

VI International Forum ATOMEXPO 2014

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**“Round Table: Planning and Optimization of the NPP Generated Power Cost
at the Design and Construction Stages”**

NPP Capital Investment Costs and key factors affecting them

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EMPRESARIOS AGRUPADOS

Engineers and Consultants

Empresarios Agrupados – Company Profile

- **An Architect-Engineering and Construction Management Company**
- Created in 1971
- Main field of activity: **Nuclear & Conventional Power Plant Projects**
- Leading engineering company in Spain
- Project experience in more than 30 other countries
- **Full range of engineering services:**
 - Consulting
 - Project Management
 - Engineering and Design
 - Procurement Services
 - Construction Management
 - Plant Testing and Commissioning
 - Engineering Support Services to Plants in Operation

■ EA Human Resources:

Total EA
1000



Home Office	Field
783	217

Fields of activity

Nuclear Projects

New-build nuclear power plants



Engineering support services to plants in operation



Decommissioning and Radioactive Waste Management



Research Reactors and Generation IV Reactors



ITER Fusión Reactor-Cadarache (France)

Architect-Engineering and Construction Management



Thermal power plants

Combined-cycle thermal power plants

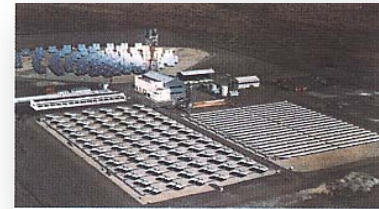


Coal and FO-fired thermal power plants



Renewable energies

Solar, Wind and Biomass



Special projects

Large Telescopes: Grantecan and E-ELT



LCE: Levelized Cost of Electricity (€/MWh)

$$\text{LCE} = \frac{\text{PW Total Plant Life Cycle Costs}}{\text{PW Total Life Cycle Electricity Production}} = \frac{\text{TCIC} + \text{FC} + \text{O\&MC} + \text{D\&DC}}{\text{PWE}}$$

The diagram illustrates the components of the Levelized Cost of Electricity (LCE) calculation. The numerator represents the Present Worth (PW) of Total Plant Life Cycle Costs, which is the sum of four categories:

- TCIC** (Total Plant Investment Costs): Represented by a pink box.
- FC** (lifetime fuel costs): Represented by a green box.
- O&MC** (lifetime O&M Costs): Represented by a purple box.
- D&DC** (Decommissioning & Dismantling Costs): Represented by an orange box.

