Nuclear Technology Roadmap & NI2050

Nuclear Energy

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Energy Technology Perspectives

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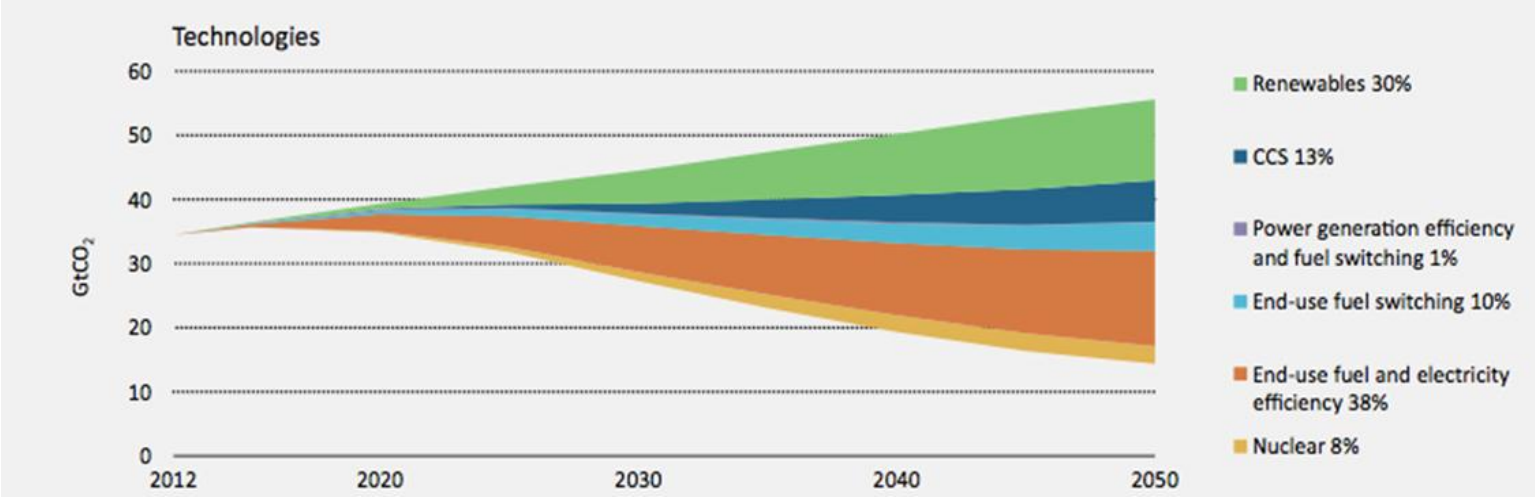
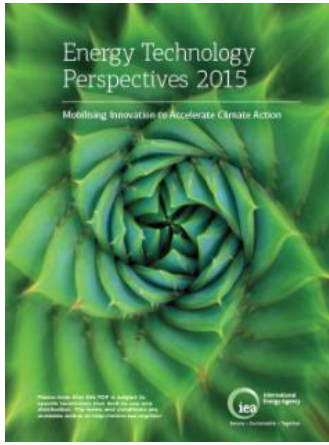
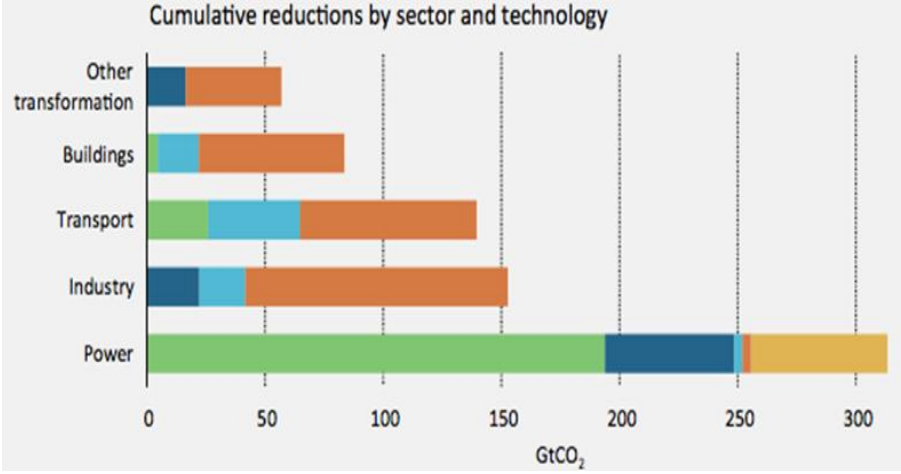
IEA Flagship Publication, Energy Technology Perspectives





