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Economic Impact of Major Industry Events

Global Nuclear Power

Edward Kee
Vice President

USA Nuclear Generator and Supplier Executive Summit
13 June 2012 – Colorado Springs

Insight in Economics™

Disclaimer

The slides that follow are not a complete record of the presentation and discussion

The views expressed in in these slides and the discussion today are mine

My views may not be the same as the views of NERA's clients or my colleagues

Global nuclear power

Two perspectives on global nuclear power:

- Who is planning/building nuclear power plants?
- What designs are being planned and built?

To understand ***who*** is building ***what*** designs. . .

. . . You also need to understand ***why***

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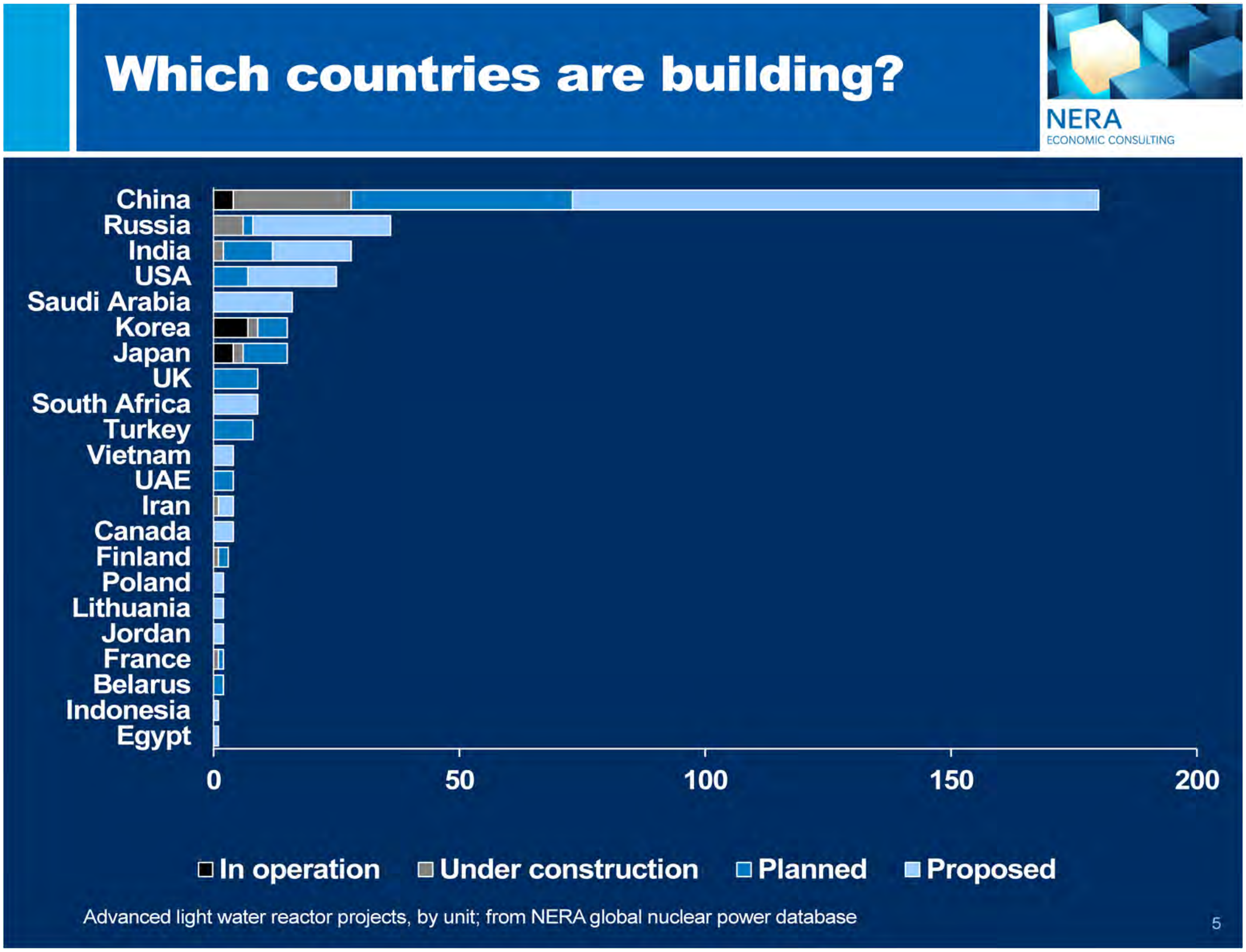
WHO IS BUILDING?

Who is building?

- Global league tables
- Three main drivers:
  - Politics and public opinion
  - Electricity fundamentals
  - Electricity industry organization



This chart is based on our database of nuclear projects.

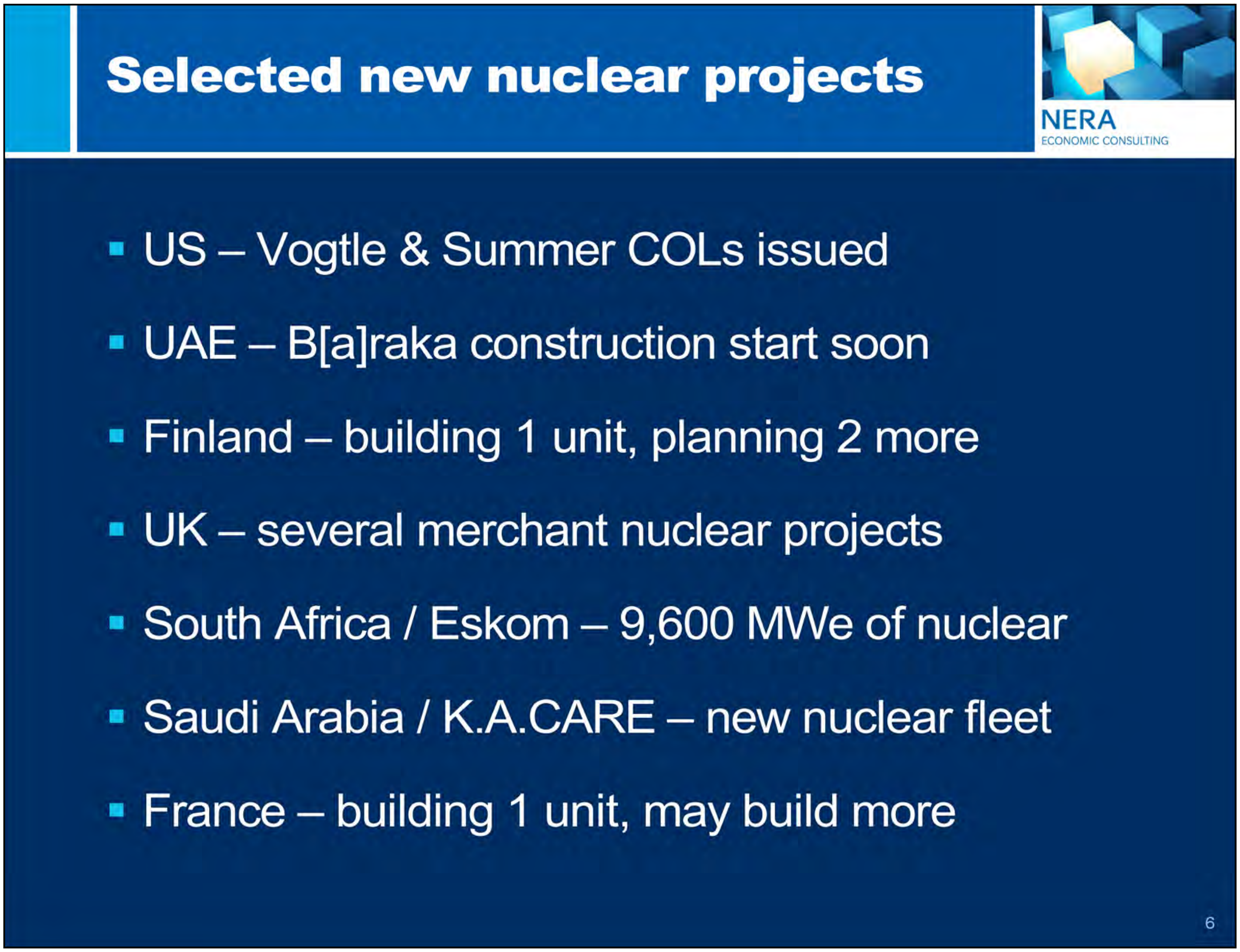
There are a lot of countries on this simple bar chart.

But there is a long and complicated story for each country shown in the chart. And each project in a country has its own complicated story.

There is also a complicated story about some countries that are not (yet) on this chart.

This data uses my definitions.

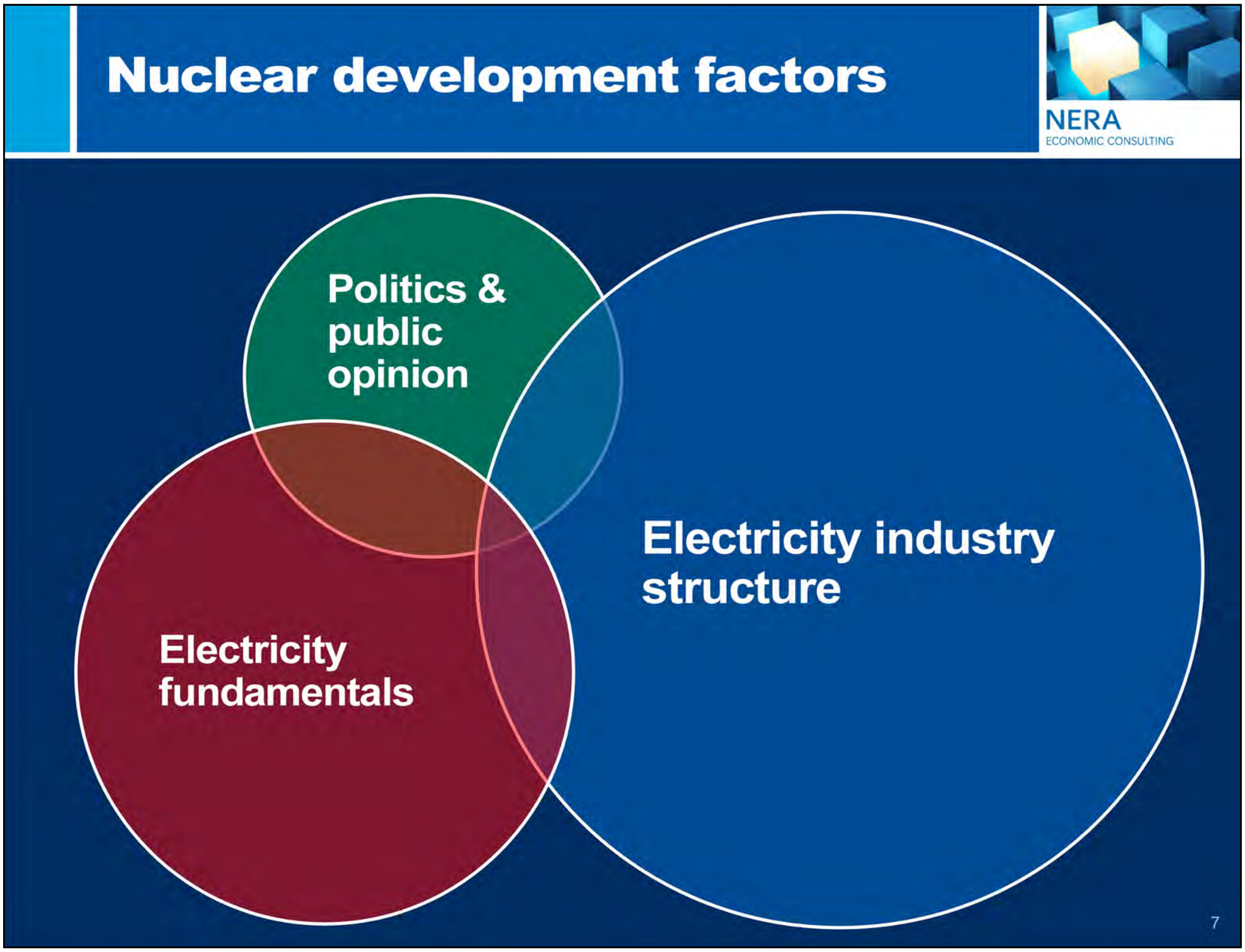
- The industry has differing views on which reactor designs should be considered as an “advanced light water reactor” and Gen II, Gen II+, Gen III, and Gen III+ categories.
- There is general industry agreement on which projects are in operation and which projects are under construction, but the “planned,” “proposed,” and “announced” (not shown in this chart) categories are less well defined category.



As examples of the projects on the prior graphic, here are some projects.

