARCH AND JUNE” (1)

“THE UK’S MARKET PRICE FOR ELECTRICITY ROSE TO A NEW RECORD OF ALMOST £1,500 A MEGAWATT HOUR [AT A SINGLE POINT DURING JANUARY 2021] AFTER A STRING OF POWER PLANT OUTAGES AND LOW LEVELS OF RENEWABLE ENERGY GENERATION.” (2)

Sources:
(1) BEIS Energy Trends 2020 (2) Guardian 2021
GREEN INDUSTRIAL REVOLUTION
Nuclear remains a key part of the forecast

ENERGY WHITE PAPER

KEY MILESTONES

“AIMING TO BRING AT LEAST ONE LARGE SCALE NUCLEAR PROJECT TO THE POINT OF FINAL INVESTMENT DECISION BY THE END OF THIS PARLIAMENT, SUBJECT TO CLEAR VALUE FOR MONEY AND ALL RELEVANT APPROVALS.”

“We will remain open to further projects later if the nuclear industry demonstrates that it is able to reduce costs and deliver to time and budget”

Sources:
(1) BEIS Energy White Paper, 2020
DEMONSTRATING VALUE
Multiple value levers for both large and small nuclear

AN INVESTABLE MODEL
PROGRESS ON FINANCING MODELS (E.G. RAB)

“SUSTAINABLE FUNDING MODEL THAT CAN ATTRACT PRIVATE INVESTMENT AT A COST THAT REPRESENTS VALUE FOR MONEY” (1)

NUCLEAR INNOVATION (1)
£385m Advanced nuclear fund

£400bn SMR / AMR by 2035

CONTRIBUTION TO THE UK ENERGY MARKET
1 LOW-CARBON HEDGE AGAINST RISING VOLATILITY
2 ASSURANCE OF ENERGY SECURITY AND INDEPENDENCE
3 COST-EFFECTIVE COGENERATION FOR OTHER ENERGY VECTORS

Sources:
(1) BEIS Energy White Paper, 2020
<table>
<thead>
<tr>
<th>Category</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NET ZERO</strong></td>
<td>• Contribute to the delivery of the net zero agenda;</td>
</tr>
<tr>
<td></td>
<td>• Delivery of firm low carbon power balancing intermittent renewables</td>
</tr>
<tr>
<td><strong>VALUE FOR MONEY</strong></td>
<td>• Nuclear sector deal – design replication and supply chain learnings</td>
</tr>
<tr>
<td></td>
<td>• Consultation on regulated asset based model</td>
</tr>
<tr>
<td><strong>SUPPLY CHAIN</strong></td>
<td>• Drive sustained demand, innovation and investment in UK supply chain</td>
</tr>
<tr>
<td><strong>UK PLC</strong></td>
<td>• “Build, back better” puts contribution to the levelling up agenda and job creation at the heart of the national infrastructure strategy</td>
</tr>
<tr>
<td><strong>NEXT GEN NUCLEAR</strong></td>
<td>• Support into next generation of new nuclear – SMR / Future Fusion</td>
</tr>
</tbody>
</table>
A SYSTEM VALUE APPROACH TO BENEFITS

The system value framework more holistically evaluates economic, environmental, social and technical outcomes of potential energy solutions across markets. The framework aims to shift political and commercial focus beyond cost to include value.

Economic, environmental, societal and energy value

- **Air Quality and Health**: Impact on human health and natural environment from air and water pollutants, land use
- **Jobs and Economic Impact**: Influx of jobs due to energy transition and renewables
- **CO₂ Emissions**: CO₂ emissions based on energy source, generation mix and load changes
- **Access to Electricity**: Physical and economic access to clean electricity to support individual or society development
- **Water Footprint**: Water footprint based on energy source, generation mix and load changes
- **Energy Productivity and Systemic Efficiency**: Energy efficiency plus systemic efficiency, optimization of interactions among energy value chain elements to maximize energy productivity
- **Foreign Direct Investment**: Market attractiveness for FDI with reliable energy and skilled resources
- **Resiliency and Security**: Uninterrupted and diversified energy supply at affordable prices and the ability to bounce back from disruptions
- **Reliability and Service Quality**: Lifecycle approach to ensuring high system availability, improved customer service
- **Flexibility**: Ability to manage generation, demand and power flows (incl. power quality) across the grid enabled by digitization and storage
- **Cost and Investment Competitiveness**: Market attractiveness and policy certainty to businesses and policymakers for investment, including R&D and leveled cost of energy
- **System Upgrade**: Technology (incl. digital) and capital investments in T&D (incl. interconnections) to upgrade the system for variable renewables and distributed energy resources (DER)
Thank you