- **6°C Scenario: business-as-usual, no adoption of new energy and climate policies. Energy demand will grow by more than 70% with respect to 2011.**
- **2°C Scenario: energy-related CO_2-emissions halved by 2050 through carbon price and strong policies (no significant technological breakthrough). Energy demand growth is limited to 25% with respect to 2011.**

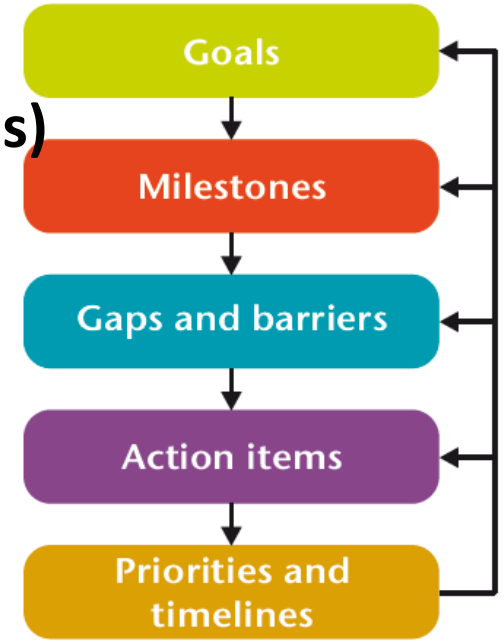


Nuclear since 2010, update of early roadmap

- Fukushima Daiichi accident (March 2011)
  - Impact on energy policies & public acceptance
  - Safety evaluations and upgrades
- Aftermath of financial crisis (2007-2008) and economic crisis
- Uranium market depreciation
- Shale gas revolution in the US (and US coal prices↘)
- Cost overruns and delays in some FOAK Gen III projects
- Lower than anticipated costs for onshore wind and solar PV

Objectives of the roadmap update

- Provide an overview of nuclear energy today, and areas of potential growth (regional analysis)
- Identify key technological milestones and innovations that can help support ambitious growth in nuclear energy
- Identify barriers to nuclear development
- Recommendations to policy-makers on how to reach milestones & address barriers
- Case studies developed with experts to support recommendations



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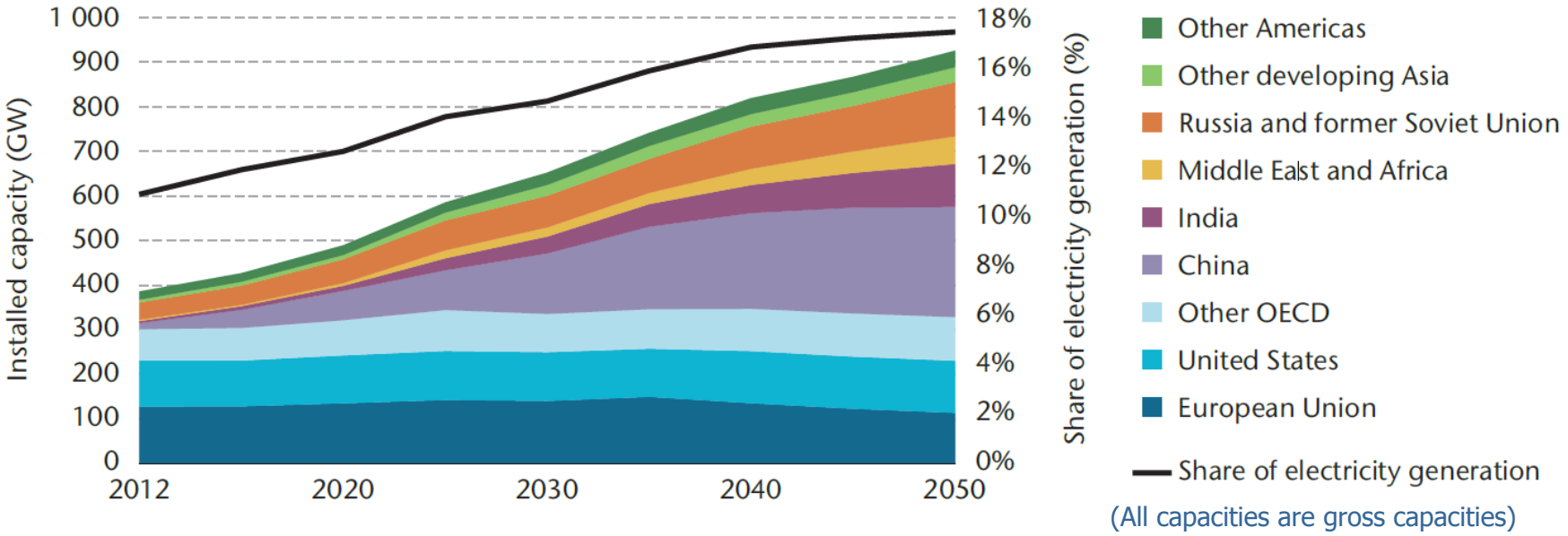
Nuclear in the 2°C Scenario (2DS)