To understand why these countries are building (or planning) new nuclear and why other countries are not, I look at three factors:

- Politics and public opinion
- Electricity fundamentals
- Electricity industry structure


Nuclear development factors
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Politics & public opinion
Electricity industry structure
Electricity fundamentals
7

Nuclear development factors - 1

Politics & public opinion

8

Politics and Public Opinion

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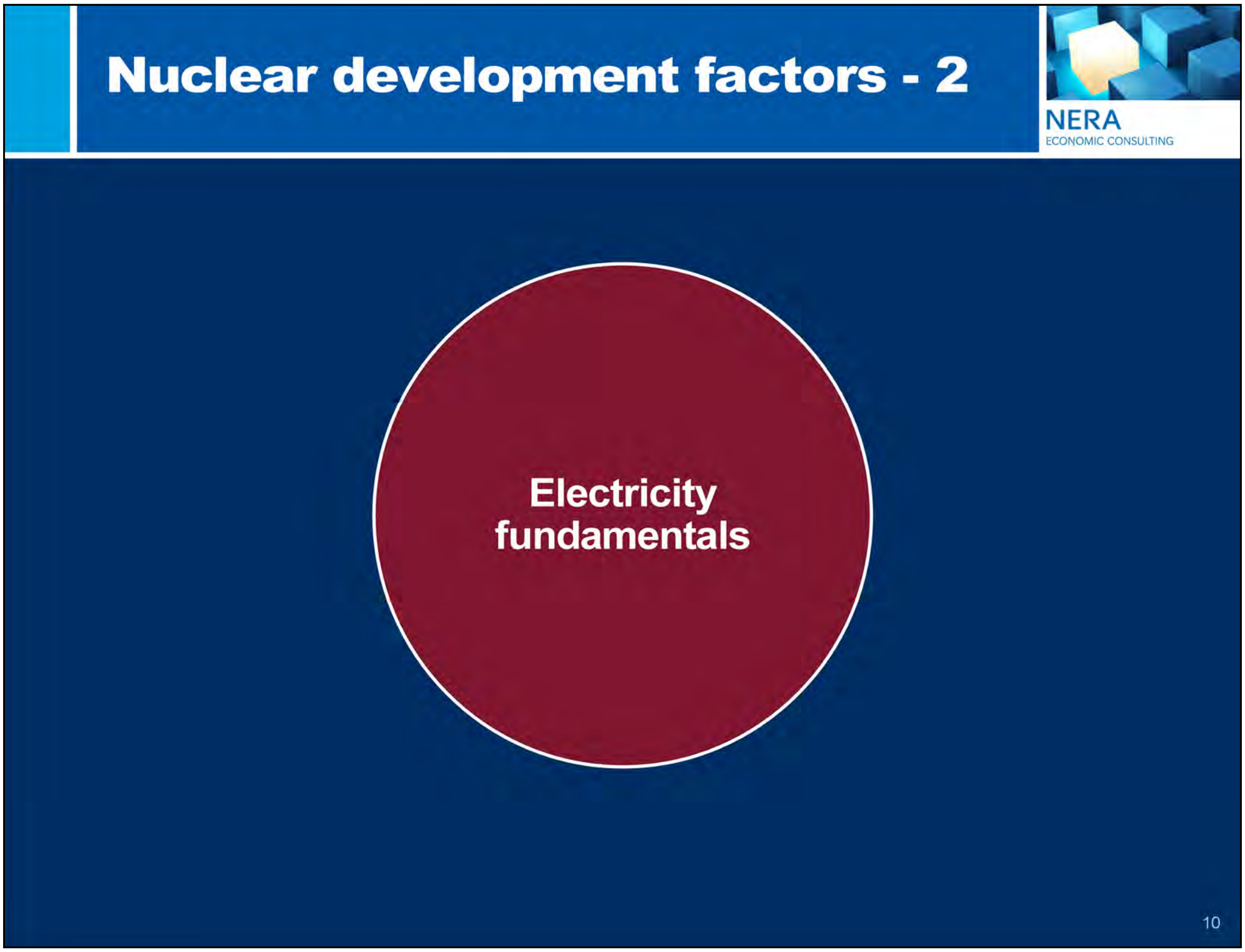
- National position against nuclear power – Austria, Germany (for now), Italy, etc.
- Approach to climate change/CO2
- Level of difficulty in going from concept to construction to operational nuclear plant
- Role of government (e.g., US DOE loan guarantees, EU State Aid laws)

9

A necessary, but not sufficient basis for new nuclear power. But a national prohibition can stop nuclear power. And the details of laws, regulations, and other things can make things easier or harder for a nuclear power project.

Case study: Austria's prohibition on nuclear power

In 1960s Austria was to have up to five NPPs; the first nuclear power plant was 723 MWe BWR by AEG/KWU; decision in 1971 to build at Zwentendorf, 60 km northwest of Vienna, on the river Danube. Construction started in 1972 and it was scheduled to start operation in summer of 1976. After two years of delay in construction the plant was nearly finished in 1978 and was scheduled to start operation in fall. Two years before, in 1976, a very intensive public and political discussion about using nuclear power for electricity production started. Based on this discussion the Austrian government carried out a referendum about using nuclear power. On November the 5th, 1978 the Austrian voted with 50.47% against the use of nuclear power for electricity production in Austria; nuclear power for electricity production in Austria is prohibited by law. In 1999, the Austrian parliament passed unanimously a constitutional law on a nuclear-free Austria



Electricity fundamentals include things like supply, demand, capital and operating costs of generating options, availability of various generation and fuel options, cooling water approaches, sites.

If the world energy situation (and the portfolio of electricity generation assets) were determined by straightforward engineering economics, these are the factors or inputs to the solution

This is not about beliefs, likes, or preferences – it is about meeting the demand for electricity in a reliable manner at lowest cost over a long period.

Electricity fundamentals

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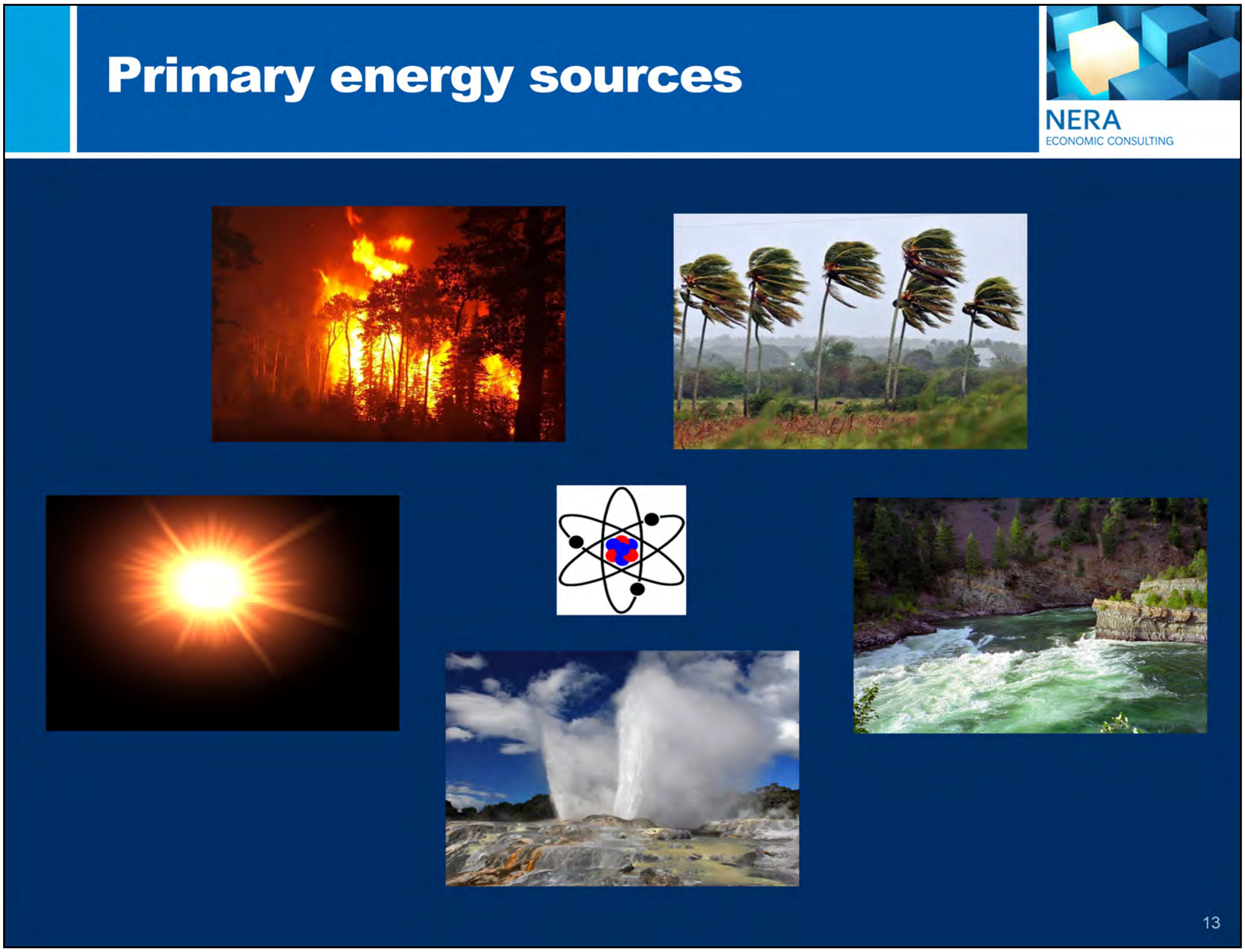
- Electricity
- Primary energy sources
- Electric generation options & cost
- Real economics vs. political aspirations

11

Importance of electricity

- Shift from primary energy to electricity is key feature of modern civilization
  - Easily distributed, controlled and used
  - Some potential for storage (e.g., batteries)
  - Integral part of modern information technology
- Many approaches to cleaner total energy mean more electricity use (e.g., electric vehicles)
- Developing world increases standard of living by electrification (e.g., shift from burning wood)

12



Some of these primary energy sources can be used directly. Examples include wood or natural gas stoves and heating, rooftop solar hot water, and wind driven mechanical water pumps.

The pervasive use of electricity in modern society means that a critical issue is how (and how much) these primary energy sources are used to generate electricity

The most common sources of energy are combustion and nuclear

Fire/Combustion

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- Stored chemical energy released by combustion
- In use for a very long time; now dominant
  - Controllable
  - Multiple fuels, most are dense and easily stored
  - Easy disposal of waste (CO_2, ash, etc.)
- Centuries of technology development
  - e.g., steam engines, IC engines, gas turbines, modern coal generation plants

14

Nuclear

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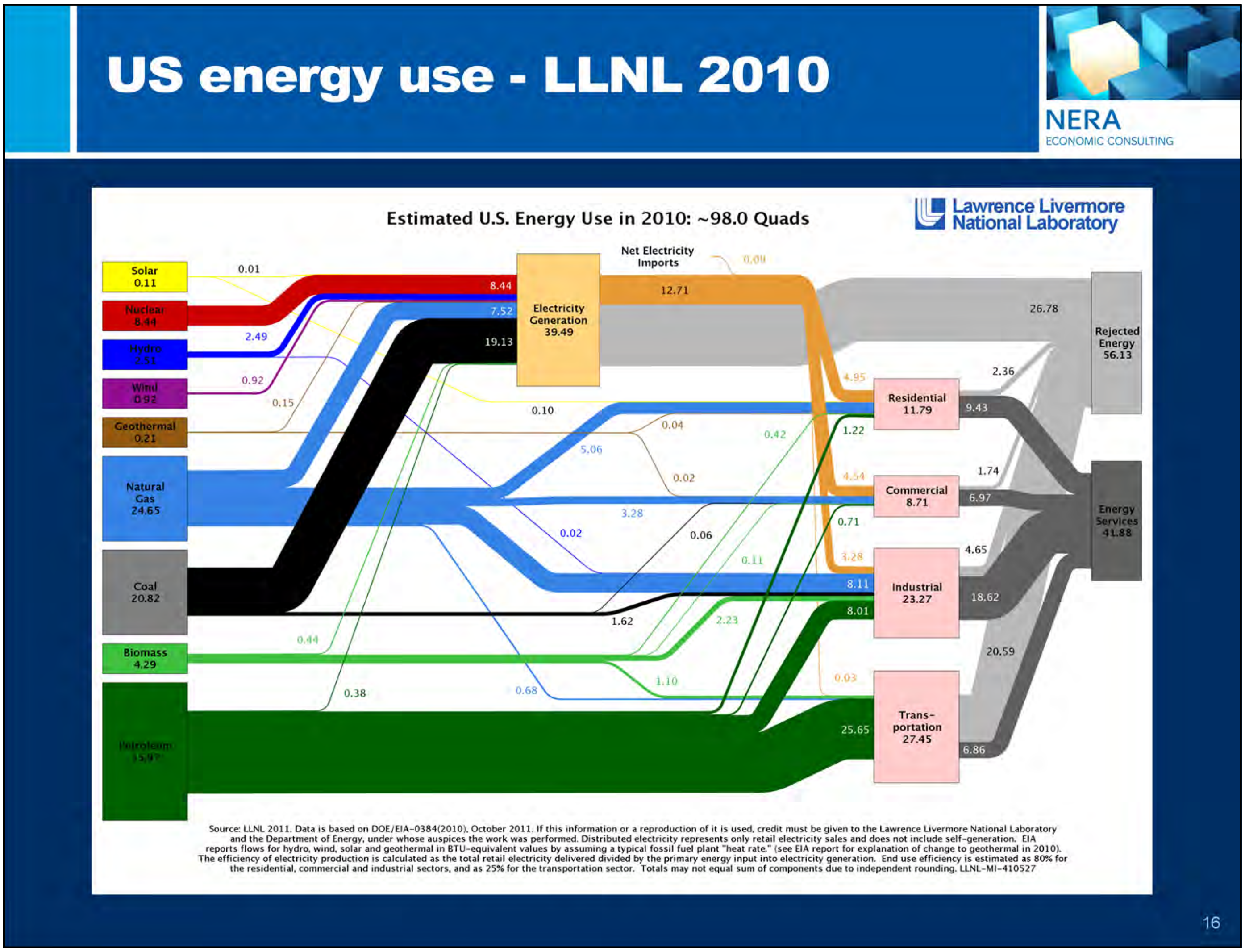
- Stored atomic energy released by nuclear fission
  - Controllable
  - Main use is electricity generation
  - Clean – operation produces no CO_2
- Very dense – large output for small size
- Only about 60 years of technology development