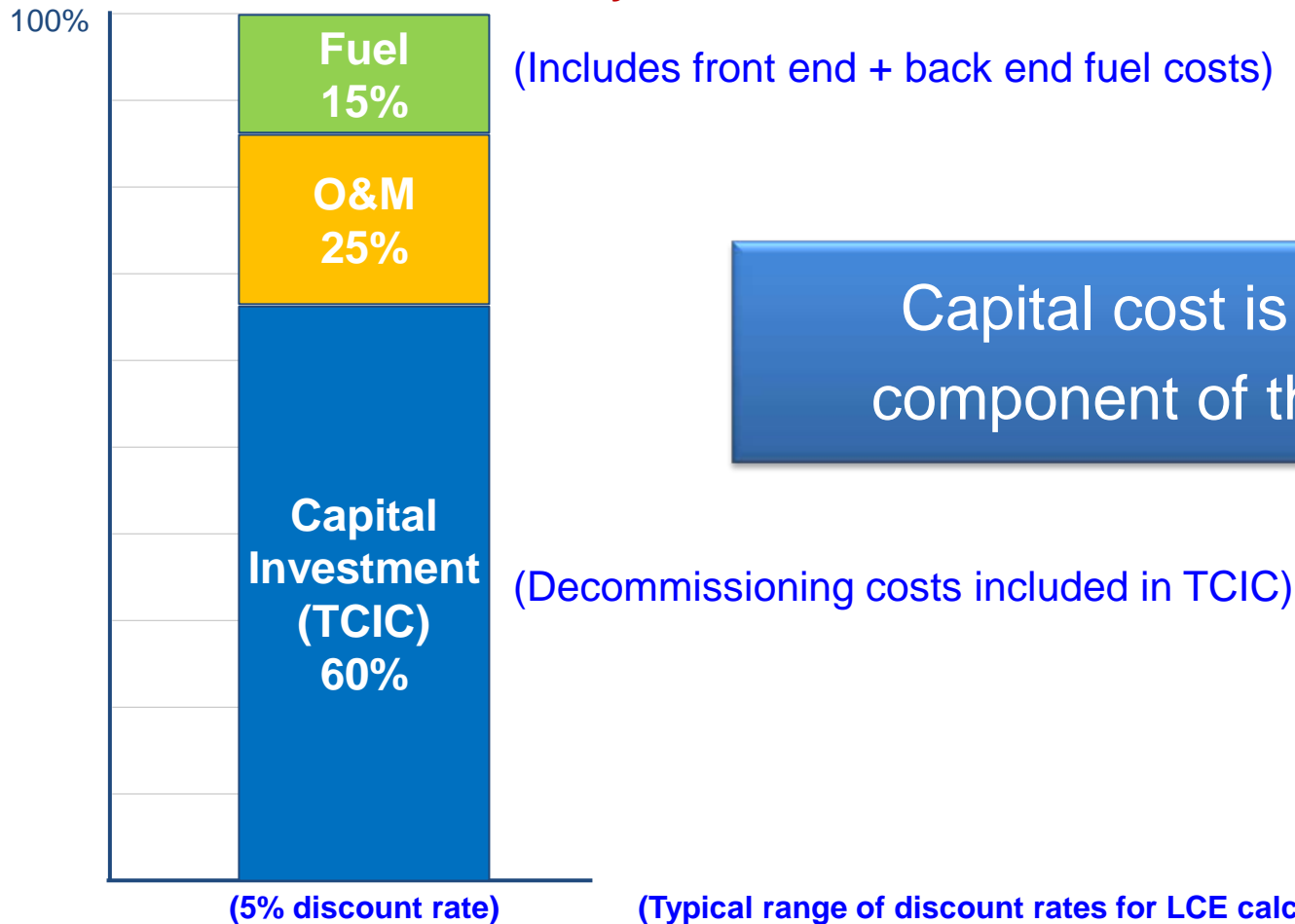
 The denominator represents the Present Worth (PW) of net electricity generated, labeled as **PWE** in a blue box.

Factors characterizing the economics of nuclear generation:

- High capital investment costs
- Low fuel costs
- High O&M costs
- Long construction schedules
- Long operational lifetime
- Need to pay for D&D and waste mgt. after end of operation

