Conceptual Design of 300 MW Modular Nuclear Plant

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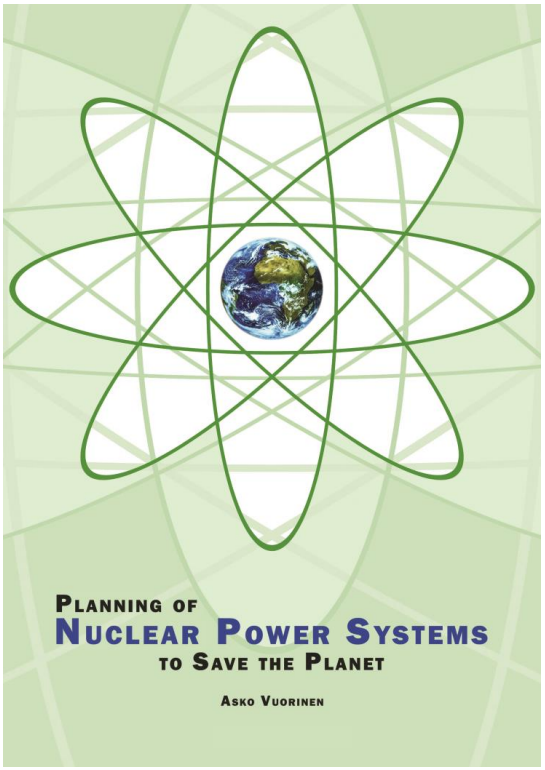
Ekoenergo Oy

Based on the Book:
"Planning of Nuclear Power Systems to Save the Planet"



Contents

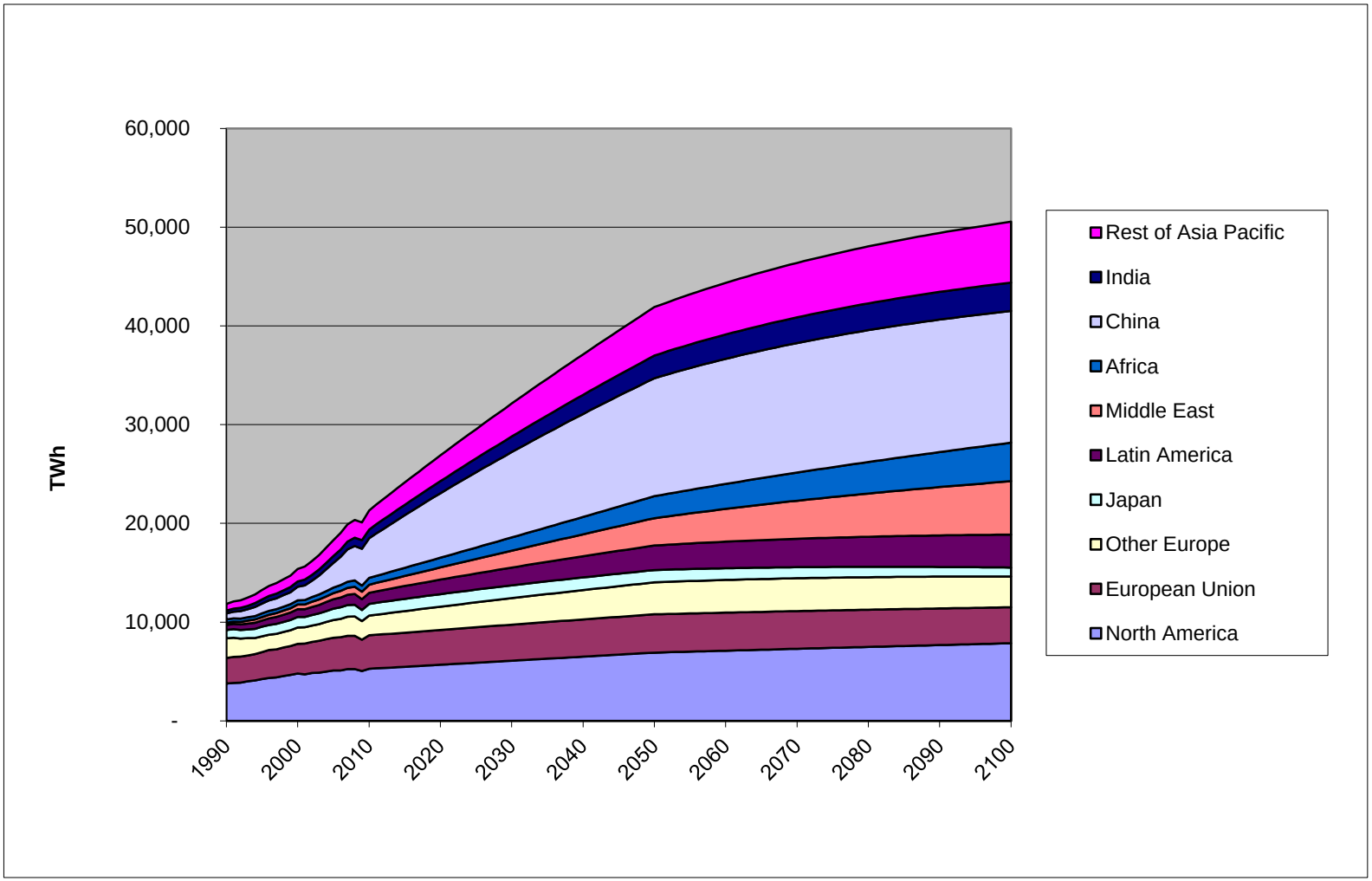
1. Finnish nuclear program
2. World electricity generation until 2100
3. Construction cost experience
4. Conceptual design of modular plants
5. Cost estimates of modular plants
6. Summary

Finnish nuclear program

- **Nuclear plants in operation**
  - Loviisa-1+2 VVER-440 880 MW
  - Olkiluoto-1+2 ABB BWR 1600 MW
- **Nuclear plants under construction**
  - Olkiluoto-3 EPR 1650 MW
- **Nuclear plants in planning phase**
  - Olkiluoto-4, Fennovoima-1 (2020), Loviisa-3 (2025)
- **Electricity generation**
  - Electricity consumption 16 MWh/capita
  - Nuclear generation (2013) 6 MWh/capita
  - Nuclear generation (2020) 10 MWh/capita