15



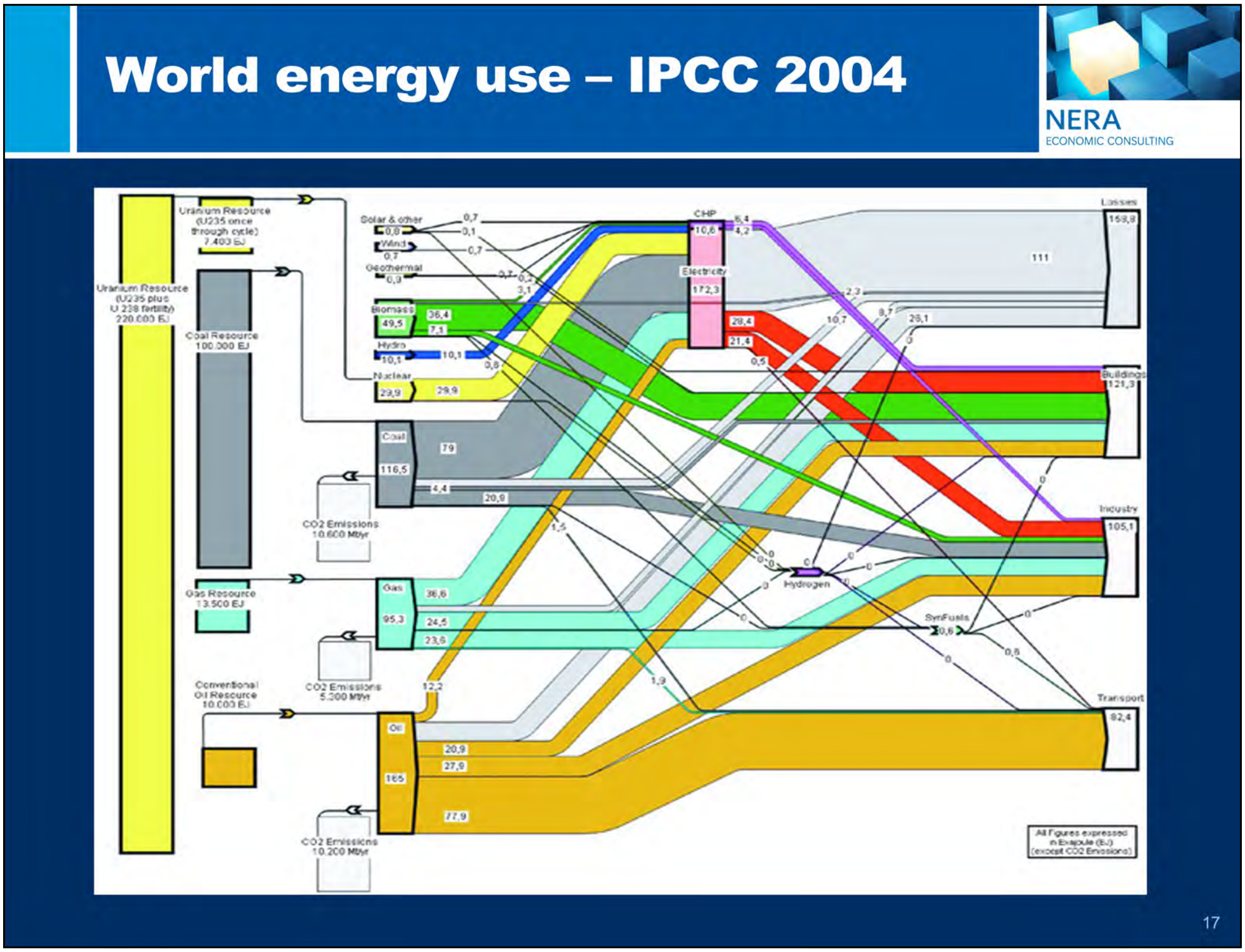
I will not cover the details of this slide (Sankey diagram from LLNL).

I show this to illustrate:

Combustion-based energy (i.e., burning NG, coal, biomass, and petroleum) is very large part of total US energy use

Shift from petroleum use in transportation will likely mean increase in (and changes in shape of) demand for electricity (i.e., electric cars)

Small contribution of solar, wind, geothermal, and hydro to total energy use



Also, no need to see or discuss the details of this slide (another Sankey diagram from IPCC).

This is similar to prior slide, but for world, rather than US and with bars on the left to show world reserves for various energy sources. There are four points here:

- Some countries burn oil to make electricity (e.g., Saudi Arabia)
- Much less oil and natural gas remaining to be burned, compared to coal and uranium
- A lot (hundreds of years) of uranium using once-through fuel cycle, centuries of uranium using fast reactors and U-238 – and this is based on known reserves – there is a lot more to be found, in sea water for example
- Thorium is not shown here – thorium may be significant source of fissile material with even greater reserves

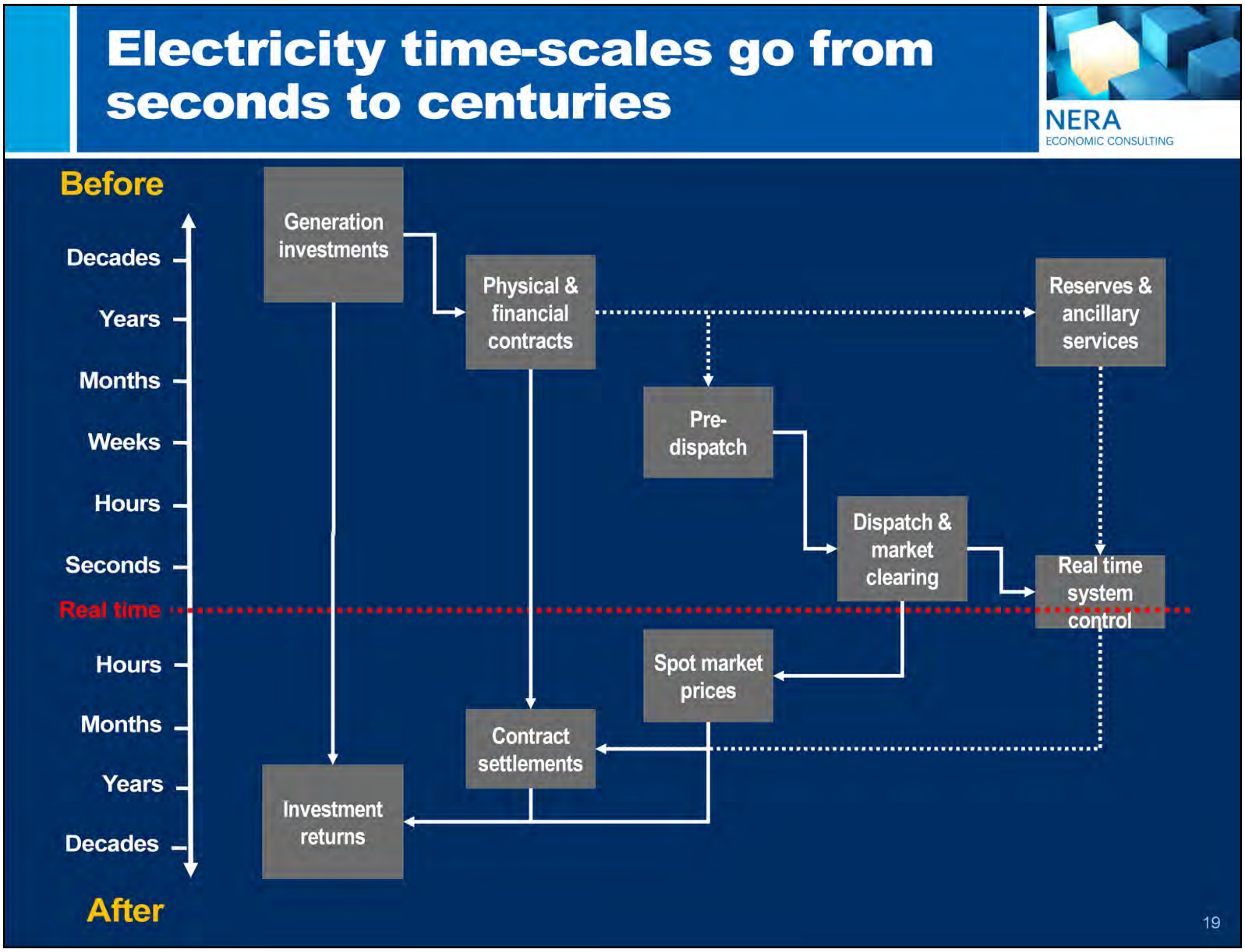
Electricity economics

- **Real-time:** System dispatch (least-cost approach to meet electricity demand) - minimizing short-run marginal costs within constraints (e.g., security & unit commitment)
- **Long-term:** Optimal least-cost resource mix/plan is complex multi-decade problem:
  - Fuel and generating option constraints
  - Short-run marginal costs (i.e., fuel)
  - Unit commitment/availability issues
  - Fixed annual costs and long-term investments

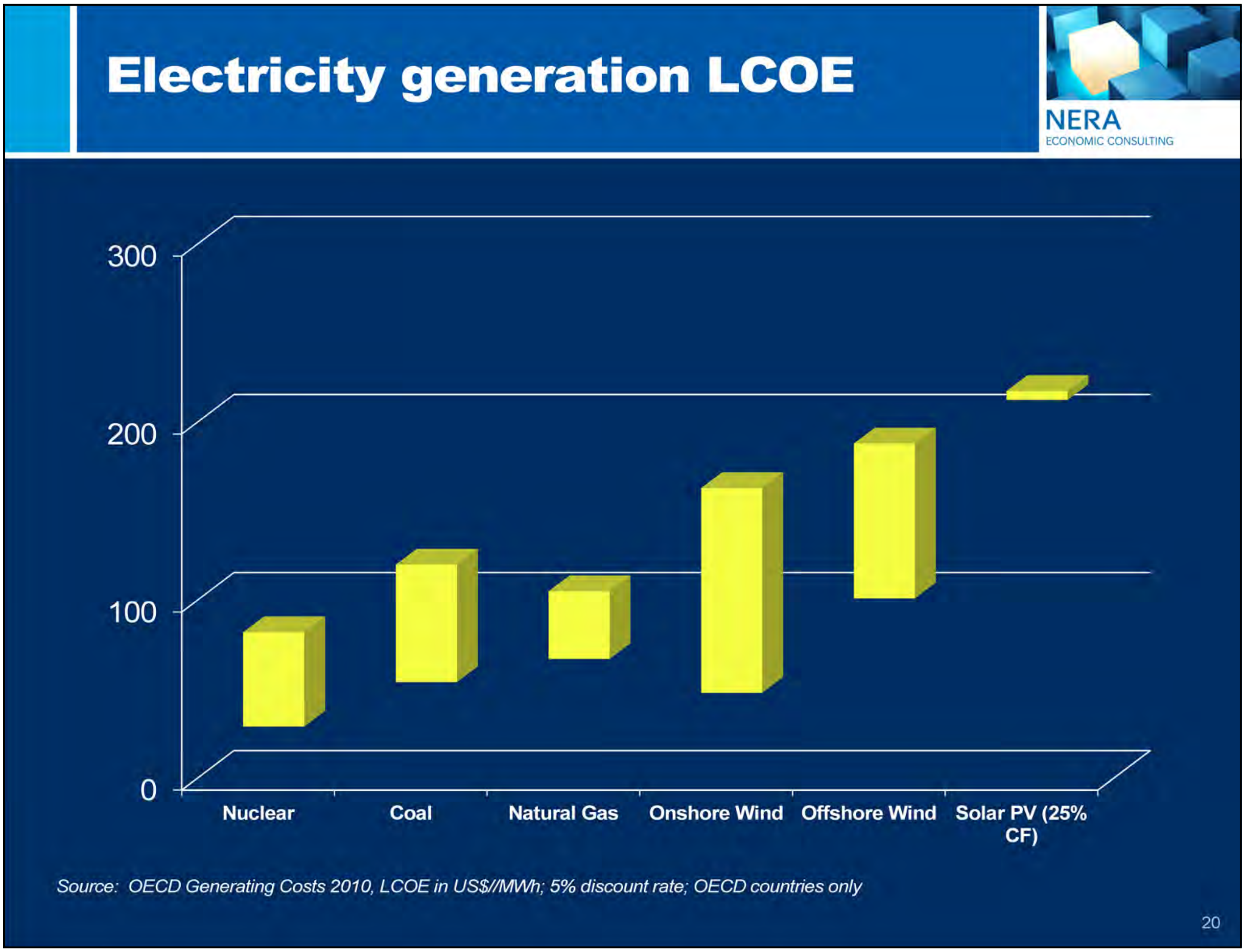
18

Real-time electricity economics is related to the efficient use of *existing and available* generation assets

Long-term electricity economics is related to the efficient investment in power plants and other assets.