(All capacities are gross capacities)

- **930 GW by 2050 (down from 1200 GW in the 2010 Roadmap)**
- **17% share electricity (down from 24% in the 2010 Roadmap)**
- **But still a formidable challenge (multiply current capacity by 2.3 in 35 years)**

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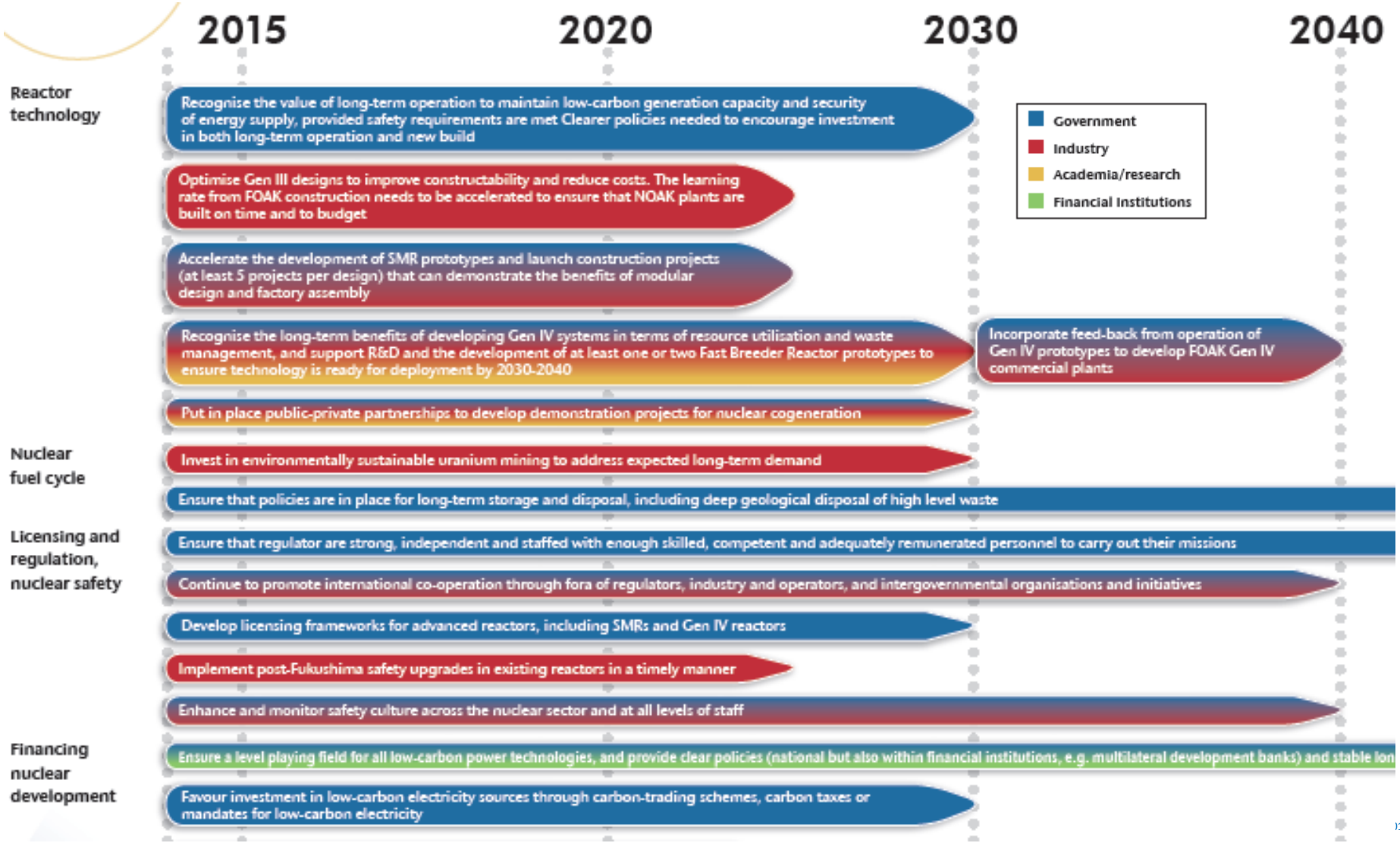
Roadmap actions and milestones