Vicky Parker
Global Utilities Strategy Lead
Accenture

Westminster Energy Forum
10th February 2021

Accenture Strategy & Consulting
Sizewell C
Doing the power of good for Britain

Julia Pyke
Director, Financing and Economic Regulation, Sizewell C
Julia.Pyke@sizewellc.com
10 February 2021
Where are we with Sizewell C?

• Detailed buildable design.

• Welcome Government’s “decision to enter into negotiations with EDF on the proposed Sizewell C nuclear project”.

• Submitted our Development Consent Order, after 8 years of consultation.

• Applied for a Nuclear Site Licence and have applied for environmental consents as well.

• Early works on Sizewell C (e.g. road schemes) are ready to go.
Sizewell C: Construction and Workforce

Sizewell C will help Build Back Better whilst supporting the Levelling Up Agenda

- 70% of Construction Contract Value to UK Suppliers
- 70,000 UK jobs* supported
- 1,500 Apprenticeships created during construction

- Levelling up areas in the East of England, Wales, the North and the South West
- Engagement with local colleges and local SMEs, investing around £4bn into the regional economy
- SZC is ready to go soon and means ~£3.5bn of investment and around 6,000 jobs onsite in the first 3 years of construction.

*References to jobs are to a full time equivalent year (and based on the estimated number of on-site hours).
The Sizewell C Consortium has come together to ensure the continuity of the nuclear supply chain in the UK

The Sizewell C Consortium represents around 180 UK based companies and over 100,000 people
Sizewell C will invest in UK skills and education to build the workforce of tomorrow

- National College for Nuclear Hubs: Somerset, Cumbria (East in discussion)
- Welding Centres of Excellence: Somerset, West Midlands and Strathclyde
- Young Sizewell C: Providing a jumping off point for young people in the East of England
- UK EPR Engineering Centre: Bristol and Somerset
East Coast College Students say yes to jobs, yes to Sizewell C
Sizewell C aims to leave a positive legacy, including a net gain in biodiversity.

Aldhurst Farm: We have created 67 hectares of new habitat, benefitting a variety of wildlife as well as rare plants.
Nuclear can provide more than electricity alone, as part of an energy hub

- Kick starting the Hydrogen economy, by a demo electrolyser potentially powered by SZB, which could be scaled up at SZC once the power plant is operational.

- Direct Air Capture (DAC) can be located at the nuclear power station to give net negative lifecycle carbon emissions. Net Zero fuel can be processed from carbon captured by DAC, which can be combined with hydrogen produced by electrolysis.

- Aligning with Freeports to create a ‘test bed’ with regulatory flexibility to deliver innovation low carbon technologies and support the decarbonisation of sectors such as shipping.
As shown in the above graph, total electricity consumption levels vary according to the time of day. Additionally, for the above period (i.e. 1 – 16 July 2020), significant levels of gas-fired generation were needed to meet demand, again illustrating the scale of the challenge to achieve a net zero future.
Nuclear has a vital role to play in decarbonising the energy mix

As shown in the graph above, three countries (Norway, France and Sweden) have achieved low carbon energy mixes through a mixture of using natural geography (e.g. utilizing hydropower in Norway) and low-carbon-energy – in particular, France using nuclear, has achieved a low carbon mix despite its large generation scale.

Source: entso-e
Doing the power of good for Britain

Julia Pyke
Director, Financing and Economic Regulation, Sizewell C
Julia.Pyke@sizewellc.com
10 February 2021
Alan Raymant
Chief Executive, Bradwell B
UK Small Modular Reactor

10\textsuperscript{th} February 2021

Paul Stein – Chief Technology Officer
The UK SMR can be used in a variety of critical applications to decarbonise the energy system.