WORLD ELECTRICITY GENERATION UNTIL 2100

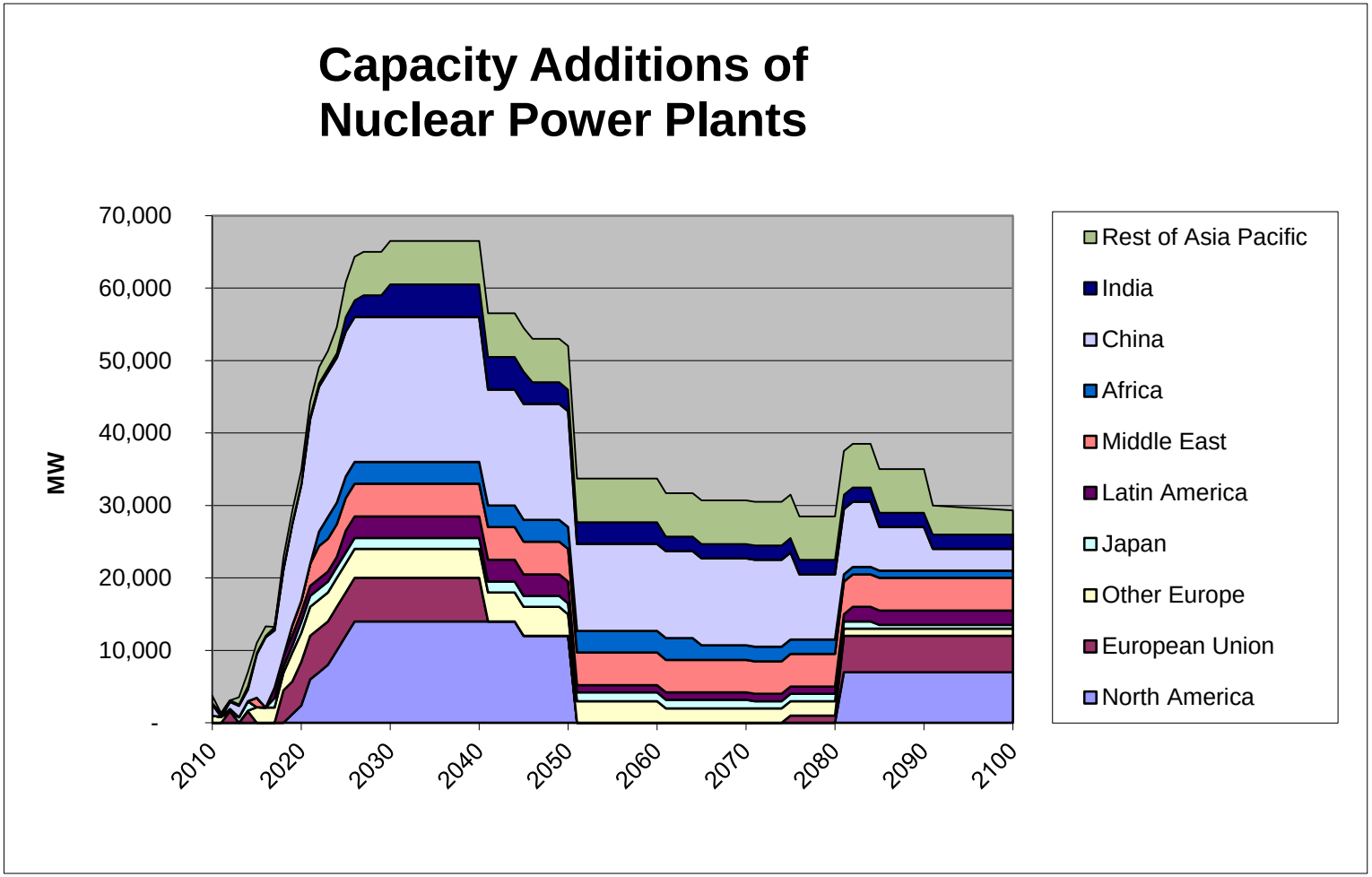
World Electricity Consumption until 2100



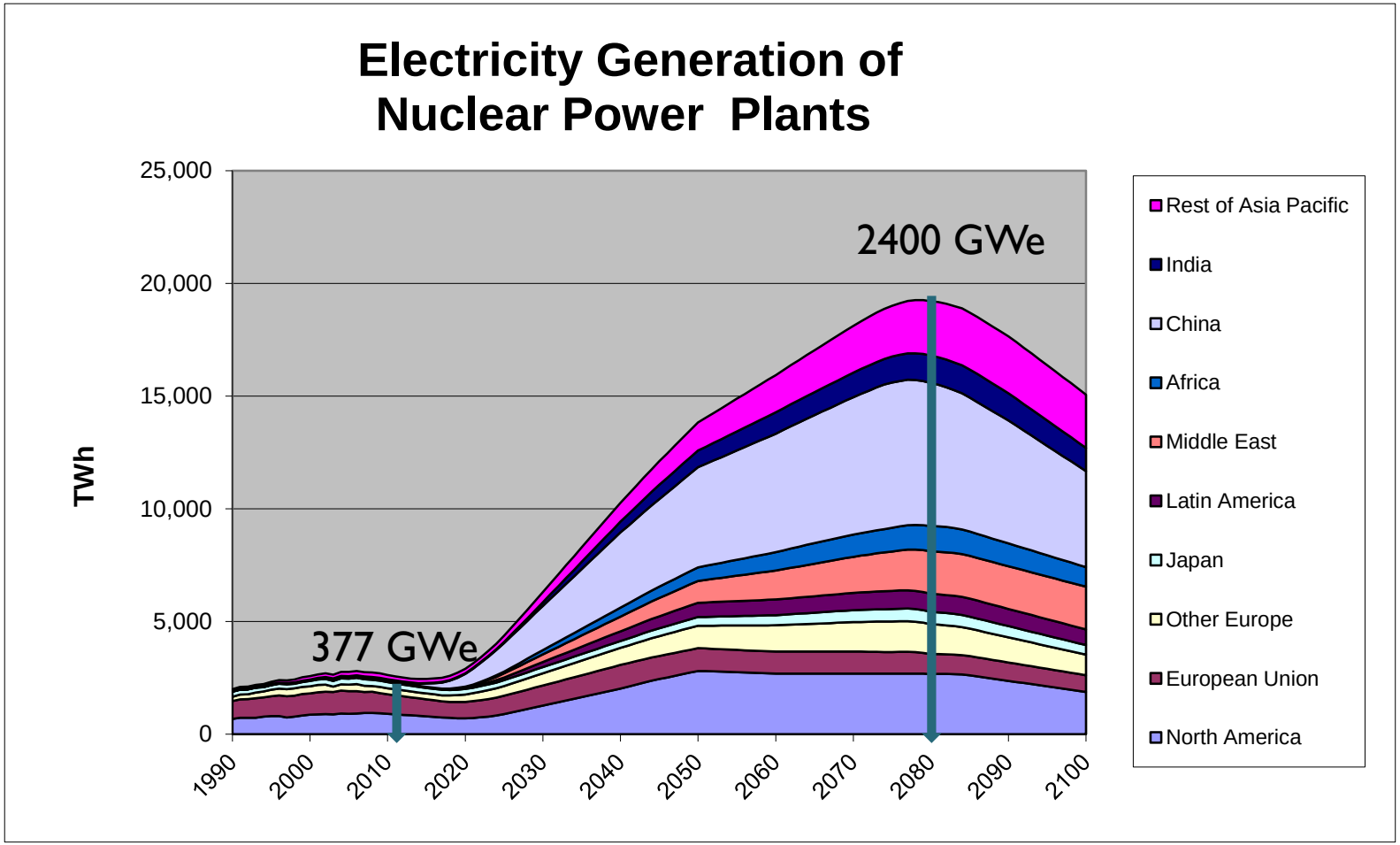
Priorities in Generation Planning

1) Renewables (hydro, wind, bio, solar)
2) Combined heat and power (CHP)
3) Nuclear plants, if needed
4) Gas and oil plants, if needed
5) Coal plants, if needed