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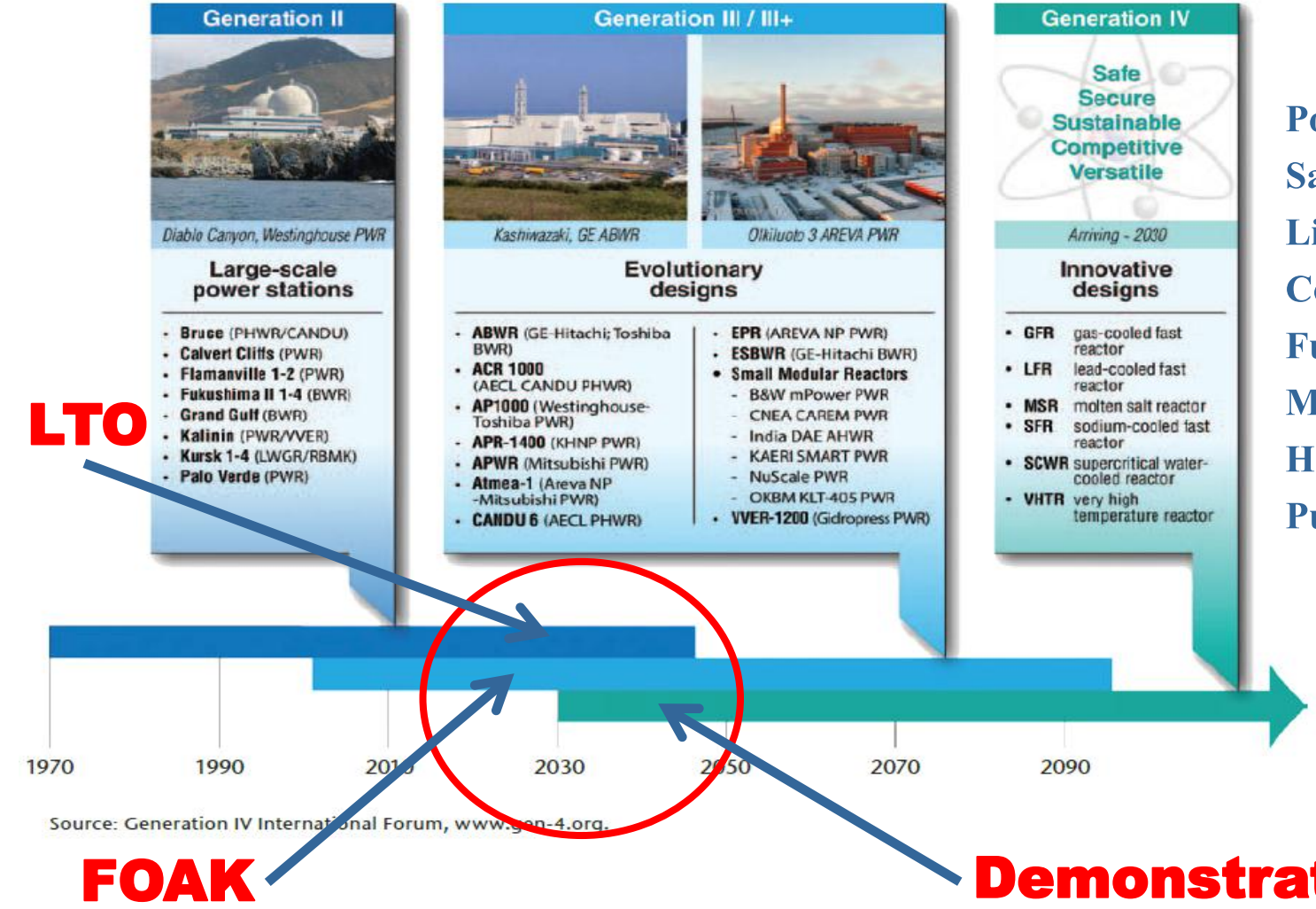
Reactor technology evolution