What happens on time scales of seconds, including dispatch and unit commitment decisions, has a profound impact on the long-term economic performance of assets with lives of decades or more.



The height of these bars is an indication of the range of costs across OECD countries. Obviously each country will have a unique set of costs and every country may not have all these options available.

The overlap across bars shows that the decision about investment may not be easy.

Add to this the uncertainty about future fuel costs, environmental restrictions, national resource availability, and other things – electricity resource planning is not easy

Primary energy constraints vs. political aspirations?

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- Limited indigenous energy sources
  - France, Finland, Japan, South Korea
- Coal resources, but not much oil or gas
  - South Africa, India
- Petroleum resources but little else
  - UAE, Saudi Arabia
- Large coal, oil, gas resources
  - US, Australia, Canada

21

The compelling value proposition for nuclear is different in each country.

In countries with limited energy options, fundamentals of nuclear energy are likely to be favorable.

In other countries with multiple energy options (i.e., a lot of natural gas and/or coal), the fundamentals of nuclear energy may be doubtful.

While political mandates (e.g., CO_2 reduction or energy independence) may provide additional incentives for nuclear in these countries, the inherent instability of political decisions and the short time frame of political administrations make these mandates a questionable basis for long-term nuclear power investments.

Nuclear development factors - 3

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Electricity industry structure

Nuclear business model

Merchant

Regulated

Government

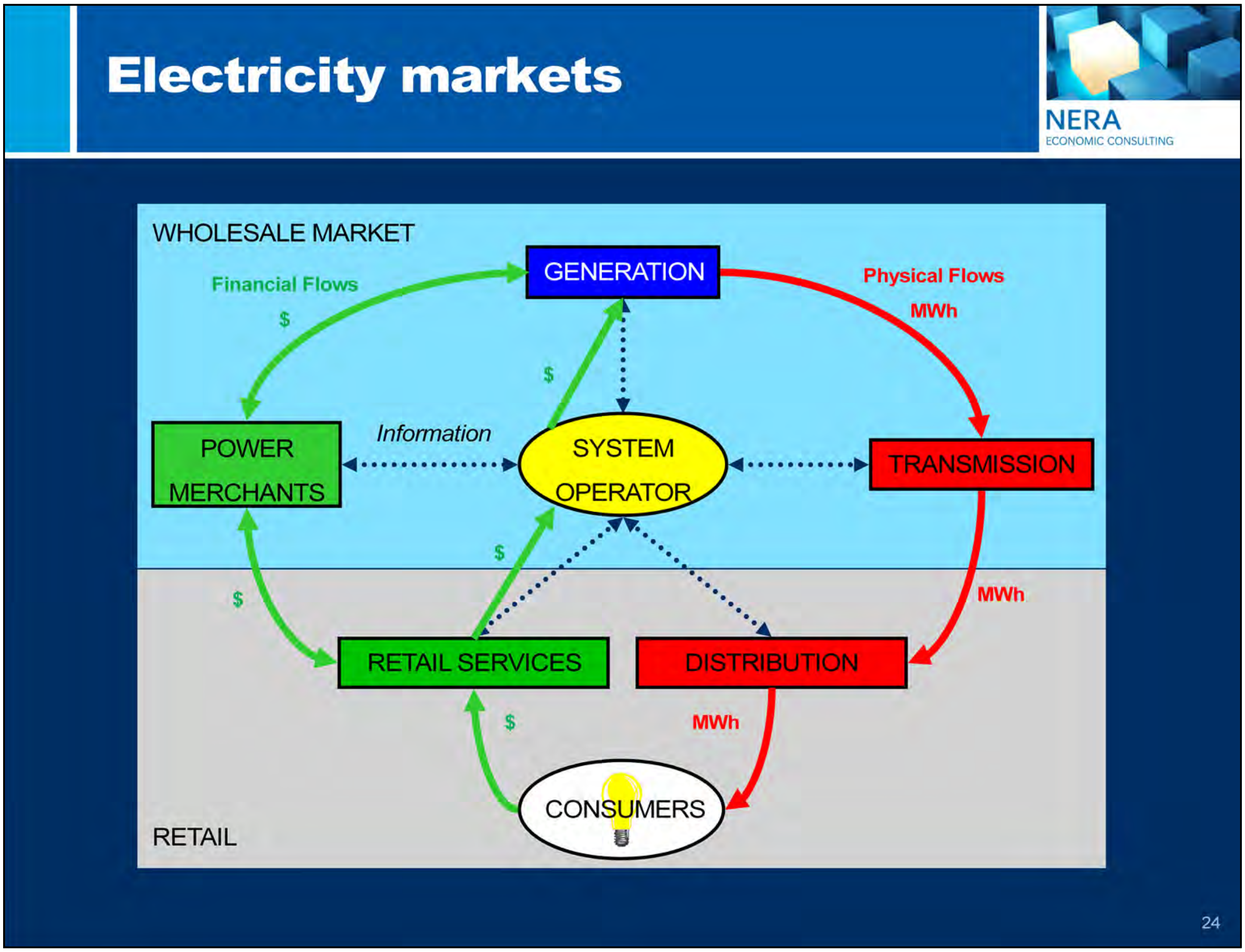
22

Electricity industry organization

- Industry structure may be more important than fundamental economics
- 3 basic models for countries/states/regions
  - Reformed/restructured electricity industry with formal electricity markets
  - Regulated electricity industry and regulated projects
  - Government-owned electricity industry

23

National or regional decisions about electricity industry structure lead to one of three nuclear business models.



Typical electricity market concept – distribution and transmission (and system/market operator) are regulated; retail, trading, and generation are not.

Investments in generation assets are investments in economic assets that will (or will not) earn a return on investment as a result of selling electricity (and related products like reserves, capacity) into the electricity market.

Accordingly, the formal structure of the electricity market (market rules, etc.), the competitive situation in the market, and the costs of power from all sources are key issues for a nuclear investment.

A conceptual diagram of the electricity market in a single trading period (e.g., a half-hour)

The fixed cost coverage for the nuclear power plant (and all power plants) is from the difference between SRMC and the SMP.

Adding a new large nuclear power plant would likely mean that the SMP is lower.

A nuclear power plant has a low or zero SRMC, so that it would be added at the left side of the supply stack. Adding a new nuclear power plant would put a new bar to the left of Plant “1” and would move the entire supply stack to the right.

As the supply stack shifts to the right due to nuclear entry, a different generator with a lower SRMC is now on the margin. This lowers the SMP and lowers the return to all generators, including the new nuclear power plant.

And if fuel cost drops for the generator that sets the SMP at some point in the future, the SMP falls and returns on the nuclear investment drops.

Merchant nuclear plants

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- This is ***really hard*** – none have been built
- Project ***and*** market risk assumed by developer
  – Project cost & completion risk - before COD
  – Project availability and market price risk - after COD
- Project finance approach strained by
  – High capital intensity and large project size
  – Long development and construction period
  – Lack of revenue certainty
  – NPV / IRR / payback period for investors/lenders

26

While there are some merchant nuclear projects today, but these became merchant generators through divestment or privatization. The shift to merchant status came after the nuclear plants were divested or privatized.

The original investments in these merchant nuclear plants was made by regulated or government utilities.

Examples of Merchant nuclear

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- Calvert Cliffs 3 – UniStar project in PJM market; high DOE loan guarantee subsidy fee; EDF
- South Texas Project 3 & 4 – NRG project in Texas (ERCOT) market; half-owner CPS withdrew, then Japanese stakeholders (Toshiba and TEPCO) hit by East Japan Earthquake
- UK new nuclear – 3 groups talking about new nuclear; Horizon dropped out, others delayed and wary; Electricity Market Reform and Energy Bill debate going on now

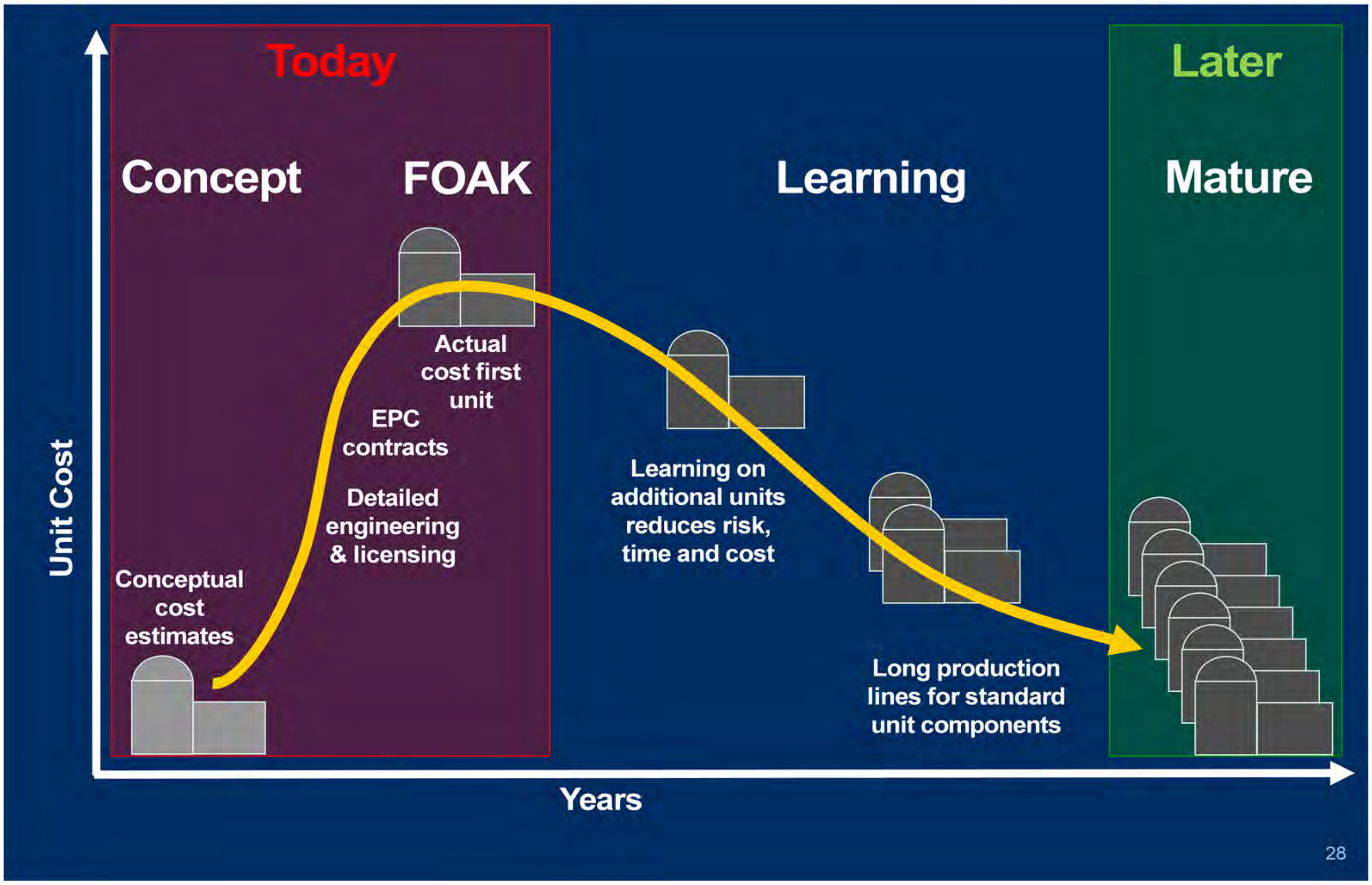
27

The first two examples were early contenders for the first new nuclear plant in the US, now both are stalled – with NRC COL applications moving forward. Even if these merchant projects are not built in next decade, having an approved NRC COL may have option value, may allow a faster start when (if) fundamental economics are more favorable, and may benefit the reactor vendor in non-US markets (i.e., due to perceived rigor of the US NRC licensing process).

The third example is the UK – where the entire new nuclear program is to be based on merchant nuclear plants. The evolving EMR process may provide enough financial incentive to investors. Likely, the appetite of state-owned EDF to invest in the French EPR reactor design in the UK market (where there is some vertical integration benefits) will be a key factor.