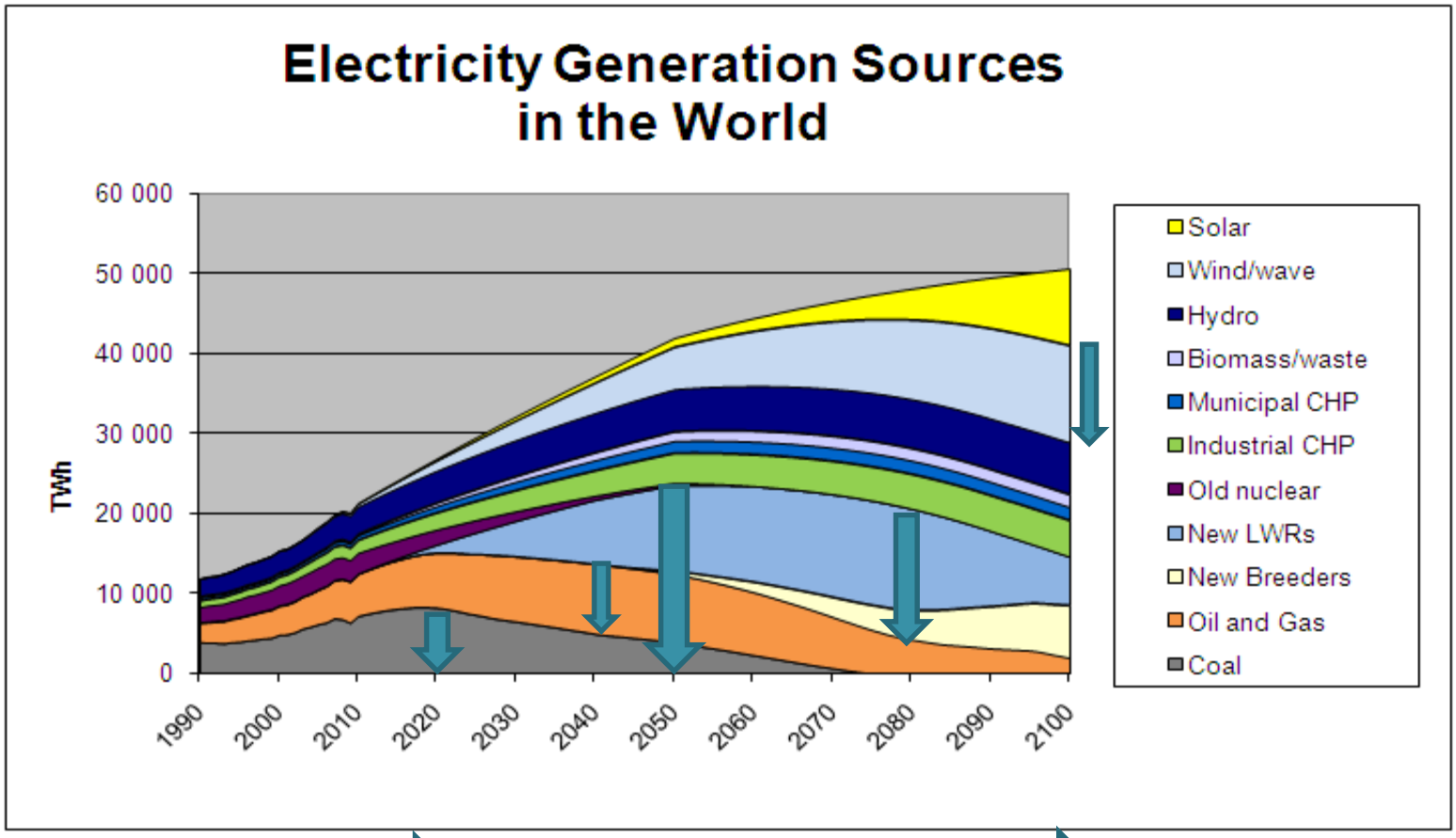
Capacity additions of nuclear plants would increase to 65 GWe/a



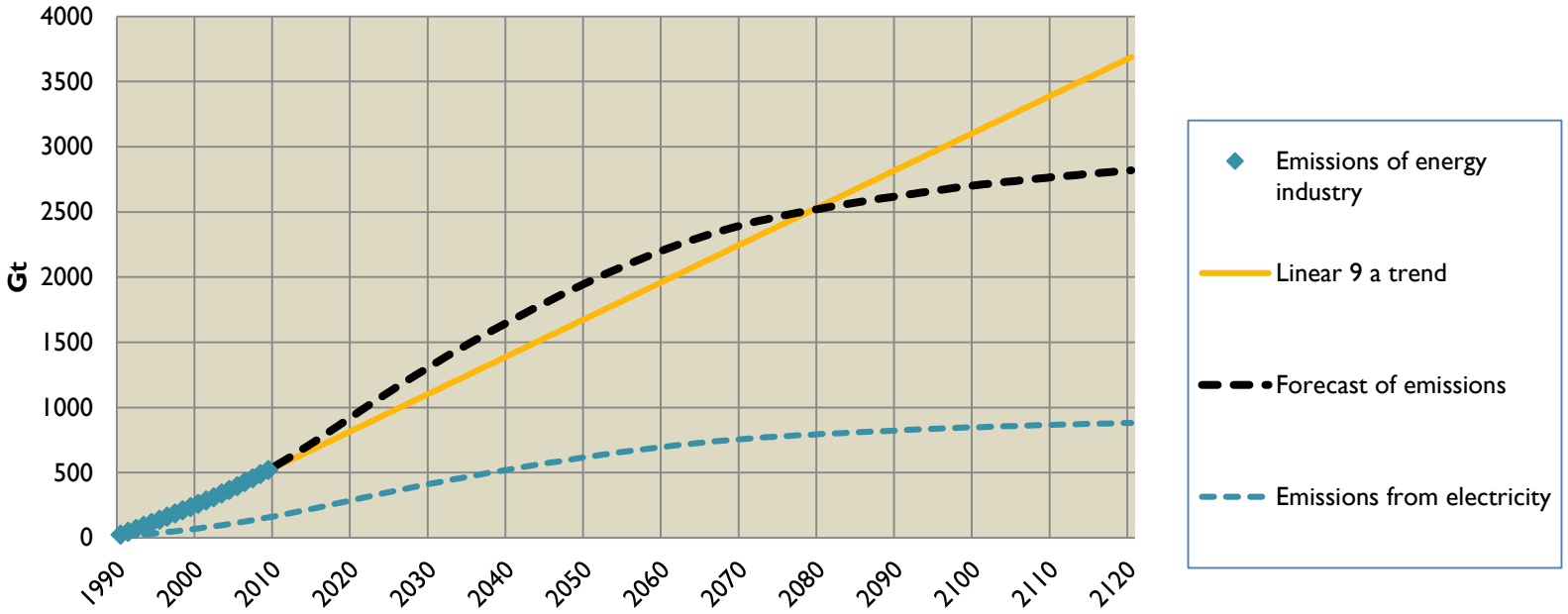
Nuclear electricity generation would peak at 19 PWh at 2080