- Policy
- Safety
- Licensing&Regulation
- Code&Standard
- Fuel cycle
- Market&Financing
- Human Resource
- Public Acceptance

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Reactor technology evolution

- **Safety upgrades & Long Term Operation of existing fleet**
- **Continuous evolution of Gen III/III+ designs:**

Experience feedback from FOAK projects → • Design simplification • Standardisation • Improved constructability • Modularity • Supply chain optimisation → Cost reduction; Build on time & to budget

- **Small Modular Reactors**
- **Operational aspects**
- **Generation IV (Fast Neutron Reactors)**
- **Cogeneration / non-electric applications**

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Nuclear fuel cycle

- Uranium supply – more than adequate to meet high demand up to 2035 (Red Book)
- Potential for laser enrichment to reduce costs
- Accident Tolerant Fuel still decades away
- Deep Geological Disposal – recommended strategy for managing HLW, what ever the route (once-through or recycling). “Wait and See” not an option
- Extended storage needed, but NOT alternative to DGD
- Optimising waste management
- Importance of “fuel services” to support development

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Decommissioning

- Perceived as an unresolved issue (~ waste)
- Issue of costs – and adequate funding
- Importance with respect to public acceptance
- Technology exists, and can be further developed to reduce decommissioning costs
- Also, newer designs take decommissioning into account

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Safety and regulation

- R&D: Severe accidents, assessment methodologies (PSA)
  - Improved understanding, reduced conservatisms
- Enhanced safety requirements (impact LTO prospects?)
- Regulation:
  - Importance of strong & independent regulation stressed
  - Concern of 'over regulation' of nuclear industry (multiplication of regulatory requirements) → more coordination/harmonisation of requirements for more efficient regulation
  - Licensing frameworks for advanced reactors (SMR, Gen IV) need to be developed
- Safety culture needs to be enforced across the whole of the nuclear sector and at all level of staff
- Importance of peer-reviews (regulators, operators)