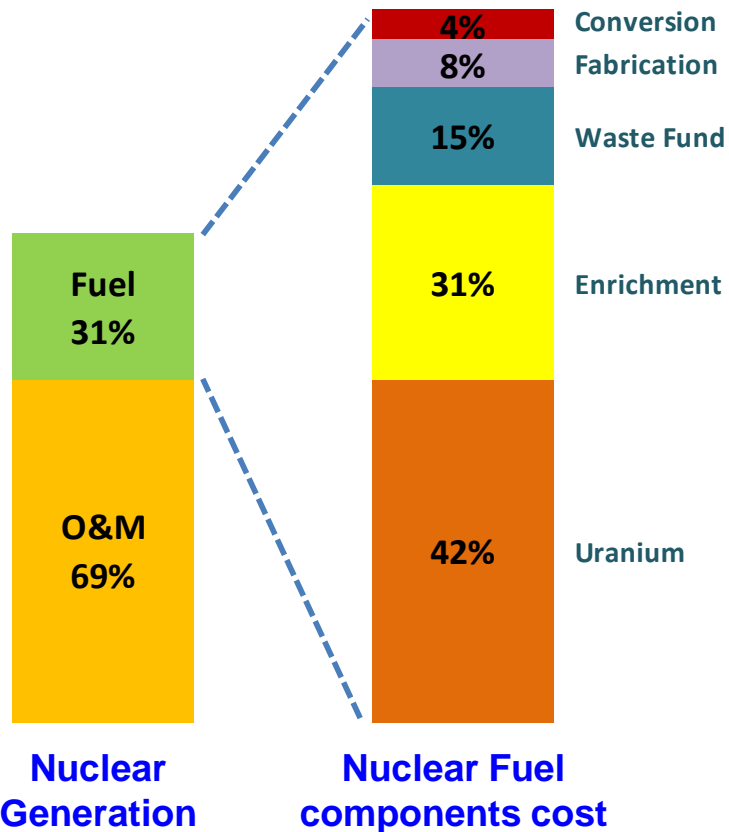
Typical breakdown of nuclear kWh costs

Typical components of Levelized Cost of Electricity



Other nuclear cost references of interest:

Nuclear Production Costs (Fuel+O&M) in the US in year 2012



Average Nuclear Production Costs in year 2012/2013

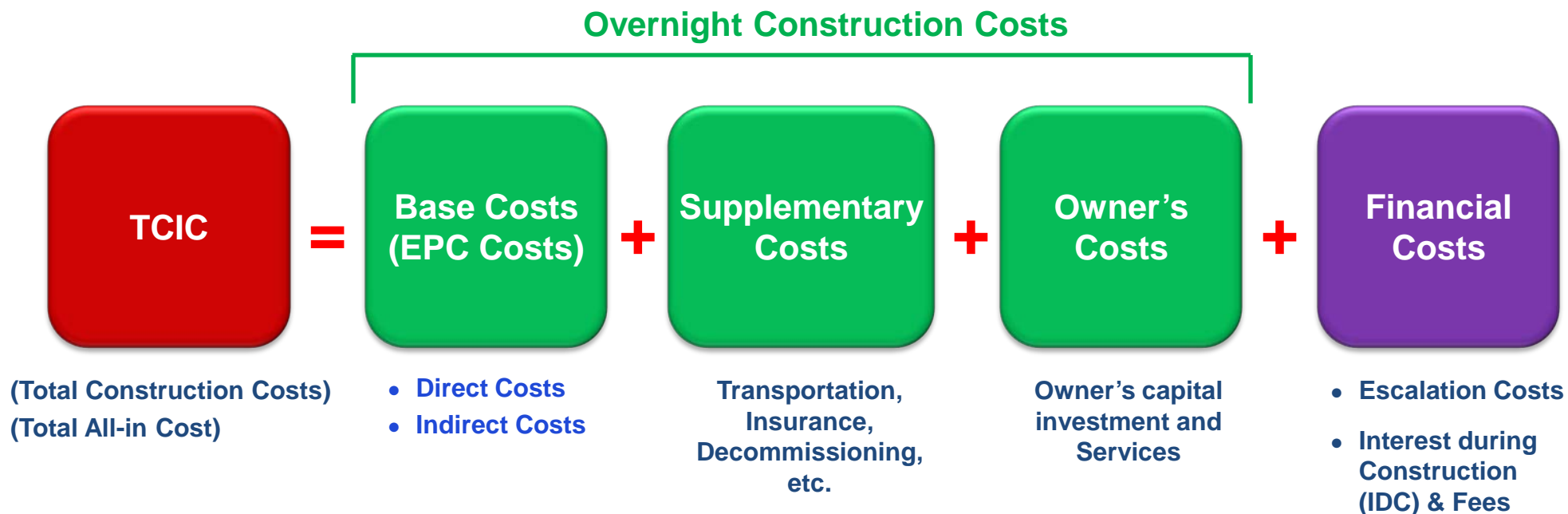
	US (2012) USD/MWh	Spain (2013) USD/MWh
Fuel:	7.5	10.6
O&M:	16.5	17.2
Production Costs	24.0	27.8