World Electricity Generation until 2100

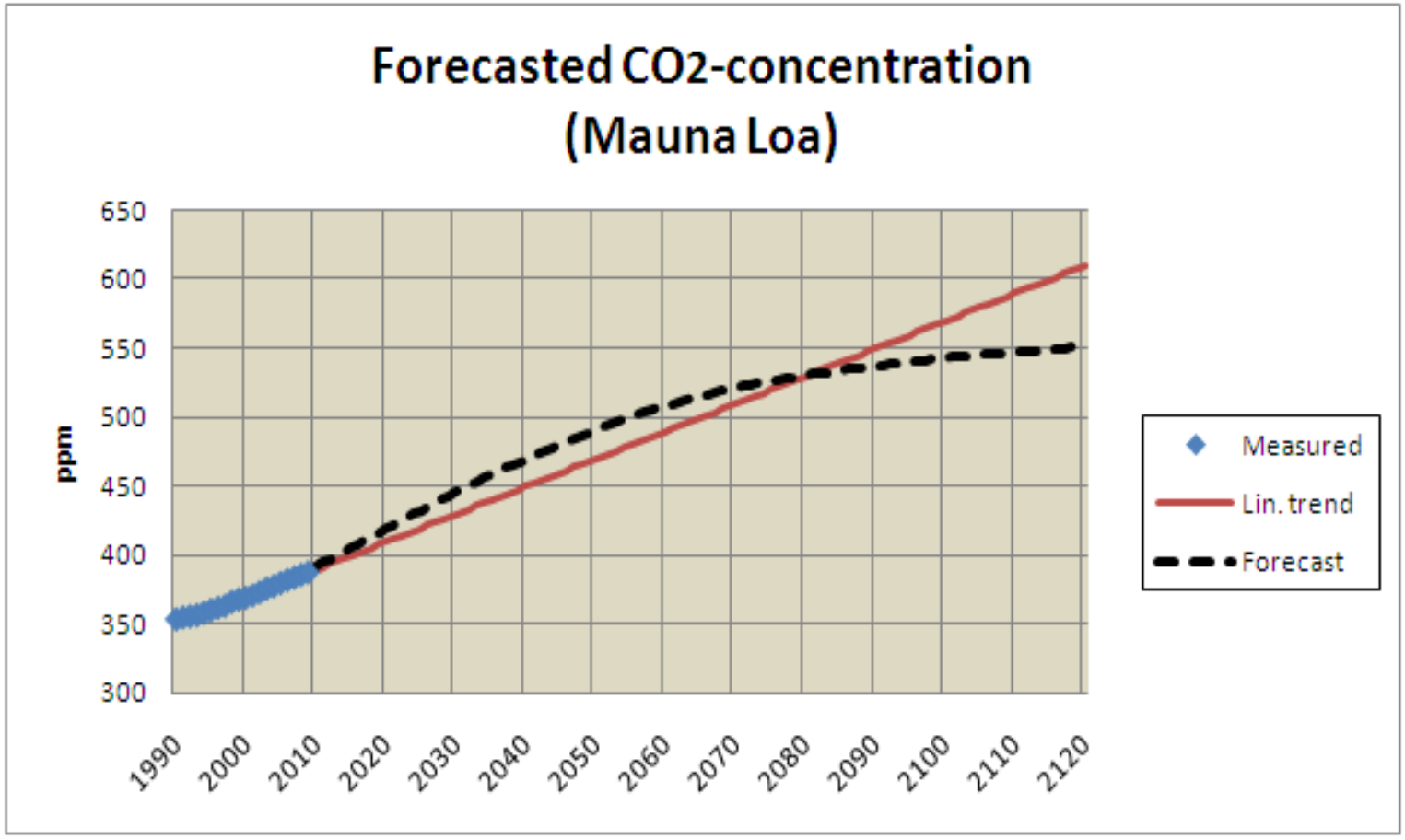


Cumulative CO2-emissions of Energy Industry



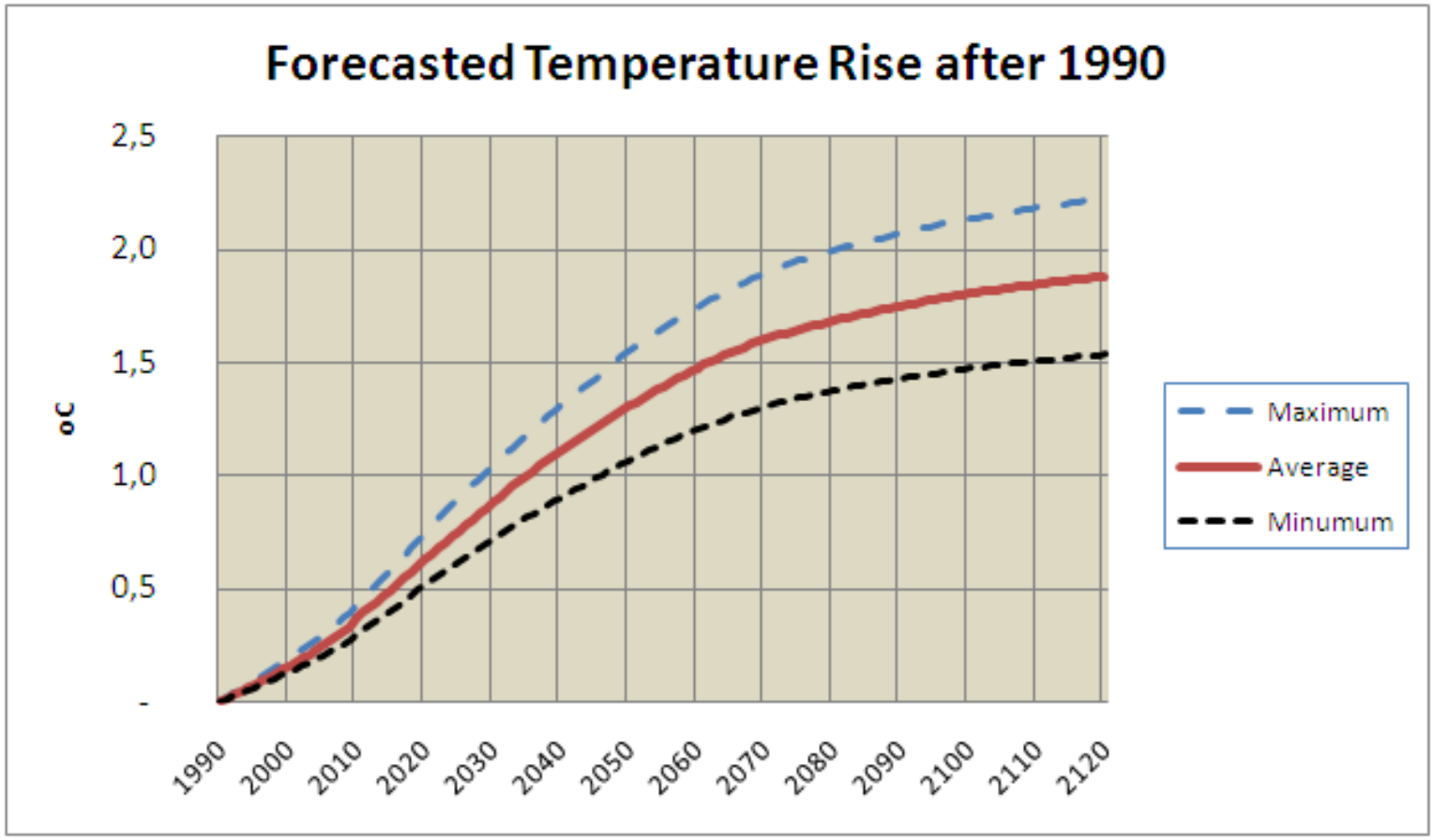
Released emissions are 500 Gt from 1990 to 2009