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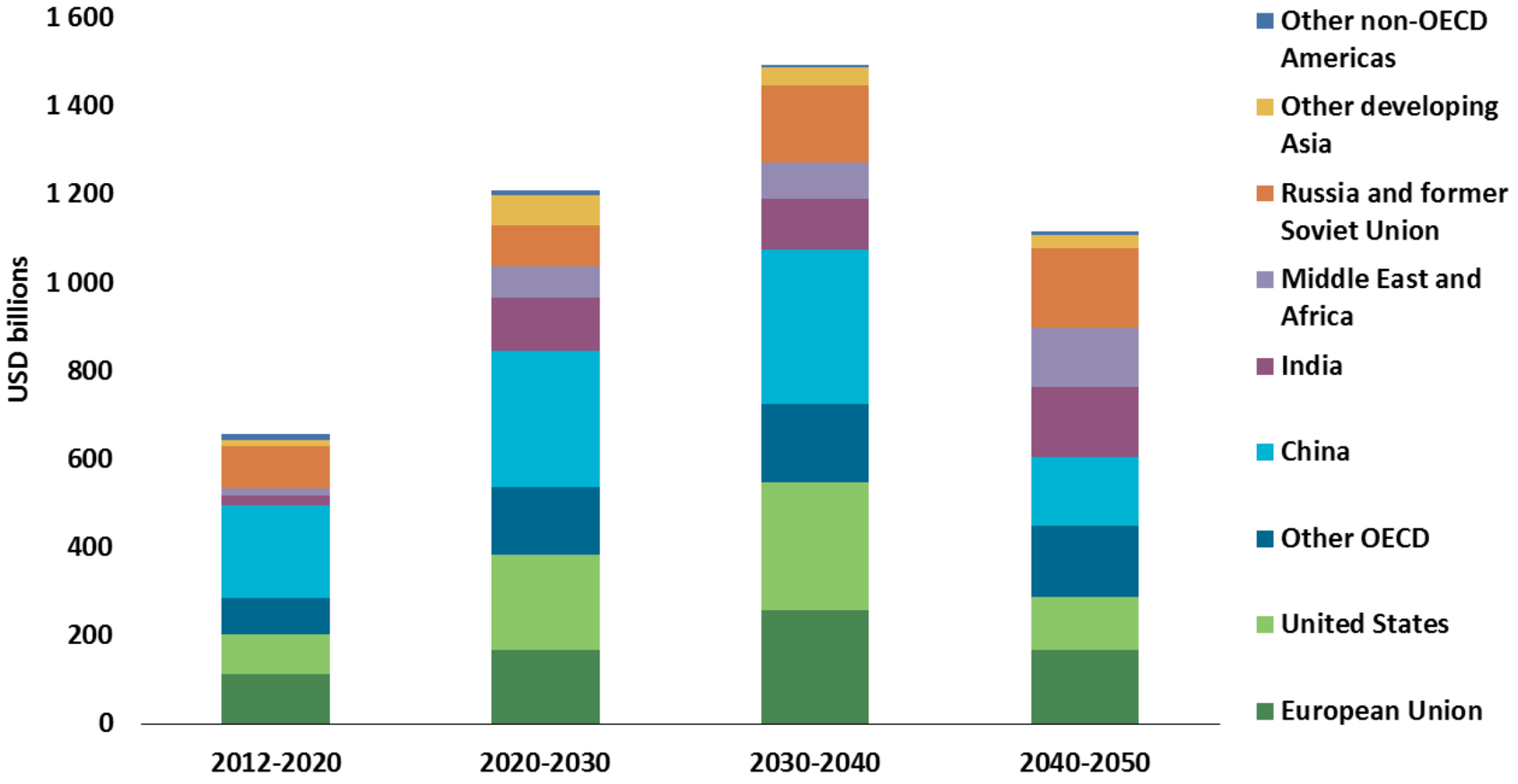
Nuclear investment requirements in 2DS, 2012-2050



Financing (1/2)

- All low-carbon technologies characterised by large upfront expenditures; nuclear has also long lead-time and payback period.
- Capital-intensive technologies are sensitive to the cost of capital (which is function of project risk).
  - 1% change in discount rate => 11% in LCOE for a nuclear project.
- Nuclear projects are particularly exposed to:
  - Construction risk.
  - Electricity market risk.
  - Political/regulatory risk.
- Financial context is unfavourable (capital losses of major utilities, Basel III requirements, low electricity prices, ….)
- Financing nuclear generation in liberalised electricity markets remains particularly challenging.

Financing (2/2)

- Government support is key: long term strategy and policy stability (importance of technologically-neutral policies).
  - Robust and predictable carbon signal remain a key strategy for developing low-carbon technologies.
- Importance of de-risking nuclear projects:
  - "Build on time and to budget" requirement.
  - Electricity price stability (market-based long-term contracts, CfD, PPA).
- Some examples:
  - BOO approach & Power Purchase Agreements (Turkey).
  - Contract for Difference (UK).
  - Mankala Model (Finland).
  - Vogtle (US): regulated market +CWIP, loan guarantees, production tax credit.
- Innovative financing schemes
  - Refinancing strategies/ownership transfer when the unit is completed.
  - Involvement of vendor in financing.
  - Potential for investments in development banks.