Recent news suggests that EDF is negotiating a deal on various EMR financial incentives and that the Horizon project may be sold to one of several entities with Chinese, Russian, French, and US entities competing to buy the entity.

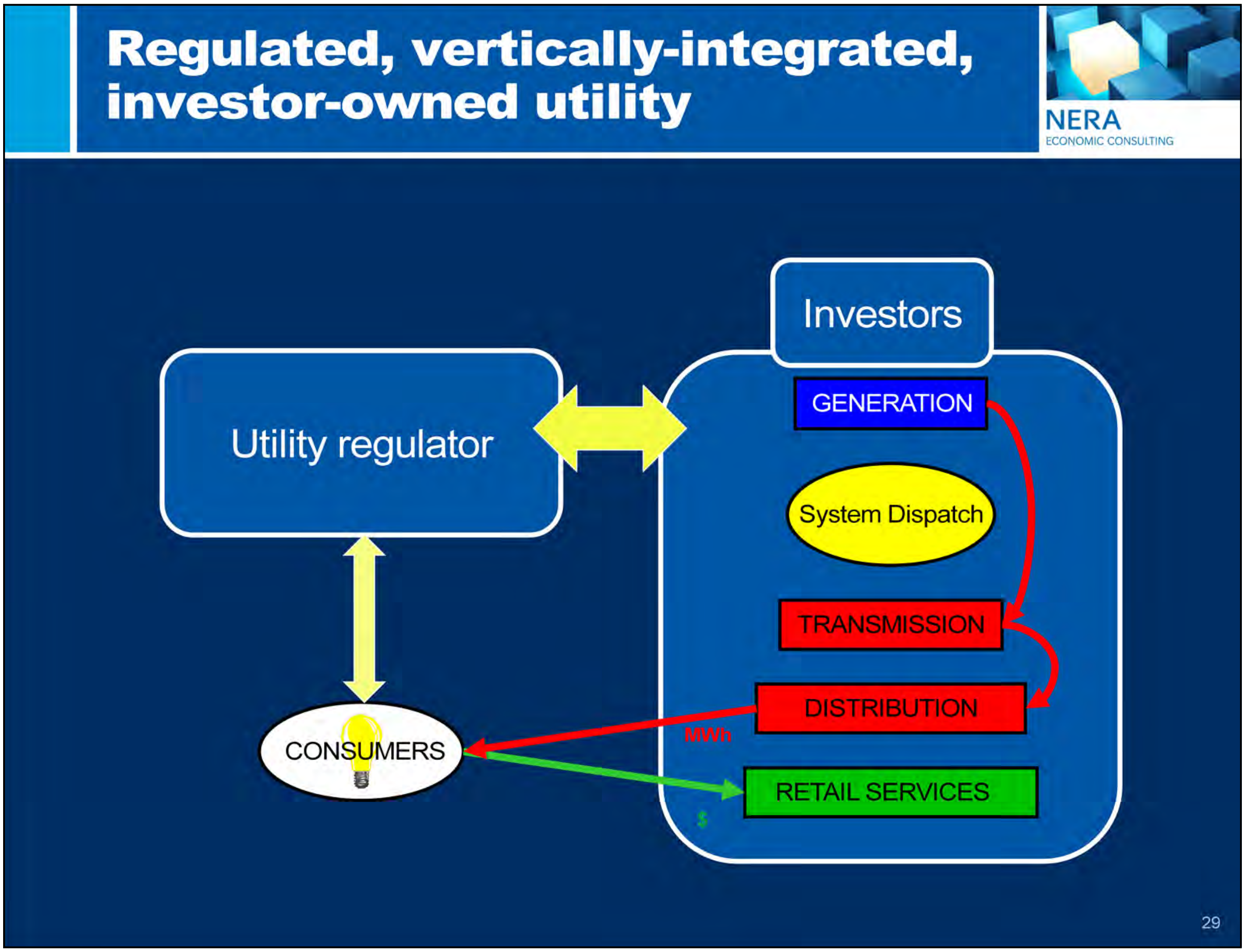
FOAK issues add difficulty to merchant projects



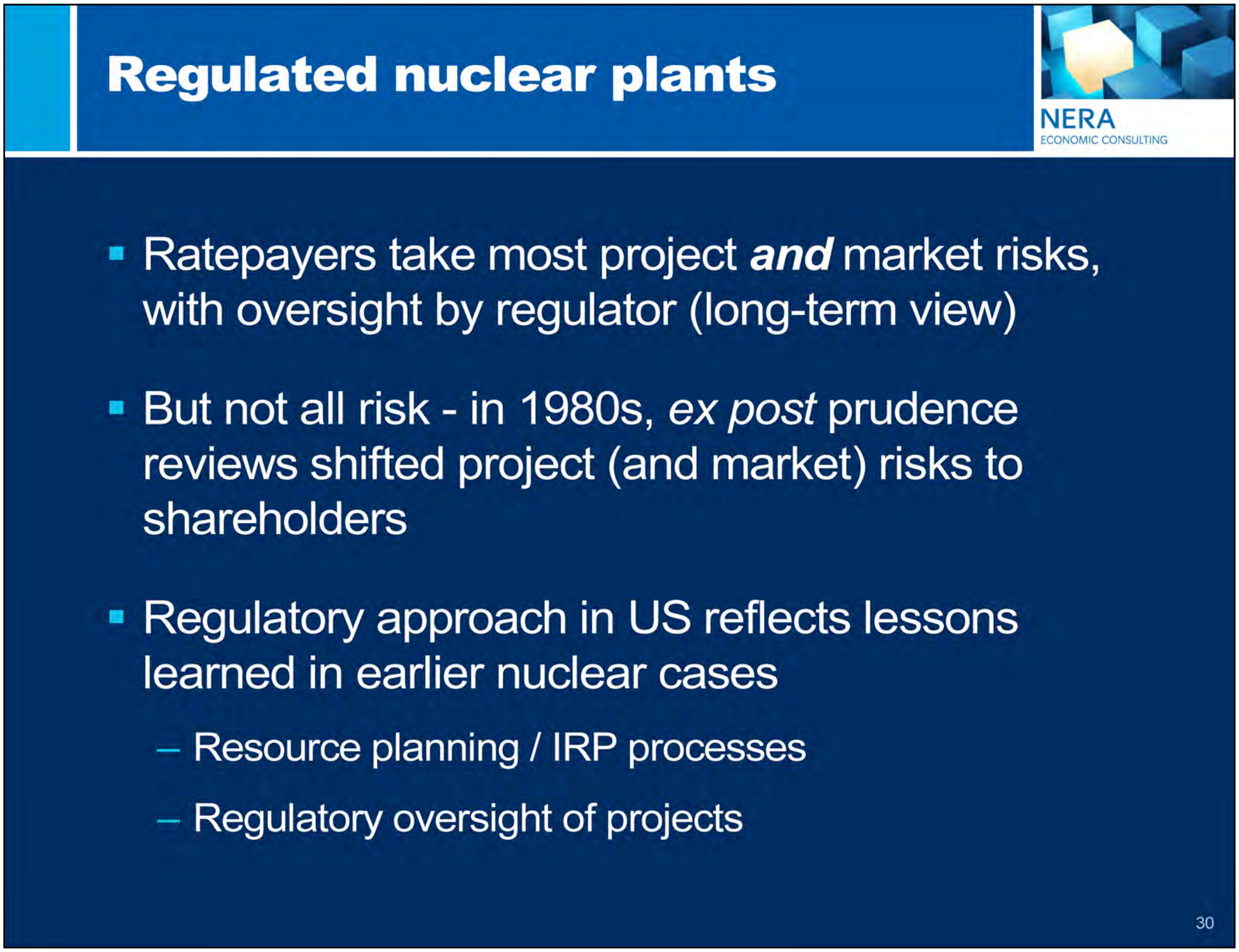
The advanced large light water reactors being considered today are in the early stages of product development, with high and uncertain costs and long and uncertain development/construction schedules.

This exacerbates the problems faced by a merchant nuclear project using these reactor designs – the difficult economics of a merchant nuclear project are even harder when higher and more uncertain costs associated with FOAK (or early units) of a particular reactor design are present.

Later in the nuclear plant development cycle, when there are tens or hundreds of a particular reactor design built and placed into commercial operation, the reduction in level and uncertainty in cost and schedule due to learning may make merchant nuclear based on a mature reactor design more feasible.



The next business model is the regulated model



Aside from the public power projects (e.g., TVA) the US nuclear fleet was built by regulated utilities.

Examples of Regulated Nuclear

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- Vogtle 3 & 4 – Georgia Power / Southern Company + public power; Georgia laws and regulations; Vogtle selected in IRP process
- Summer 2 & 3 – SCE&G + public power is owner; South Carolina laws and regulations; selected as baseload expansion option
- Levy County – Florida state laws and regulatory approach; some issues remain
- South Africa?

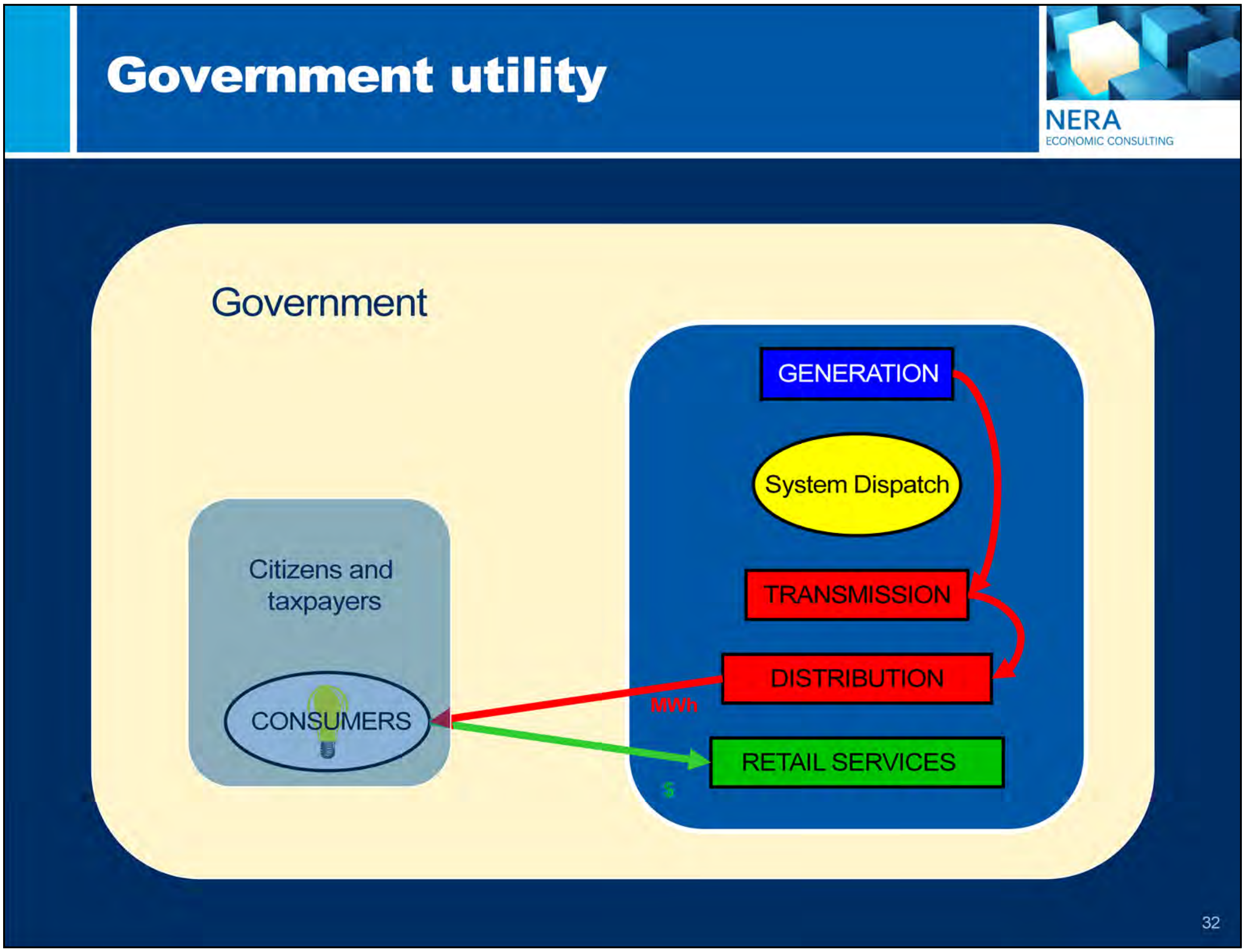
31

The Vogtle and Summer projects are based on comprehensive regulatory approach in Georgia and South Carolina. Both projects were selected in about 2007 in separate state integrated resource planning processes that both resulted in a regulatory agreement and commitment to build.

Levy Country is in Florida, where laws and regulations were put in place that favored nuclear. However, the implementation of these laws and regulations has run into political opposition and this project faces state regulatory uncertainty.

The Eskom Nuclear One procurement in 2008 ran into financial difficulties and did not result in a purchase. The Eskom financial difficulties were, to a large extent, the result of rate-setting decisions by the "independent" South African electricity regulator, NERSA.