Forecasted CO2-concentration



500 Gt increase in emissions corresponds to 34 ppm addition in concentration

Forecasted temperature increase



If emissions reach 2800 Gt, tempereture will rise 1.5 – 2.2 oC after 1990. The increase before 1990 has been 0.4 – 0.6 oC.

Conclusions

1. **Without nuclear the CO2-emissions will grow until 2050**

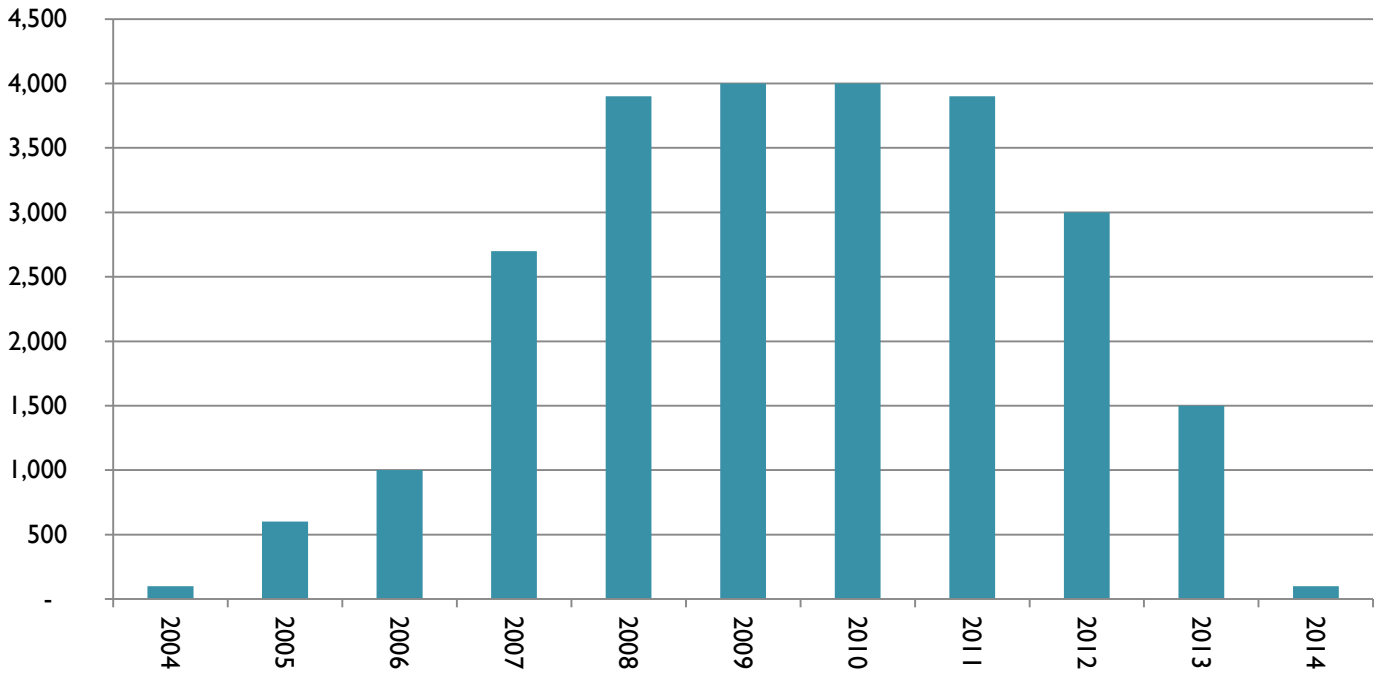
2. **Nuclear capacity additions could save the planet by keeping global temperature rise below 2 oC**

COSTRUCTION COST EXPERIENCE

Construction cost experience of EPR-1600 MW in Finland

- Construction costs
  - Contract price €2000/kWe
  - Actual costs €3500/kWe (+75%)
- Construction schedule
  - Planned 4 a from first concrete
  - Actual 8 a (+100 %)

Site manpower in Olkiluoto-3



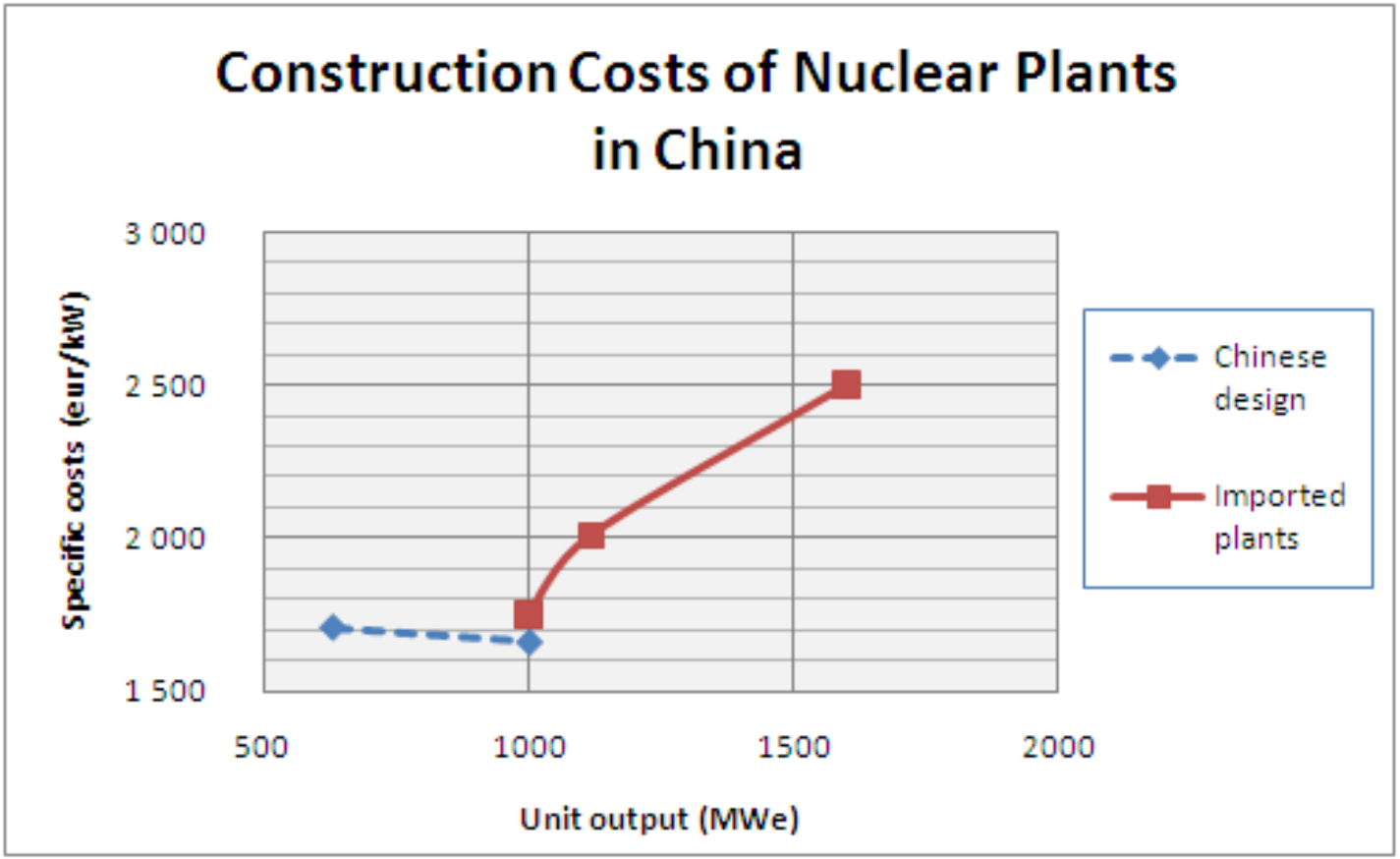
Site manpower 25 h/kWe
Costs of manpower €1000/kWe