- One Fuel Reload (1000 MWe plant, 1/3 of fuel elements): 42 million USD
- Decommissioning costs: 300-400 Million USD

Capital Cost Categories

■ Total Capital Investment Costs (TCIC):

- The total cost of building a NPP and bringing it to commercial operation



- NPP costs shall be compared on a consistent basis
- Verify whether published cost data are:
 - Just EPC costs, (i.e. without owner's costs), or
 - Overnight construction costs, (i.e. including owner's costs but excluding financing costs), or
 - Total ("all-in") construction costs (i.e. including financing costs)
- To compare EPC costs or owner costs or any cost category, the following should be clear:
 - Plant capacity (MWe net)
 - Single or multi-unit plant
 - Country where the plant will be constructed
 - The scope of supply included in the cost:
 - ▶ Supplier's scope of supply for the EPC cost
 - ▶ Owner's scope of supply for Owner's costs
 - Costs are in constant money in a reference year or in current money?
 - Costs correspond to:
 - ▶ A first-of-a-kind (FOAK) plant
 - ▶ A Nth-of-a-kind (NOAK) plant

- **Overnight costs (EPC + Supplementary + Owner Costs):**

Although they are not all - inclusive (they exclude financing costs) **represent the more consistent cost category for comparison purposes**

- **Total Construction Costs (TCIC) should be used with care in cost comparisons, because they include:**

- Escalation costs, which depend on the project schedule and on assumptions on future inflation, and
- Interest During Construction (IDC) which also depends on construction schedule and financing arrangements specific for each project
- **They are useful for determining the effects on costs of construction delays**

Published NPP cost data

- Great dispersion of published NPP capital cost data
- New build NPP capital costs estimates have been continuously increasing over time and is reasonable to expect they will continue to grow
- Most of the new build nuclear plants a still under construction and cost data are uncertain
- **Reference Capital Cost range for new build NPPs, year 2014:**
(EA's own estimates based on the analysis of published cost data and capital cost calculations for different technologies, plant sizes and countries)

Dual unit plant, 2 x (1100-1500) MWe, OCDE countries

- **Overnight Cost** (w/o financing): 5000-5500 USD/kWe
(Financing (38%) \leftrightarrow x 1.38 factor)
- **Total Capital Investment Cost** : 5000-5500 USD/kWe x 1.38 = 6900-7560 USD/kWe
(incl. financing costs)
- **Summary (rounding off):**

▶ Overnight Cost range:	5000-5600 USD/kWe	\leftrightarrow	3625-4060 €kWe
▶ Total Investment Cost range:	7000-7700 USD/kWe	\leftrightarrow	5073-5580 €kWe



Organizing NPP Cost Estimates: The IAEA NPP TCIC Account System

Modified IAEA TCIC Account System (two digit level)

10. Pre-Construction Costs

Acc. No.:

- 11. Land & Land Rights
- 12. Site permits
- 13. Plant Licensing
- 14. Plant Permits
- 15. Pre-Constr. Studies
- 16. Plant Reports

20-49 Base Cost (EPC Costs)

Acc. No.:

Direct Costs

- 21. Building & structures
- 22. Reactor plant eqpt.
- 23. T-G plant equipment
- 24. Electrical and I&C eqpt.
- 25. Water intake and Plant Cooling
- 26. Miscellaneous plant equipment
- 27. Special materials
- 28. Simulators

Indirect Costs

- 30. Engineering at Supplier home office
- 31. PM at supplier home office
- 32. Engineering by supplier on-site
- 33. PM by supplier on-site
- 34. Construction supervision on-site
- 35. Construction labour on-site (incl. in 21)
- 36. Commissioning services on-site
- 37. Trial-run services by supplier
- 38. Construction facilities on-site
- 39. Commissioning materials and tools
- 40. Owner's staff training
- 41. Housing facilities

50-54 Supplementary Costs

Acc. No.:

- 50. Transportation
- 51. Spare parts
- 52. Contingencies
- 53. Decommissioning (If not incl. in O&M)

70-72 Owners Costs

Acc. No.:

- 70. Owner's capital investment and services
- 71. Escalation on O.C.
- 72. Financing of O.C.