The new South African nuclear procurement, expected to start by the end of 2012, will likely involve a deeper level of involvement by the South African government, both to ensure that the projects are financially feasible and to ensure that the government's nuclear localization and industrial development objectives are achieved. It is unclear whether the new South African nuclear program will be a regulated utility program (i.e., through Eskom) or a South African Government program.



Many of the nuclear power plants in the world were built by governments or government utilities.

Corporatization was done in some countries, so the government utility went from being a government department to a government-owned enterprise.   While some national utilities are separate corporations, most of these remain closely controlled by the national government.

The way that rates are set also ranges from country to country – in most cases, the government has a role in setting rates and can absorb losses (or gains) if rates are different from costs. Even with corporatized utilities, the government owner can take positions on dividends and subsidies that insulate the utility from the full impact of regulatory decisions.

In some countries, an independent utility regulator has been established. The detailed working of such utility regulators that regulate government-owned utilities may not be the same as the regulation of private investor-owned utilities (e.g., as in the US).

Government nuclear plants

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- Government assumes project and market risk
- ***May*** mean faster decision-making
- Big purchases by creditworthy buyer may mean strong bargaining position with vendors
- Buyer want power ***and*** non-power outcomes
  - Develop local jobs and skills
  - Develop industrial capability / join global supply chain
  - Implement energy / climate change policy

33

Apologies to any government folks in the audience, but in US we are usually skeptical that government-led projects will go well.

However, governments can get large infrastructure projects done. Governments have money and can move quickly (this can be good if decisions help the project; not so good if the decisions do not help the project, as in Germany)

In some countries, the government may be a very effective owner of the electricity industry and may be the most appropriate entity to invest in large, capital intensive infrastructure projects like nuclear power plants.

Governments may also have important non-power objectives:

- Estimating value of non-power objectives (often to entire economy) is not easy
- Utilities may not have expertise to evaluate or implement these non-power objectives

Examples of government nuclear

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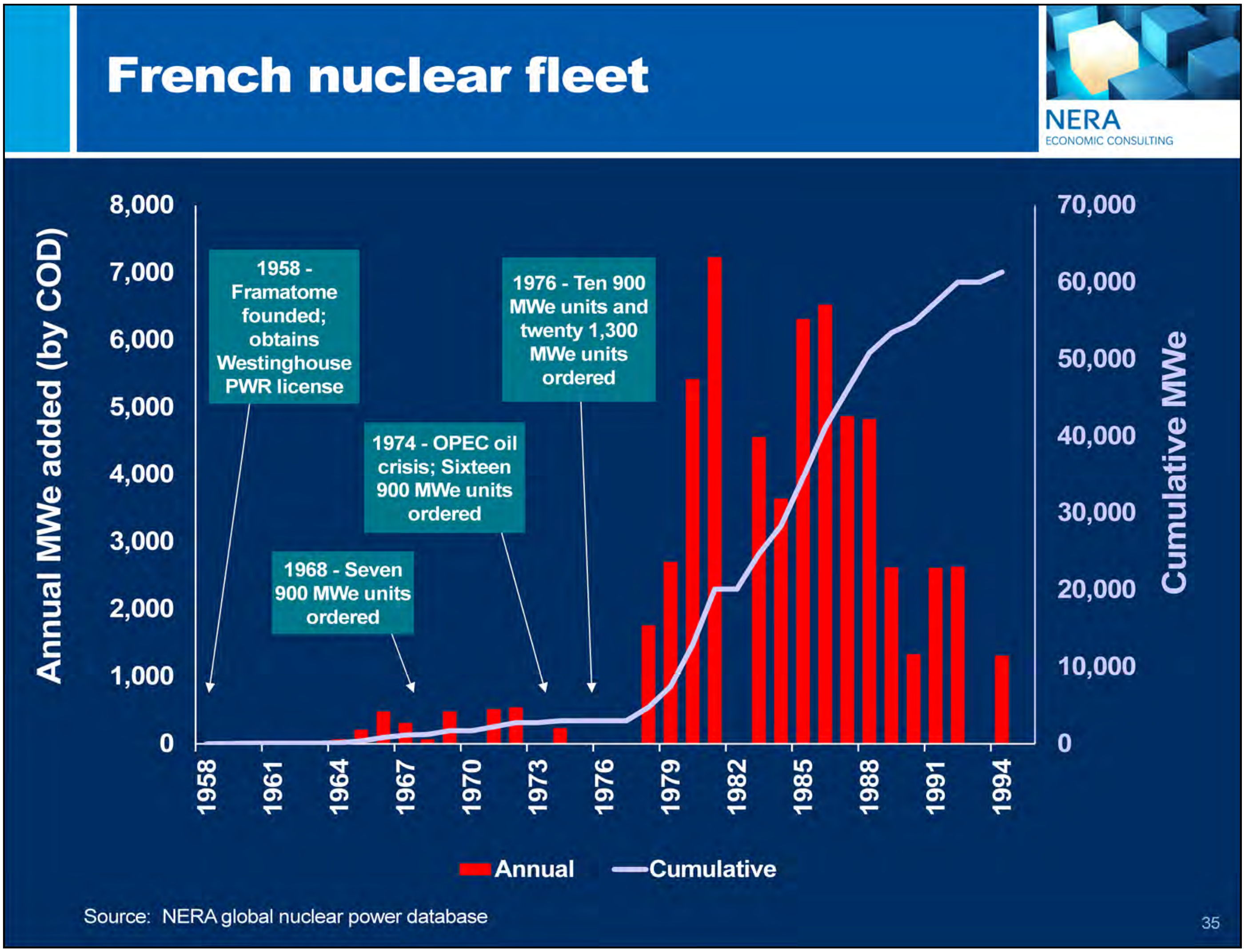
- Public power co-owners of US nuclear plants
- TVA, Energy Northwest, OPPD/NPPD
- CEGB (now dismantled) - existing UK nuclear
- China, Russia, France, India, etc.

34

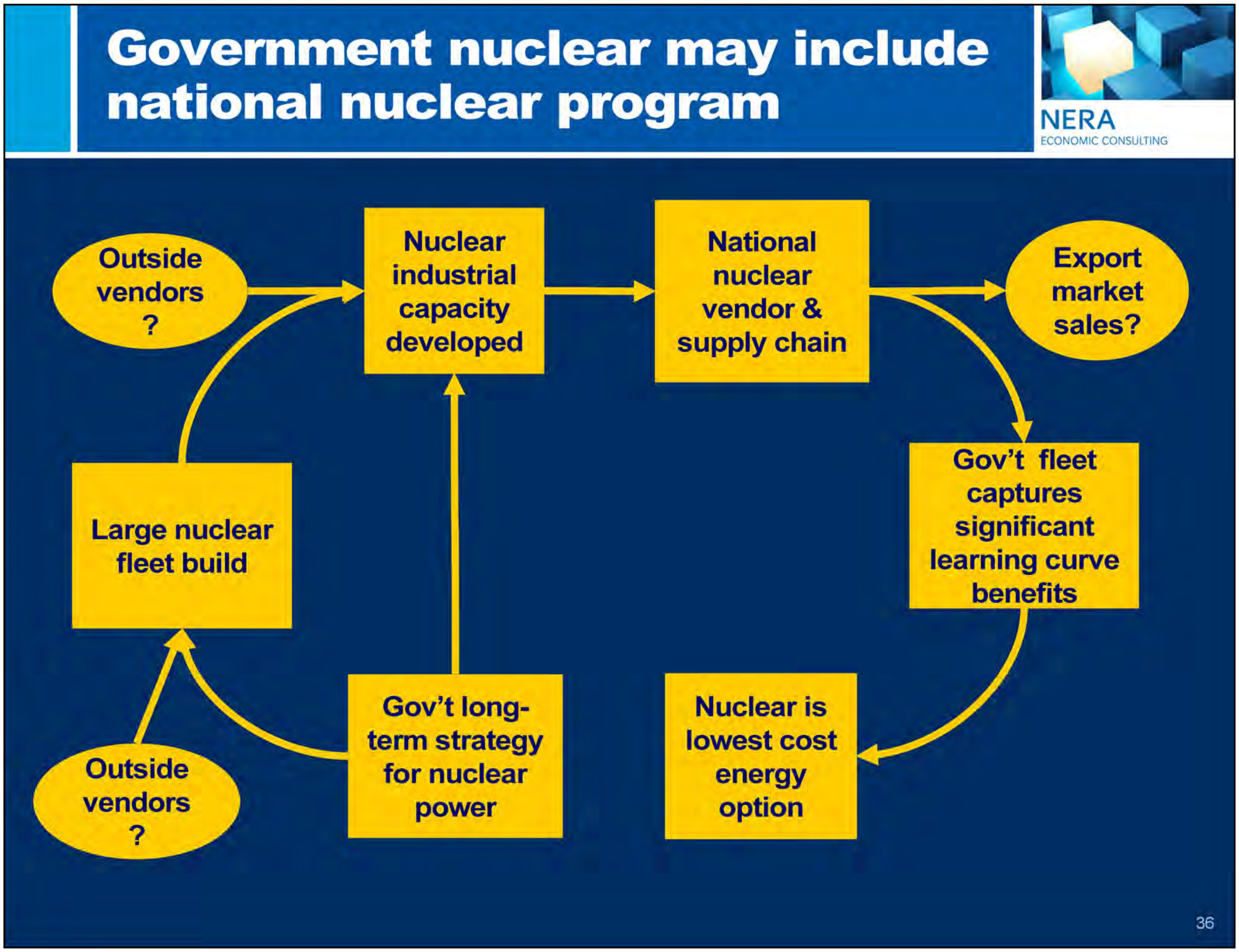
As an example, public power companies own about half of the two new US nuclear power projects under construction (i.e., Vogtle and Summer).



The French nuclear fleet is a great example of a government nuclear build program.

Who got the orders for these nuclear plants? The answer is French nuclear industrial companies! To some extent, the French nuclear build program was as much about building nuclear power industrial capability (and jobs) as it was about building nuclear generating capacity.

Next page: Like in France, government nuclear programs are usually about more than just ***buying*** nuclear plants



This cycle was implemented in France, in South Korea, and in China.

New industry competitors

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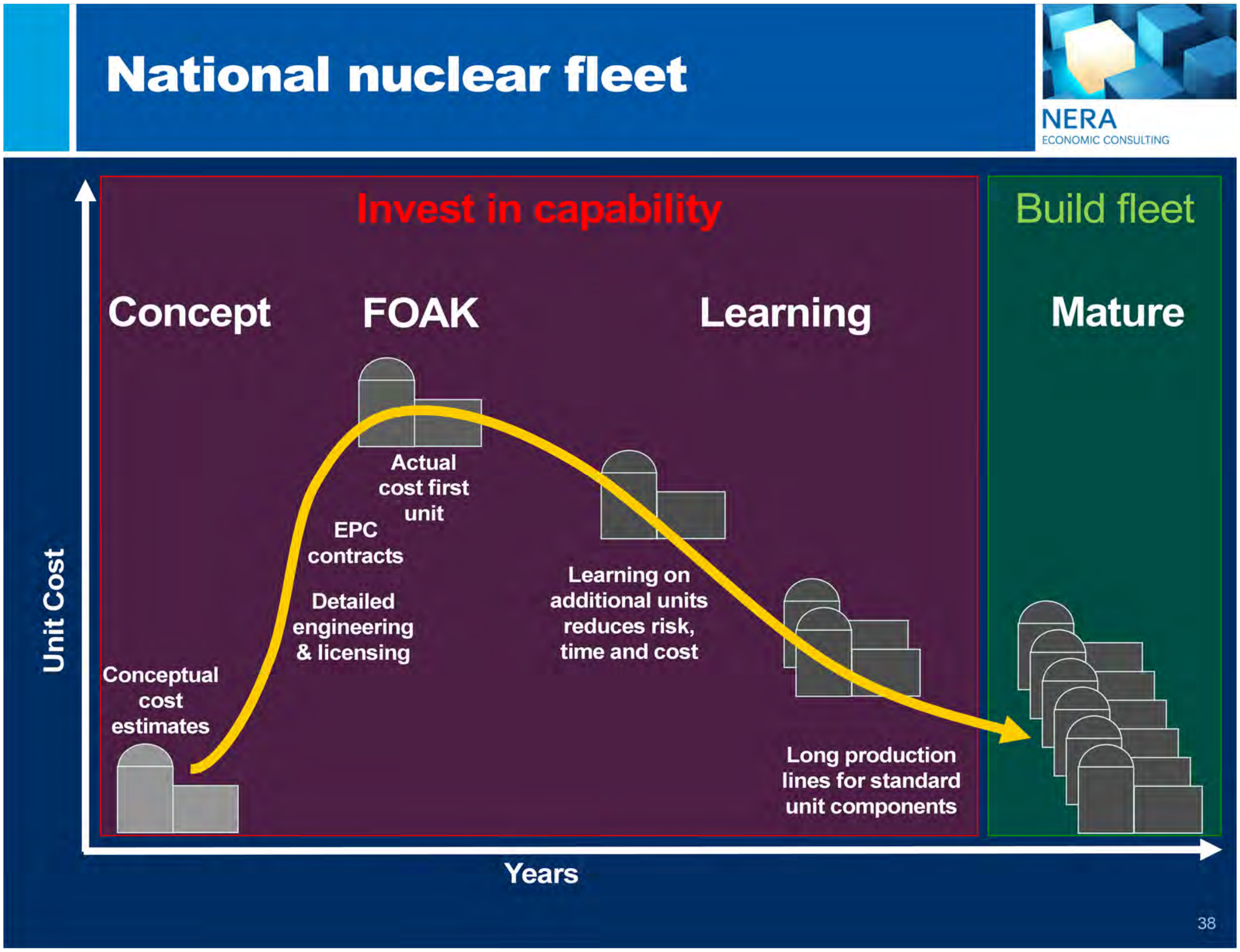
- South Korea
  - Exporting APR1400
  - APR+ design by 2013 (with no US content)
- China
  - CAP1400 to be built in China, then exported
  - ACPR1000 was to be offered to export market
- Only about 60 years (2 or 3 generations) of reactor designs – improvements will come (small, innovative & advanced reactors?)