Construction costs of PWR plants in Finland

• **Loviisa-1**	**488 MWe**	**€1540/kW**
• **Loviisa-2**	**488 MWe**	**€1244/kW**
• **Total**	**976 MWe**	**€1390/kW**
• **Olkiluoto-3**	**1600 MWe**	**€3500/kW**

- **Large nuclear plant has higher specific costs than small plant in Finland**

Economics of scale stops above 1000 MWe



Conclusions

1. **Small plants seem to be more economical than large plants**

2. **Modular costruction will be needed**
   - **to improve site labour productivity**
   - **to reach 65 GWe annual capacity additions**

MODULAR PLANTS

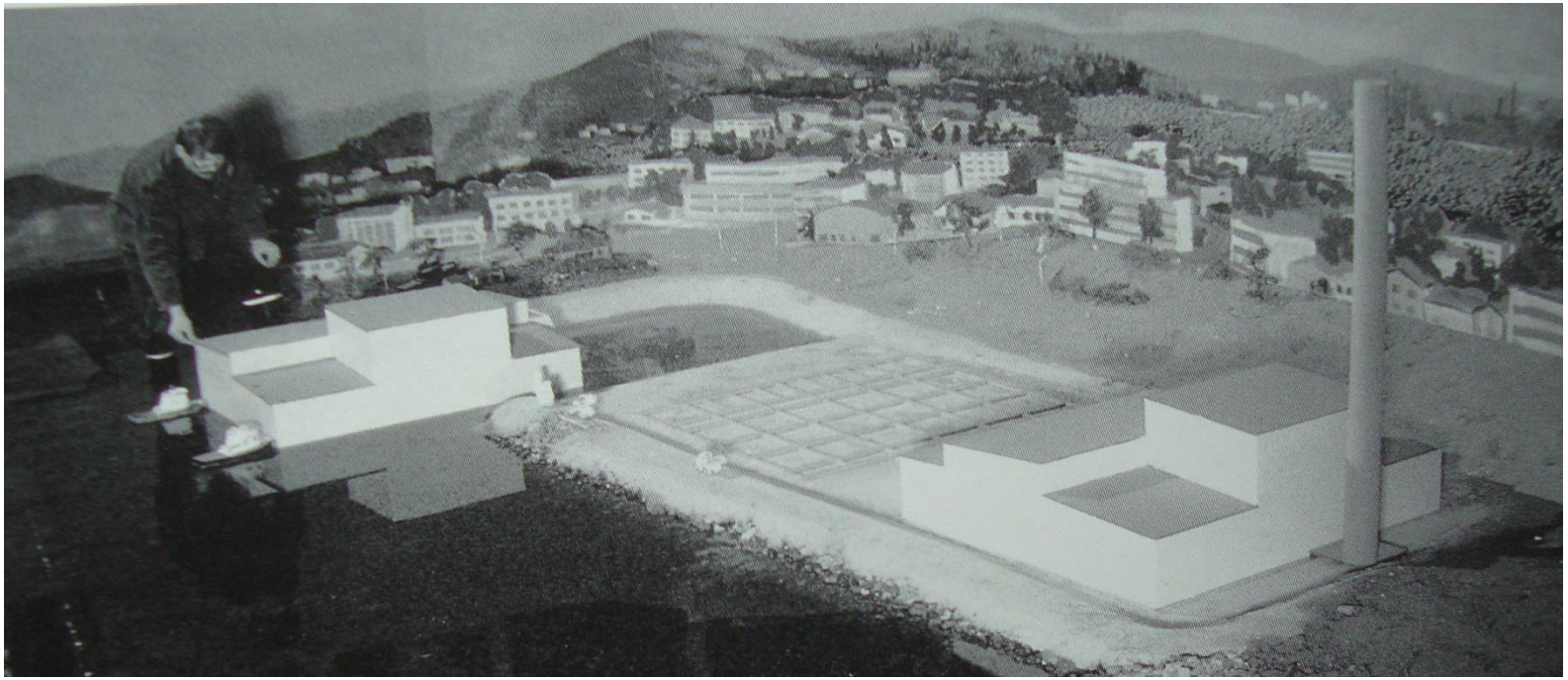
M/S Oasis of the Seas

Largest cruising ship in the world
-Ordered Feb 2007 (Turku shipyard)
-Lounched Nov 2009 (2.5 years)
-47 m wide, 361 m long,
-Displacement 100 000 tons
-Engines: 3x13 MW + 3x18 MW