**UK SMR for Net Zero**

**Desalination**

One SMR and associated desalination plant can produce 500 million cubic metres of potable water per year.

Global demand for potable water to rise beyond 1 trillion cubic metres per year by 2040.

**Hydrogen & Synth Fuel**

One SMR and plant can produce 170 tonnes of H₂ or 280 tonnes of net-zero synth fuel per day.

Global market by 2040 is >500 million tonnes synth fuel per year.

**Grid Electricity**

One SMR can power a city the size of Leeds.

Global grid capacity demand for SMR set to exceed 79 GWe by 2040.

**District Heating / Cooling**

One SMR and associated infrastructure can heat or cool a city the size of Sheffield.

Annual global requirement over 10,000 TWh by 2040.
Power station design:

A requirements based design approach recognising customer, environmental, regulatory requirements.

Cost of Electricity (£/MWhr) = (capital + total O&M + decom + fuel costs + financing cost) / Power Generating potential x Capacity factor

- Reduce capital
- Manage Investment
- Reduce O&M
- Maximise power
- Maximise reliability
- Reduce Fuel cost

Compatibility with support Infrastructure and Sites
Public Perception
Utility Familiarisation / Selection of Technology
Delivery Partnership Potential
Global Market
UK SMR is a different approach to nuclear new build

### Route to Market Elements

#### Low Cost Nuclear
- Use of proven Technology
- Simplified and Standardised Equipment
- Predictable and Repeatable

#### Deliverable Solution
- Factory Built Commodity
- Site canopy for controlled site environment
- Maximize Productivity and Innovation across Fleet

#### Investable Product
- Factory solution to build out Fleet
- Significantly reduced construction risk
- Acceptable Completion Risk given commodity nature of product

#### Role of Government
- Minimal impact on Government Balance Sheet
- Strong Demand Signal
- Policy landscape
- Political outcomes – Jobs, Industry, Regional benefits

### Integrated Modular Factory Built Power Plant

#### End to End Product

#### Delivery Excellence
Innovation for benefit not for technology sake to reduce:

- Capital
- Construction period
- Risk

- **Power station** design NOT just nuclear reactor

- Smaller in physical size and power output (440MWe)

- Designed for all aspects of **lifecycle**

- **Seismic raft** to standardise all plant modules

- **Short construction** period, lower levels of site activity

- **Site canopy** to improve efficiency / remove weather risk from construction schedule

- **Commercial separation of** ground construction
UK SMR

- UK SMR is a power station design **not** a nuclear reactor
- ~470 MWe output
- Compact site footprint
- 4 year construction duration for fleet units
- 60 year plant lifetime
- >90% availability factor
- Enhanced Gen III+ levels of safety and security

A factory fabricated product
ENABLER OF ENERGY & DIGITAL REVOLUTIONS

Westminster Energy Forum
Nuclear Review Webinar
10 February 2021
UK ASSESSMENT OF BUSINESS MODELS AND REQUIREMENTS TO ENABLE DEVELOPMENT AND DEPLOYMENT OF STRATEGIC NUCLEAR TECHNOLOGY


2. Supply Chain Companies Supporting the Deployment of International New Nuclear Technology in the UK.

3. Resourcing Strategic Nuclear Technology Deployment in the UK.
Advanced nuclear technology designs are based on factory-assembled modules that are delivered to site, installed and commissioned.

→ Necessary to realise economies of volume
→ But this represents a fundamental shift in behaviours needed from all parts of the supply chain

• Additional assembly, transport and installation loads must be considered by designers and justified in safety cases.
• Integration of equipment, components and skilled trades (welders) in a module manufacturing facility is well understood in automotive, aerospace, but not in energy.
• The re-definition of the construction site to installation site opens options to really innovate around how construction is delivered.

Business models that draw on cross-sector expertise need to be developed that enable the assured delivery of Advanced Modular Nuclear.
International supply chains are assessed to be fully competent and capable to support the delivery of their domestic programmes

→ The differences in UK licencee/regulatory requirements are not always understood
→ Equipment shipped that doesn’t meet quality requirements/paperwork incomplete.