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Training-capacity building

- Perceived as one of the key barriers:
  - In nuclear countries: retirement of a significant share of current workforce in coming decades & in newcomer countries
- Many initiatives to identify needed skills, HR requirements – and set up E&T schemes
- Role of R&D to attract and train researchers/engineers

Public acceptance

- Remains a key issue
- Particularly sensitive in non-OECD / newcomer countries
- Need to provide adequate communication / targeted factual information on risks & benefits

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Near Term Actions for Government

- Provide a clear **commitment and long-term strategy** for nuclear development.
- Recognise the importance of **long-term operation** to maintain low-carbon generation capacity and security of energy supply; provide clear prospects to encourage operators to invest in refurbishments.
- Support efforts in **safety research**, and ensure that results are communicated to a wide audience.
- Continue to co-operate to discuss **international fuel services** as a means to secure the development of nuclear power. Ensure that policies are in place for long-term storage, including DGD of high-level waste.
- Continue to support **R&D in advanced recycling technologies** to reduce the volume and toxicity of high-level waste.
- Ensure that dedicated funds are set aside for **decommissioning** activities and that operators provide sufficient funding to these funds during operation of NPPs by regularly reviewing the adequacy of accrued funds.
- Work with industry to open up the market for **small modular reactors** by accelerating the deployment of SMR prototypes that can demonstrate the benefits of modular design and construction.
- Support R&D and prototype development for **Gen IV systems** to ensure technologies are ready for deployment in 2030-40.
- Ensure **regulators** are strong, independent and staffed with enough skilled and competent personnel to carry out their missions.
- Encourage the development of licensing **frameworks for advanced reactors**, including SMRs and Gen IV reactors.
- Expand public-private partnerships with industry to develop demonstration projects for **nuclear cogeneration**, in the areas of desalination or hydrogen production. Develop education centres to support effective communication and public knowledge about the facts of nuclear.

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Near Term Actions for Industry

- Implementation of **Post-Fukushima safety upgrades** by operators of NPPs in a timely manner.
- **Optimisation of Gen III designs** to improve constructability and reduce costs.
- Lessons learnt from current FOAK projects should be used to ensure that NOAK plants are built **on time and to budget**.
- Investments are needed in **environmentally sustainable mining** to address expected long-term demand.
- Nuclear facilities that have been shut down should be **decommissioned in a timely, safe and cost-effective manner**.
- Enhance **safety culture across** the nuclear sector and at all levels of staff.
- Improved communication with institutional investors and other financial institutions to better educate **investors** on the economic benefits of investment in NPPs.
- Continued harmonisation of **codes and standards** to improve the integration of a global supply chain.

Near Term Actions for Universities and other research institutions

- **R&D in ageing and improved safety** is needed to support long-term operation of existing NPPs for 60 years of operation or more.
- Studies should be carried out to ensure **extended (dry) storage of spent nuclear fuel** satisfies the highest safety and security requirements.
- Devote more effort to **safety research** and communicate results to a wide audience.
- **A national skills evaluation** should be undertaken to quantify the need for a skilled nuclear workforce.
- International co-operation is needed to help **transfer nuclear training programmes** from existing nuclear countries to newcomer countries.
- **Student exchange programmes** aimed at newcomer countries should be developed and where possible include a period of practical work experience at a nuclear facility.

Near Term Actions for Financial institutions

- **Export credit agencies** should continue to support nuclear financing by providing loan guarantees.
- **Pension funds and other institutional investors** should consider investments in NPPs.
- **Development banks** could support nuclear training and capacity development needs in new comer countries.

Key actions for the next 10 years

- Offer same level playing field to all low C technologies (electricity markets)
- Industry to build on time and to budget, FOAK →NOAK
- Enhance standardisation, harmonise C&S and regulatory requirements
- Continue to share information & experience (among regulators and among operators) to improve safety
- Public acceptance must be strengthened (post F safety upgrades, fact-based information)
- Develop long-term strategy for radwaste management

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Hope NI2050 to provide insight on how to do, and background to set up necessary Research and Innovation plan….