60-62 Financial Costs

Acc. No.:

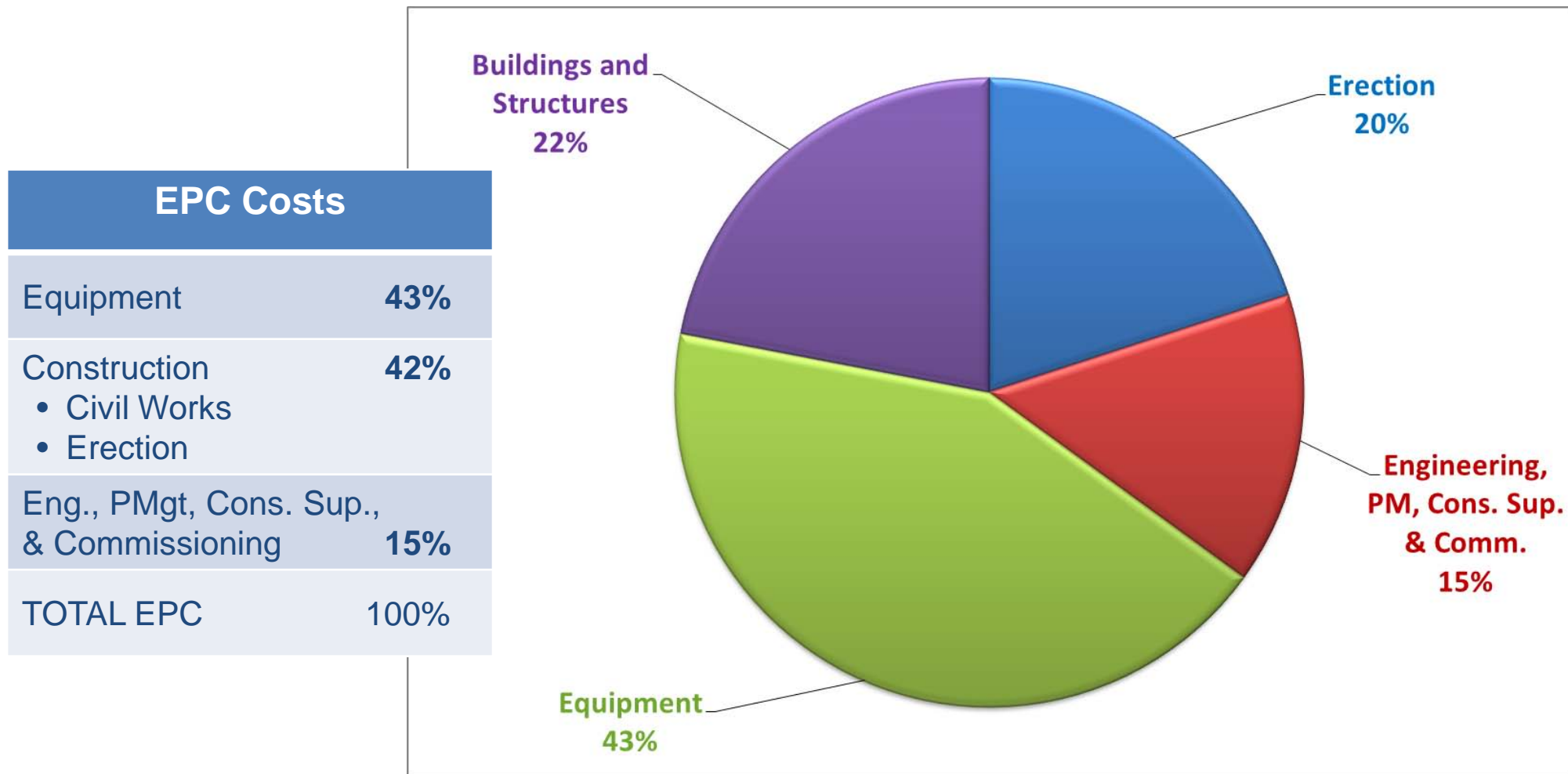
- 60. Escalation costs
- 61. IDC
- 62. Fees