N/S Taimyr

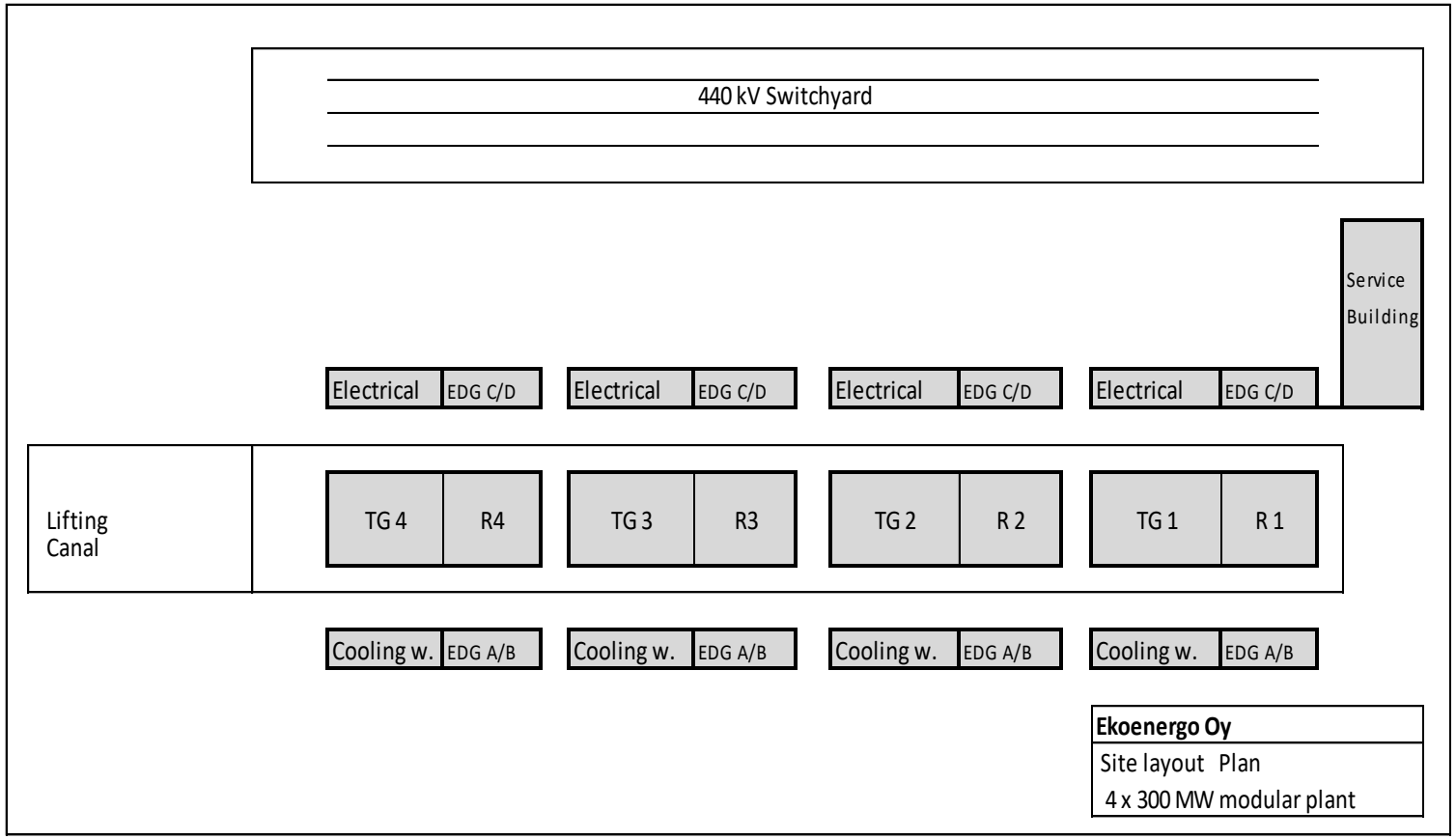
Nuclear Icebreaker (Wärtsilä Helsinki Shipyard)
Ordered 1987 Launched 1989
KLT-40 reactor and 2 x 18 MW steam turbines

Modular Combined Cycle Plant



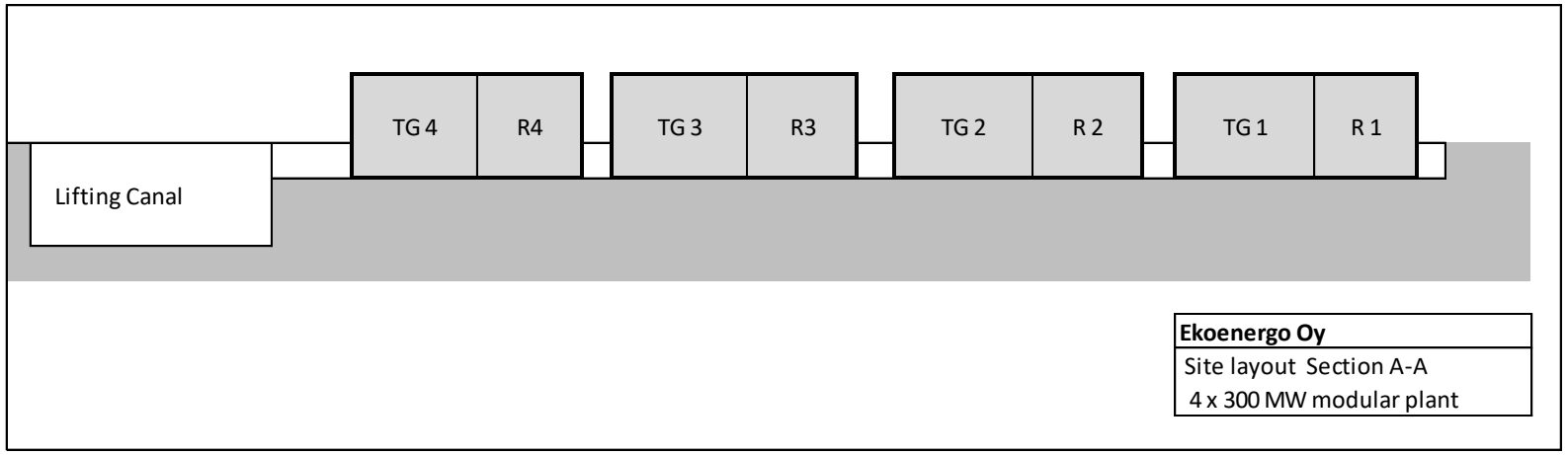
4x190 MW plant was designed in 1989 for Norway by IVO
Size of largest module: 40 m long, 58 m wide, 8000 tons
No permission was given because of CO2-emissions

4x300 MWe Modular Nuclear Plant



Reactor module: 40 m wide, 60 m long
Turbine module: 40 m wide, 80 m long

4x300 MWe Modular Nuclear Plant



Modules can be lifted 10-20 m up by using a lifting canal

Lifting canal can be used as cooling water inlet canal

Units can be transported into a rock tunnel by the same way

Selection of the reactor

- **Boiling water reactors**
  - VK-300 (750 MWt/250 MWe) Rosatom
  - LSBWR (900 MWt/306 MWe) Toshiba
- **Pressurized water reactors**
  - IRIS (1000 MWt/335 MWe)
  - VBER-300 (917 MWt/325 MWe) Rosatom
  - Westinghouse 800 MWt/250 MWe
- **Breeders and gas cooled reactors**
  - not yet in commercial stage

COST ESTIMATES OF MODULAR PLANTS

Estimating investment costs by using scaling

C(P) = Cr x (P/Pr)S**

where P= Output in (MWe)