- International ISO 9001 accreditations cover factories that produce equipment, not the production process (the “how”) or those manufacturing/assembling the equipment (the “who”).
- Specifications do not fully detail the EQ and QC requirements.
- Suppliers follow a replication approach and may fail to meet UK EQ/QC requirements
- Qualification and testing records are missing / quality records gaps cannot be filled

A proactive UK – supplying country approach is needed to bridge the gap in UK licencee/regulatory understanding from contract specification through to equipment setting to work
There is a need to develop capability and capacity in the supply chain to deliver both large scale nuclear and advanced modular nuclear at-scale.
→ This capability/capacity development needs to start now if deployment timescales are to be achieved.
→ The resource "pinch" could be exacerbated by other countries’ new build programmes starting.

- Assystem Nuclear Institute – UK roll-out starting in 2021
- #IncredibleWomen
- HPC Gender Project

*Developing the resources the UK will need to realise its net zero commitments*
ASSYSTEM SUMMARY

For 50 years, Assystem has supported governments, owners, contractors and OEM to develop, deliver and operate critical and complex infrastructures mainly in Nuclear, Healthcare, Life Sciences and Transportation.

Assystem believes sustainable growth requires an energy mix favouring carbon free electricity. Nuclear power is the main reliable mid-term solution.

KEY ELEMENTS

- 50 years of expertise
- 5000+ experts (including civil/design/mechanical/EC&I/ HVAC/safety engineers, R&D and digital specialists)
- 56% of our staff have more than 5 years’ service, 43% have more than 10 years’ nuclear experience
- Expertise in remote handling, stress engineering, non-contact surface metrology and industry 4.0 expertise (BIM, digital asset engineering, etc.)

€500m*
revenue

More than
5,700*
employees

2nd
nuclear engineering
company in the world

*Figures as of 2019
ENABLER OF ENERGY & DIGITAL REVOLUTIONS
challenges and opportunities for fusion
First Light Fusion
- University of Oxford spin-out, fusion energy pioneer
- Ground breaking R&D in many areas including: pulsed power; simulation; and fusion plant engineering
- $25m of funding in 2020 from both specialised cleantech and global institutions

Projectile-driven inertial fusion
- Sidesteps major known challenges of fusion engineering
- Offers a simpler route to a commercial power plant
- Has the potential to generate energy at very competitive LCOE

Advanced capabilities
- World-class plasma simulation tools that are regularly validated against boundary-pushing experiments
- Machine 3’s advanced engineering accelerates our projectile from zero to >15 km/s in less than 1 cm.

Cooperation is key
- Currently collaborating with UKAEA, academia and power plant engineering consultants
- Unique opportunities for collaboration in balance of plant and fusion island development
Some known challenges of the fusion sector

• Financial support
• Regulatory regime
  • How should fusion be regulated?
  • Who should the regulatory body be?
• Supply chain limitations
  • Lithium
  • Tritium
• Technical challenges
  • Breeding enough tritium
  • Withstanding the neutron flux
  • Withstanding the heat flux
  • Secondary activated materials
  • …
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leverages an existing technology pool-type liquid metal coolant as used in fast breeder reactors
Residual and newly introduced challenges for FLF

• Financial

• Regulatory
  • (how) should fusion be regulated?
  • Who should the regulatory body be?

• Technical challenges
  • Secondary activated materials
  • Liquid Li engineering
  • Rep rated projectile launch
  • …
Perspectives on North American Nuclear

Presentation to Westminster Energy Forum

February 2021
Content

- About Bechtel
- Bechtel & Nuclear
- Nuclear Power in the USA
- Exporting and Collaborating on Nuclear
"We have shown, through the Channel Tunnel Rail Link, when people were sceptical as to whether it ever could happen, that it can happen, and there are not, quite frankly, many Prime Ministers, or indeed many Ministers, that launch an infrastructure project, or accept its completion in front of the words; “On Time and On Budget”. We have done that with the Channel Tunnel Rail Link.

British Prime Minister Tony Blair, 2003

Opening of HS1 - Section 1"
Bechtel is a trusted global engineering, construction and project management partner to industry and government. Differentiated by the quality of our people and our relentless drive to deliver the most successful outcomes, we align our capabilities to our customers’ objectives to create a lasting positive impact. Since 1898, we have helped customers deliver more than 25,000 extraordinary projects—many first-of-a-kind—in 160 countries on all 7 continents.
Bechtel Corporation

Bechtel’s four global business units are trusted engineering, construction, and project management partners to industry and government. We align our capabilities to our customers’ missions with safety, quality, ethics, and integrity.