■ IAEA NPP TCIC Account System

- Commonly used Europe
- Usually requested in Owner BIS for NPP bidding and proposed by NPP Bidders in their bids
- Modify the IAEA Account System to better fit the specific plant contract model or reactor technology

New Build 1100-1350 NPP

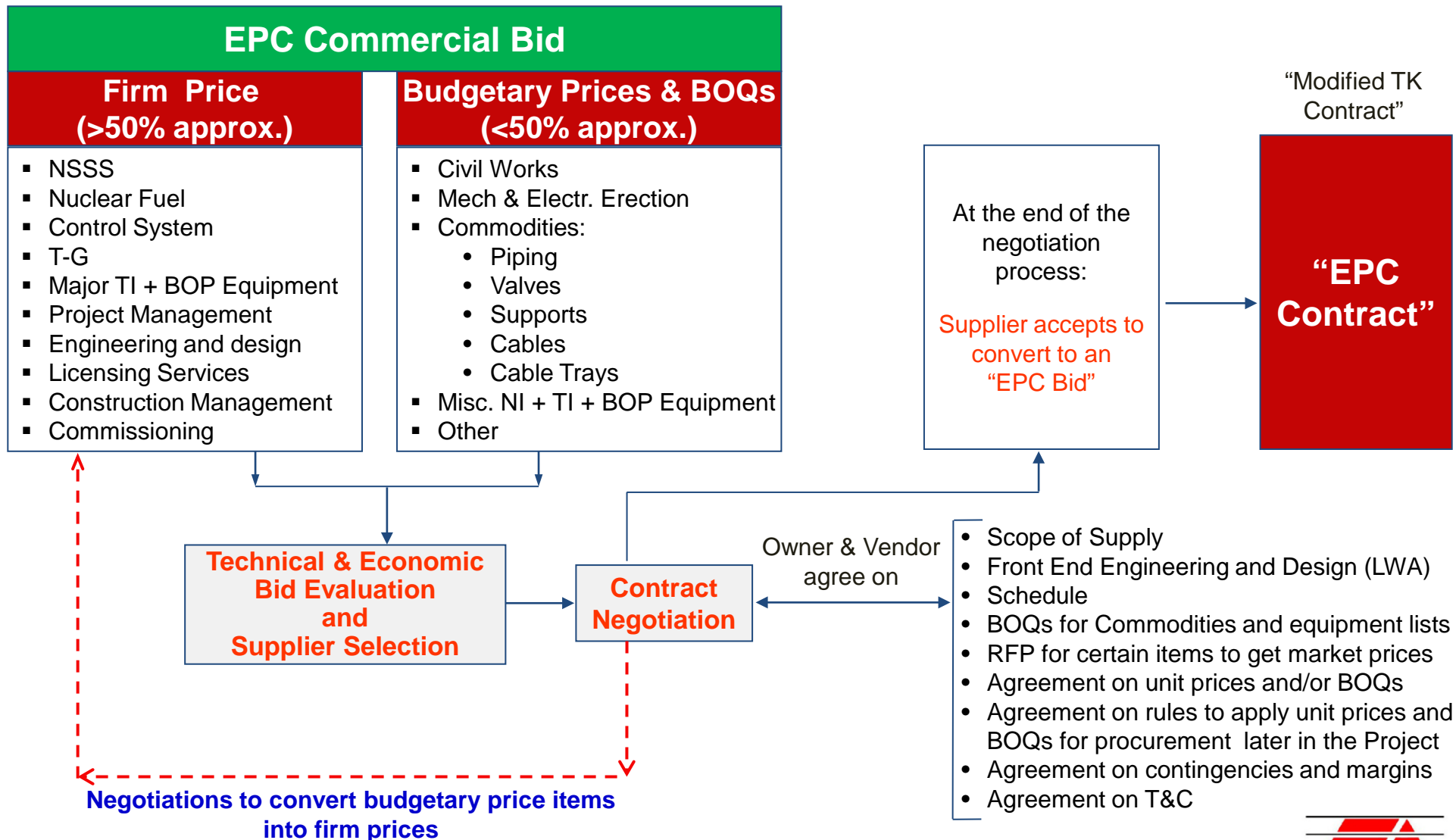
Simplified Typical EPC Costs breakdown (base costs) (%)