37



The nuclear plant product life cycle is less problematic for a national nuclear power program.

The value of the learning in the early stages is owned by the government nuclear companies and the benefits of this learning can be directly captured by the national nuclear program in lower costs for its nuclear fleet.

State Capitalism

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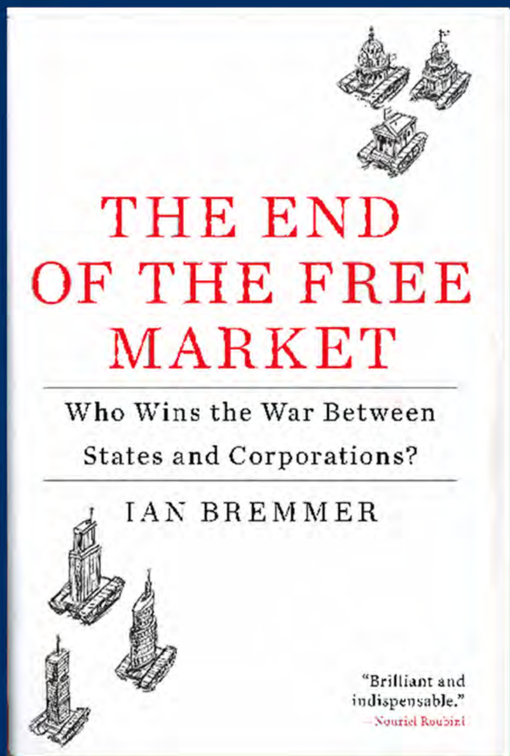

- National Corporations & State-Owned Enterprises
- State domination of markets over long-term
- Gov't - to - Gov't deals with multiple objectives
- Strategic objectives more important than profitability

Published by Portfolio/Penguin in May 2010

39

The bigger issue of state-owned corporations, like national nuclear companies, competing in the world market is covered in this book

While Bremmer's book is not about the nuclear power industry, it could be!

This should be required reading for anyone trying to understand the global nuclear markets.

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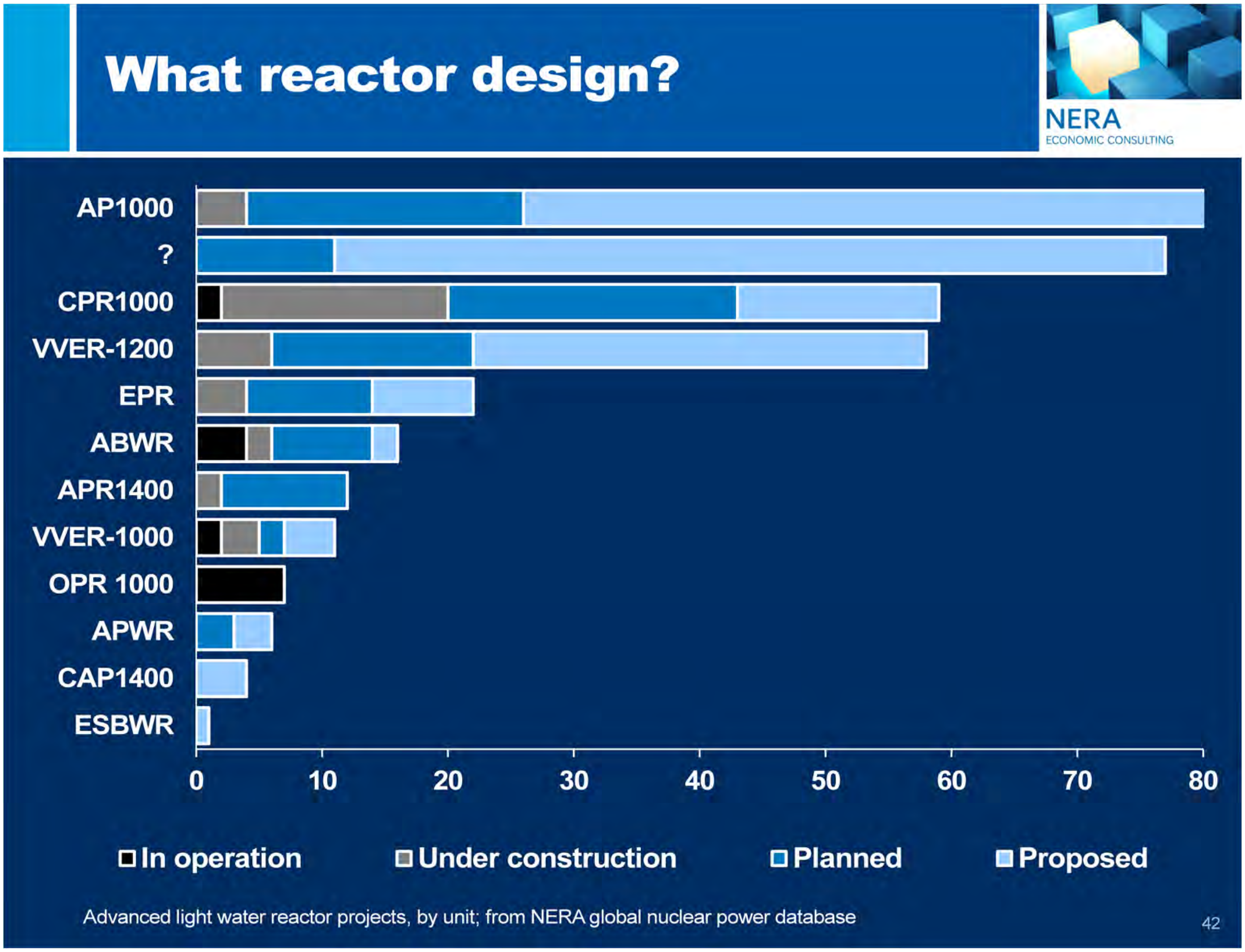
WHAT REACTOR DESIGNS?

What reactor designs?

- Global league tables
- Design drivers
- Costs
- SMRs
- Market preferences

41



Another bar chart using the same data as the country league table chart I showed earlier.

The second bar from the top ("?") comes from programs that are now in procurement or that will be in procurement. These are opportunities for nuclear power plant vendors. There are enough orders that will come from these programs to push any of the designs to the top.

The current phase of nuclear build is about which reactor designs can get down the product development curve early and successfully. Being early is important, but having successful project completions is even more important.

Design drivers in US

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- US was seen as largest nuclear market by global industry – a lot of vendor effort (and DOE support) to get US NRC Design Certification
- US regulated projects – mostly selected AP1000
- US merchant projects – vendor support for developers and need for a real sponsor for NRC COL, drove selection (e.g., EPR at Calvert Cliffs 3; ABWR at STP; APWR at Comanche Peak

43

From the 1990s, most reactor vendors expected the US market to be the largest market – the US had a lot of nuclear plants and nuclear operators, a well-established nuclear regulatory approach, a large electricity system.

Accordingly, nuclear power plant vendors pursued NRC reactor design certification – a necessary requirement to participate in the US new nuclear market.

When the EPAct of 2005 was put in place, there was a flurry of activity because most of the benefits (e.g., loan guarantees, production tax credits) were limited and available on a first-come, first-served basis.

Now it seems that only two of these projects (the regulated Vogtle and Summer projects) will move forward in the near term – both of these selected the AP1000 design, as did some other regulated projects (e.g., Lee, Harris, Levy Country).

The US NRC design certification process is seen as a valuable credential for any reactor design in the global market. In order to get a design into the NRC design certification process, a site and a sponsor needs to be involved.

Design drivers outside US

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- TVO selects AREVA EPR
- China selects AP1000 as preferred Gen III
- Russians
  - BOO 4-unit nuclear plant in Turkey
  - Financing for Belarus & Vietnam programs
- UAE – selects Korean APR1400 design
- Lithuania, Poland, South Africa, Saudi Arabia

44

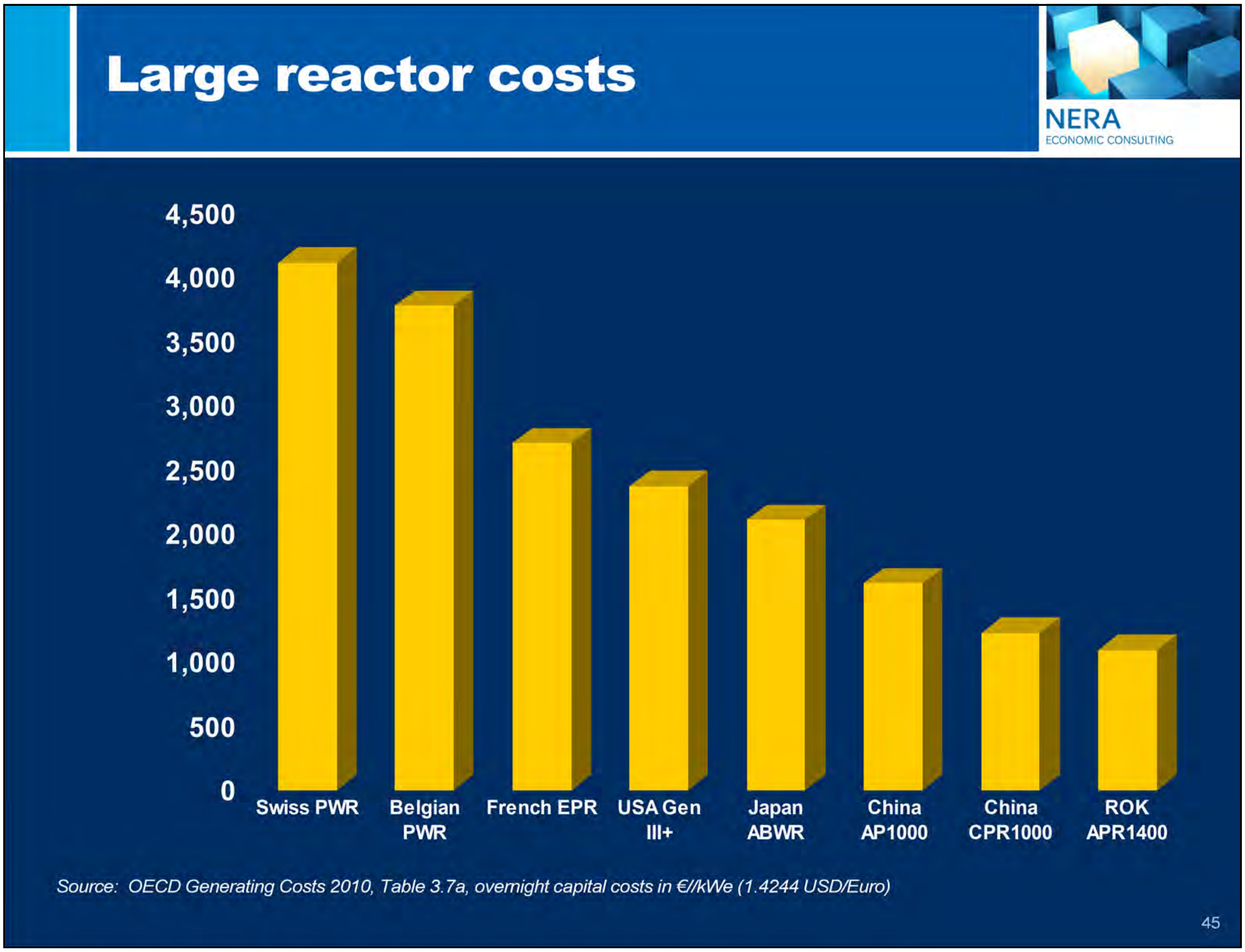
The TVO selection of the AREVA EPR design in 2003 was an opportunity for the EPR design to get an early start on the nuclear product development process.; implementation of this project has not gone as AREVA expected in 2003.

The Chinese selection of the AP1000 as their preferred Gen III design was a significant event in the world nuclear markets – the Chinese build program is the largest factor in the global nuclear market today.