**Nuclear, Security & Environmental**
- 80% of nuclear plants in the U.S., and 150 worldwide designed, serviced, or delivered by Bechtel
- Construction and operation of national security facilities
- Building the world’s largest and most complex radioactive waste treatment plant

**Oil, Gas & Chemicals**
- 1/3 of global LNG capacity currently under construction
- 275+ refinery expansions and modernizations
- 50,000 miles (80,500 km) of pipeline systems
- 380+ major chemical and petrochemical projects

**Mining & Metals**
- 200 million metric tons per annum of installed iron ore productions
- 42 major copper projects
- 30 aluminum smelter projects
- 8 alumina refinery projects

**Infrastructure**
- 300 subway and rail projects
- 17,200+ miles (27,700 km) of highways and roads
- 6,200+ miles (10,000 km) of railroads
- 390 individual power plants
Seven Decades in the UK

We are proud to have been chosen to support some of the nation’s iconic projects, including the Channel Tunnel, Crossrail, West Coast Main Line, High Speed 1 and St. Pancras International Station, the Jubilee Line, Heathrow, Gatwick, London City Airport expansions and Sellafield.

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<th>1950s</th>
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<td>■ Pembroke Refinery</td>
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<td>■ Channel Tunnel</td>
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Our Commitment

- **Develop innovative solutions** to deliver the best engineering and construction services in rail, aviation, power, and digital infrastructure
- **Grow our partnerships** with the UK supply chain – building on a track record of billions of pounds invested in UK businesses and people
- **Promote a truly global Britain** by supporting the UK’s engineering and construction capability, as well as exporting domestic talent and suppliers on our projects worldwide
- **Actively encourage and grow a diverse engineering community**
Bechtel, a Global Leader in Nuclear Power

80% of nuclear plants in the U.S. designed, serviced, or delivered by Bechtel

150 Worldwide

75,000+ Total Megawatts
Engagement with:

Mark Peters, Idaho National Laboratory Director

"We are excited to work with the Bechtel-led team. They will bring a lot of design and construction experience to the VTR project. This is essential since it has been several years since we have built a test reactor in the United States."

Mark Peters, Idaho National Laboratory Director

Versatile Test Reactor Project
Benefits of the Existing Fleet

- The USA is the world's largest producer of nuclear power, accounting for more than 30% of worldwide nuclear generation of electricity.
- Nuclear power supplies, circa 20% of US electricity
- Nuclear provides 55% of the US’s carbon free capacity.
- Existing plants prevent almost 500 million metric tonnes of carbon dioxide emissions each year.
- Two new generation 3+ reactors are under construction by Bechtel at Plant Vogtle.
US Investing in Nuclear Power – Plant Vogtle Update

Vogtle Unit 3 & 4

Vogtle Unit 3 Dome Placement

Vogtle Tension Ring Panel for Shield Building

Vogtle – Tension Ring Panel for Shield Building
The US Government is investing in the Versatile Test Reactor (VTR), a project led by Bechtel.

- Fast neutron test capability
- Materials and fuels performance testing
- Supporting future advanced reactor programmes

Advanced Reactor Demonstration Programme, the winning technologies are the:

- Xe100 Helium Gas Cooled reactor and the
- Terrapower/GE Hitachi Natrium, sodium cooled, fast reactor with innovative molten salt heat storage- Bechtel is the EPC Partner to Terrapower.
“I can earnestly say that working with you and your team has been the best Contractor/Client collaborative experience that I have had during the 23 years I have been working in Nuclear.”

Commissioning Manager, James Dickaty, Sellafield Ltd

Sellafield PFCS, Project
- US Government supportive of exporting nuclear technology.

- Wylfa remains a highly attractive site for GWe nuclear development.

- Finance solutions, remain key to nuclear development.

- UK is a very important partner to the US on nuclear.

- COP26 presents a unique opportunity for the UK and the US to firmly position nuclear as key to achieving Net Zero.
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Any Questions?