The EPC Costs risks are mainly in Construction (C.W. + Erection) and in the Indirect Costs (Eng., PMgt., Cons. Sup. & Comm.)

Sharing the risks of the EPC Costs: Modified Turnkey Approach

“Open book collaborative contracting process”



■ **Licensibility:**

- High assurance of licensibility in the country of installation
- Design modifications to comply with country's regulatory requirements shall be proven to be feasible and their costs taken into account at EPC bidding stage

■ **Simplicity:**

- Plant simplification shall be an integral part and a high priority of the design process
- Use a minimum of systems, pumps, H/Xs, valves and other mechanical and electrical components compatible with essential functional requirements

■ **Design Completion:**

- A high percentage of detail design to be completed before placement of structural concrete. Target: 60% minimum; 90% optimum)

■ **Design Process and Constructability:**

- Use modern computerized design tools (e.g.: 3D modelling and DB) to generate design drawings, equipment lists, bill of quantities, etc. for procurement and construction
- Constructability shall be addressed at the design stage
- Design to simplify and facilitate construction

■ Information Technology:

- Establish a computer-based integrated project information management system for project design, procurement, construction commissioning and operation phases

■ Supply Chain:

- A solid supply chain for equipment, materials and construction subcontractors shall be secured

■ Schedule:

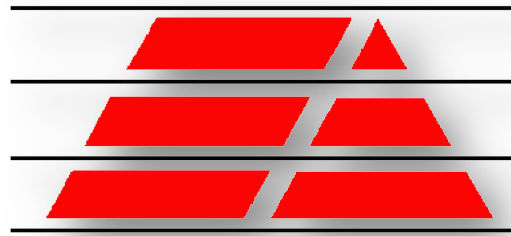
- Detailed and realistic project schedules shall be prepared before start of construction integrating design, procurement, construction and commissioning
- A strict and continuous schedule monitoring system shall be established

■ Design changes:

- Design changes shall be controlled through a rigorous management and approval procedure before implementation

■ Construction:

- Construction personnel shall participate in the design process to assure constructability
- Continuous monitoring of the construction process to measure progress and to anticipate deviations from schedule
- Use standardized components (e.g.: types, sizes, construction details, etc.) to improve construction productivity and reduce material inventories
- Specify reasonable construction tolerances to minimize rework
- Advanced construction techniques shall be considered at the design stage to help reducing construction duration and predictability of construction schedule
- Design to allow fabrication and assembly of large construction elements at site and installation into the plant using large cranes
- **Modularization:**
 - ▶ Consider modularization to reduce field works and congestion at site
 - ▶ Modularization may reduce costs and improve the schedule if it is applied appropriately
 - ▶ Modularization should be evaluated for each specific project and construction site



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Thank you for your attention