S=Scaling factor=0,75

Size (MWe)	Costs (€/kWe)
1000	2970
800	3105
600	3300
300	3840

Costs in serial production

Formula C=C1 x n **-e

where C= costruction costs

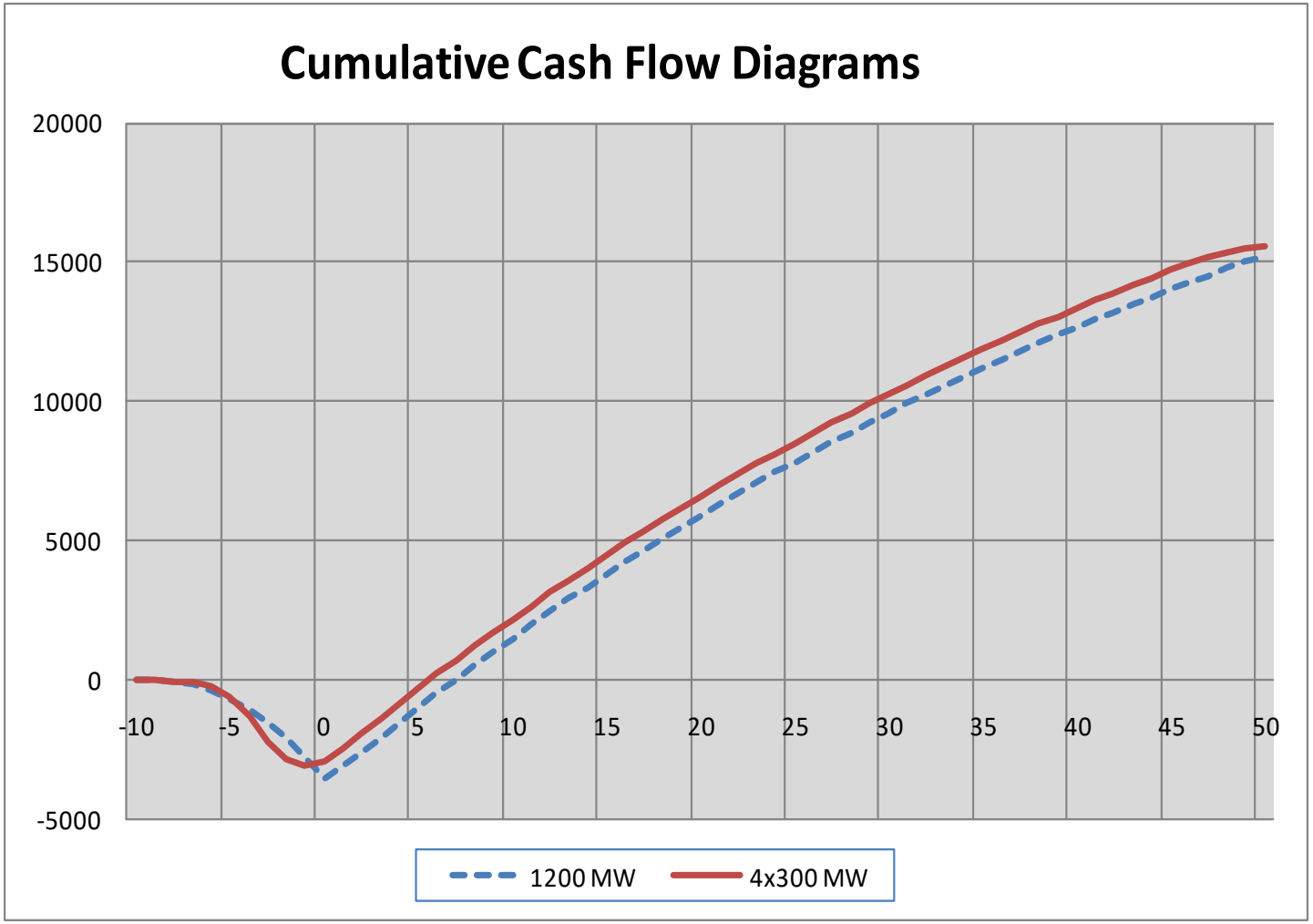
n= number of unit

e= elasticity = 0.15

Costs of a 4 x 300 MW plant

1. unit	€3840/kWe
2. unit	€3370/kWe
3. unit	€3130/kWe
4. unit	€2970/kWe
Whole plant	€3330/kWe

Cumulative cash flow diagram



Reserve power costs*

- **1200 MWe plant needs**
  - 1200 MWe frequency responce reserves (15 s)
  - 1200 MWe fast reserves (5-15 min)
- **4x300 MWe plant needs**
  - 300 MWe frequency responce reserves (15 s)
  - 300 MWe fast reserves (5-15 min)
- **Difference**
  - 2x900 MWe = 1800 MWe
  - Additional reserve costs= 1800 MWx€700/kW =€1260 million =€1050/kWe

* Book: "Panning of Optimal Power Systems"

Summary and conclusions

1. **It is possible to built 300 MWe modular plants with lower costs than 1200 MWe plants**

2. **Serial production in a shipyard**
   - Decreases costs, schedule and site manpower
   - Increase quality

3. **300 MWe size should be standardized**

Reference

Book:

”Planning of Nuclear Power Systems to Save the Planet”

Author: Asko Vuorinen

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Soft cover ,176x250 mm, 304 pages, 149 figures, 100 tables

Price: €20 + sending costs

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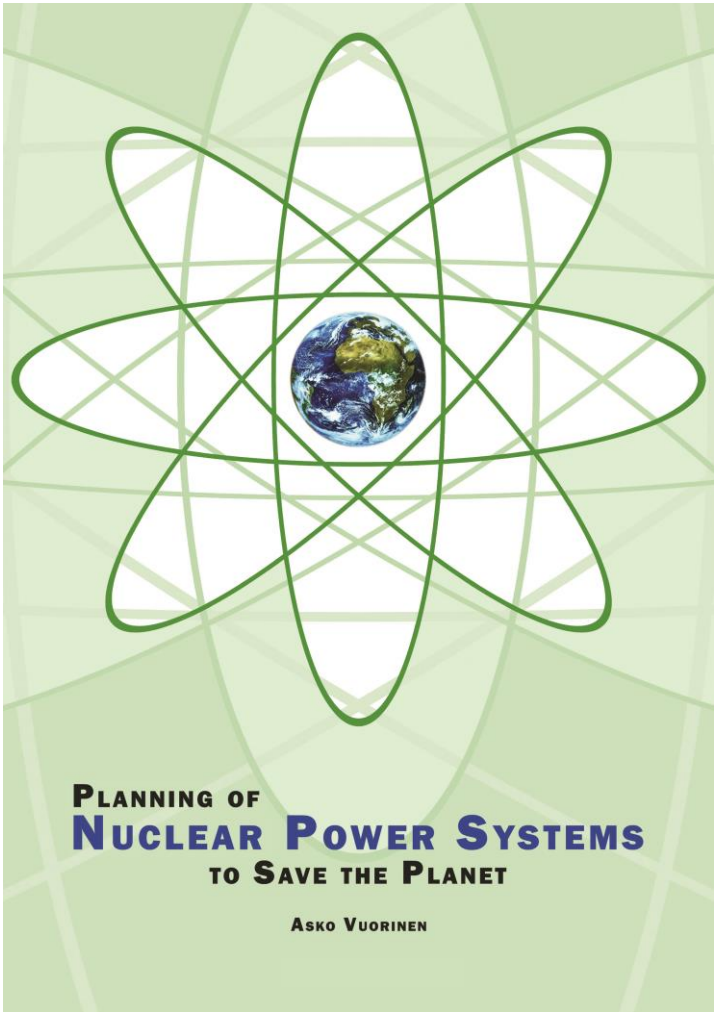

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