The Russian approach of bundling significant capital investment/loans with the sale of advanced VVER reactors, has changed the dynamic of vendors that sell nuclear power plants. Will this will spread to other vendors (e.g., Hitachi in Lithuania, EDF in UK, etc.).

UAE selection of the APR1400 represents the success of South Korea's 30-year effort to achieve global success as a nuclear power plant vendor. Like AREVA's OL3 project in Finland, the world is watching the Korean Baraka projects to see how the Koreans implement their reactor export strategy.

Some other big programs in the near future may result in additional shifts in the global nuclear industry dynamic



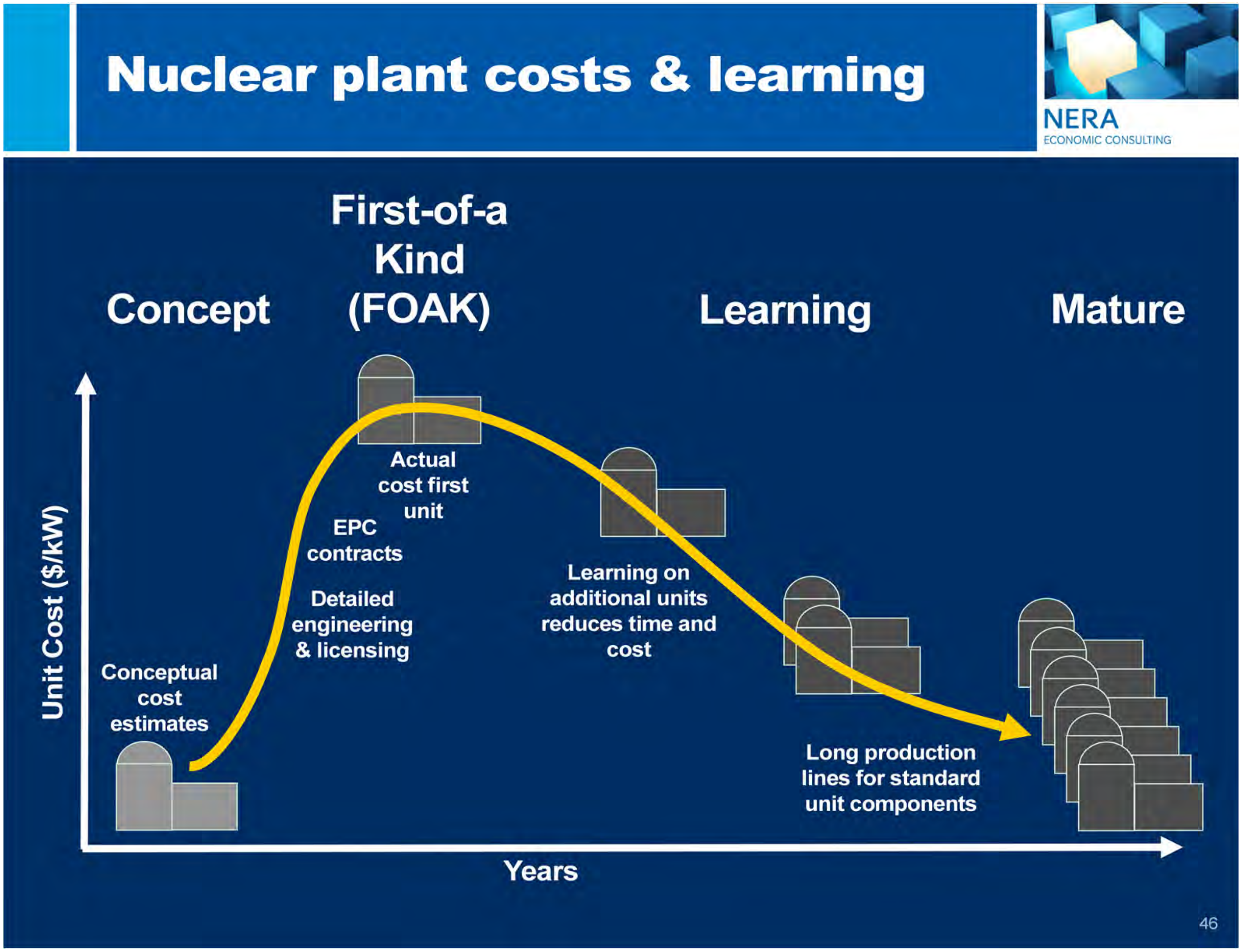
OECD report with data based on survey of member countries

There is a wide range of nuclear power overnight capital costs.

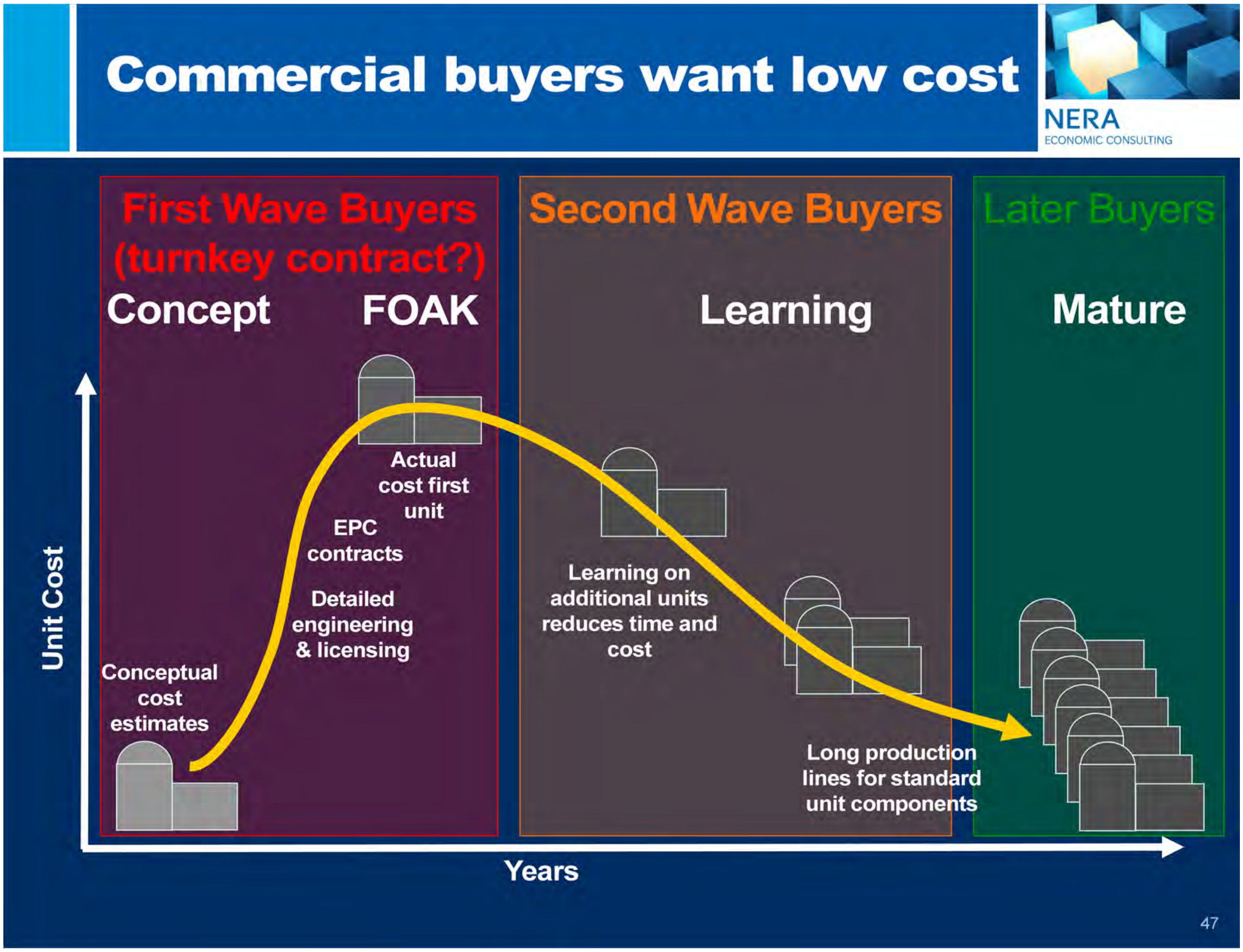
These differences arise from a combination of national practices and local costs AND the extent to which a particular design is down the cost/learning curve.

It is difficult to see how such wide differences can be sustained.

As more units are built, under the new standard reactor design approach, the low end will become lower and more consistent/predictable



Let’s return to the nuclear product life cycle chart



In a commercial sale, a nuclear power plant buyer would prefer to buy a reactor design from the right side of this chart, where the nuclear power plant design is mature and has stable, predictable and low costs and time to build.

A key selling point for a new reactor design is the number of units already built and placed into operation, how well these prior nuclear projects went, and how well the units are operating. None of this experience can be obtained until the FOAK unit is sold and built.

To make a sale of a FOAK reactor design to a commercial buyer, the deal may mean that the seller offers a lump-sum turnkey contract (i.e., similar to the TVO OL3 contract).

This arrangement means that the nuclear plant vendor invests in (and owns) the learning that comes from the FOAK project and can benefit from this learning by selling later units in the market.

Small and innovative reactors

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- A lot of interest; promising features
  - Capital cost still unknown
  - High cost / long time to get any new reactor to market
  - Regulatory paradigm is based on large LWR
  - New design & industry learning curves
- Uncertain if private/commercial companies can take small reactor designs to market – role of government is critical (e.g., DOE funding)

48

SMRs fit technology paradigm

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- **Public view driven by consumer electronics**
  - Moore's Law is dominant technology paradigm
  - Larger number of transistors on silicon chips
  - More capability in smaller & cheaper devices
- **Why not smaller/cheaper nuclear plants?**
  - Moore's Law may not apply to power generation
  - Large power plants and large transmission wires
  - Scale and scope economies remain important

Market may be confused

- What is an SMR?
- Different reactors & business models lumped together (SMR + Gen IV + ?)
- Press coverage creates high expectations
  - Near-term alternative to large LWR
  - Timing and maturity
  - Economics
  - Regulatory issues diminished

International market views

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- I have recently worked with several countries considering a new nuclear power plant (the first one in some engagements)
- Reactor technology and design preferences:
  - "No FOAK"
  - "Option for future"
  - "Need nuclear power fast"

51

"No FOAK"

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- A lot of risk for any nuclear plant due to political / regulatory / public opinion / economic issues
- No desire for added technology / design risk
- Only consider proven designs, where construction and operation are complete for reference plant
  - Few large LWR options are suitable now
  - SMR options off the table in near term

52

"Option for Future"

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- Nuclear is option in about 2030
- Requires crystal ball gazing:
  - What are nuclear & non-nuclear options and costs?
  - Which large LWR options will survive?
  - Which SMR options will become commercial?
- LCOE analysis starting 20+ years in future (comparing nuclear and non-nuclear options)
  - Estimates of costs and features
  - Ranges to reflect uncertainty

53

While a realistic approach is to consider a new nuclear power program or project after the world nuclear market settles and there are mature reactor designs available, it is difficult to make good predictions about the state of the nuclear power industry 20 years into the future.

“Need nuclear power fast”

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- Large and fast nuclear power build program
- Best mix of large and small reactors?
- Different strategies
  - Large LWR = investment for power generation
  - SMR = R&D / Technology Development investment
    - Long and uncertain path to power generation
    - More uncertainty may mean more opportunity
    - Small investment to control company (Fluor example)

54

Reactor design preferences

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- Safety – passive vs. active approach
- Other – PWR vs. BWR; new vs. old
- Advanced construction techniques – modular, open-top, steel plate reinforced concrete, etc.
- Scale – larger is usually cheaper in nuclear power
- Maturity – the earlier that reference units are in operation, the better

55

Based on my client work and on reviewing other sources of information, these are factors that seem to be important to buyers when evaluating reactor designs.

Advanced construction may also include digital I&C (less wire, cable runs, trays, pulling); bent pipe (instead of welding in corner pieces – fewer welds, faster work); advanced concrete; 3D/4D modeling; embedded attachment plates!

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CONCLUSIONS

Who is building?

- Government and regulated utilities
- Biggest reason is industry structure
- A good regulatory approach or a government can provide the long-term revenue security and planning process to facilitate nuclear projects:
  - 100-year time frame
  - Very large initial capital investment
  - Most risks in the long development period (prior to commercial operation)

What reactor designs?

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- Large LWR designs are key - a decade or more before new advanced/small reactors in market
- Preference in market for
  - Advanced designs with high (passive) safety
  - Proven designs
  - Advanced construction approaches
- Key issue is getting units built and in operation
  - AP1000 is leading the race
  - Opportunities for other designs in coming years

58

"Who" may determine "What"

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- Link between national nuclear champions and the designs they offer
- Vendors with deeper project role to make sales
  - Buyers looking for more than just a power plant
  - Strategic investors and non-power objectives
  - National vendors have an edge due to deep pockets
- National nuclear vendor offering proven reactor design with preferred features - hard to beat

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Contact Us

Edward Kee

Vice President
NERA – Washington, DC
+1 (202) 370-7713
edward.kee@nera.com