NUCLEAR ENERGY IN SWEDEN

From the happy 1960:s to the gloomy first years of the 21:st century

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Björn Kjellströms nuclear energy career

1955 High school teacher woke interest in nuclear energy (age 17)

1958 Part time employed at design office of AB Atomenergi

1960 Thesis research work for AB Atomenergi

1962 Employed as research engineer at Heat transfer lab. of AB Atomenergi, Studsvik. Development of design basis for the Marviken reactor project.

1970 Promoted to manager for thermohydraulíc R&D. Increasing focus on safety system design and validation

1973 Consultant to SKI on Ringhals 2 – 4 thermohydraulic safety

1975 Increasing doubts about nuclear reactor safety in praxis

1976 Left AB Atomenergi after conflict with top management

1976-78 Member of first Swedish Energy Commission

1979-80 Nuclear referendum campaign – leading ideologist for option 3

1980 - Occasional consultancy on nuclear safety issues

This is where the nuclear age started in Sweden.....

The first decade – R&D for building capacity in a new field of science and technology

1945 Nuclear weapons used over Hiroshima and Nagasaki

End of World War 2

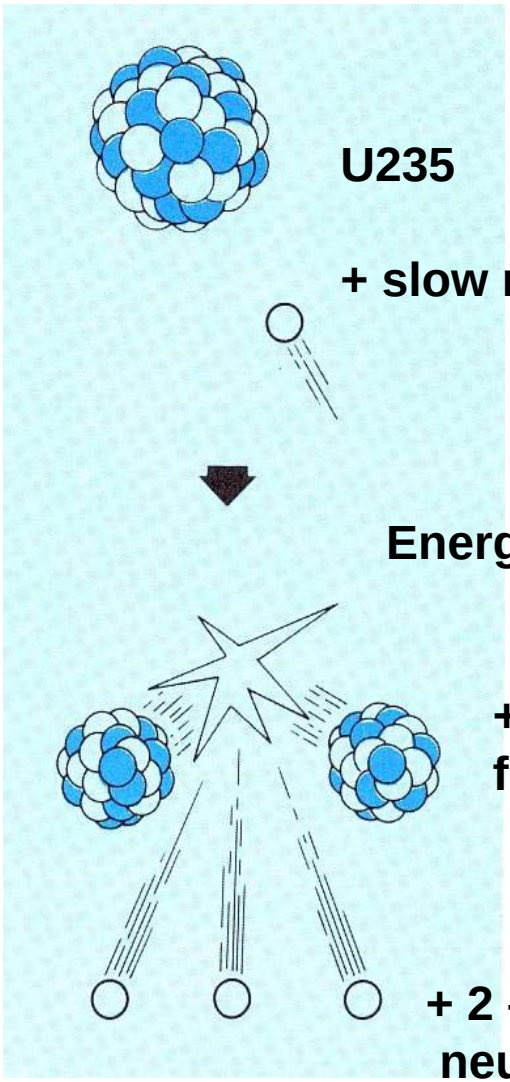
Swedish gov:t appointed committee to propose research for peaceful and military use of nuclear energy in Sweden

1947 Gov:t owned company ”AB Atomenergi” formed. Objectives: R&D and later commercial introduction of nuclear power. Design of first reactor in Sweden R1

1954 R1 (located at KTH) operational (heavy water – natural uranium)

ASEA decided to start development of commercial reactors

The nuclear fission is simple in principle

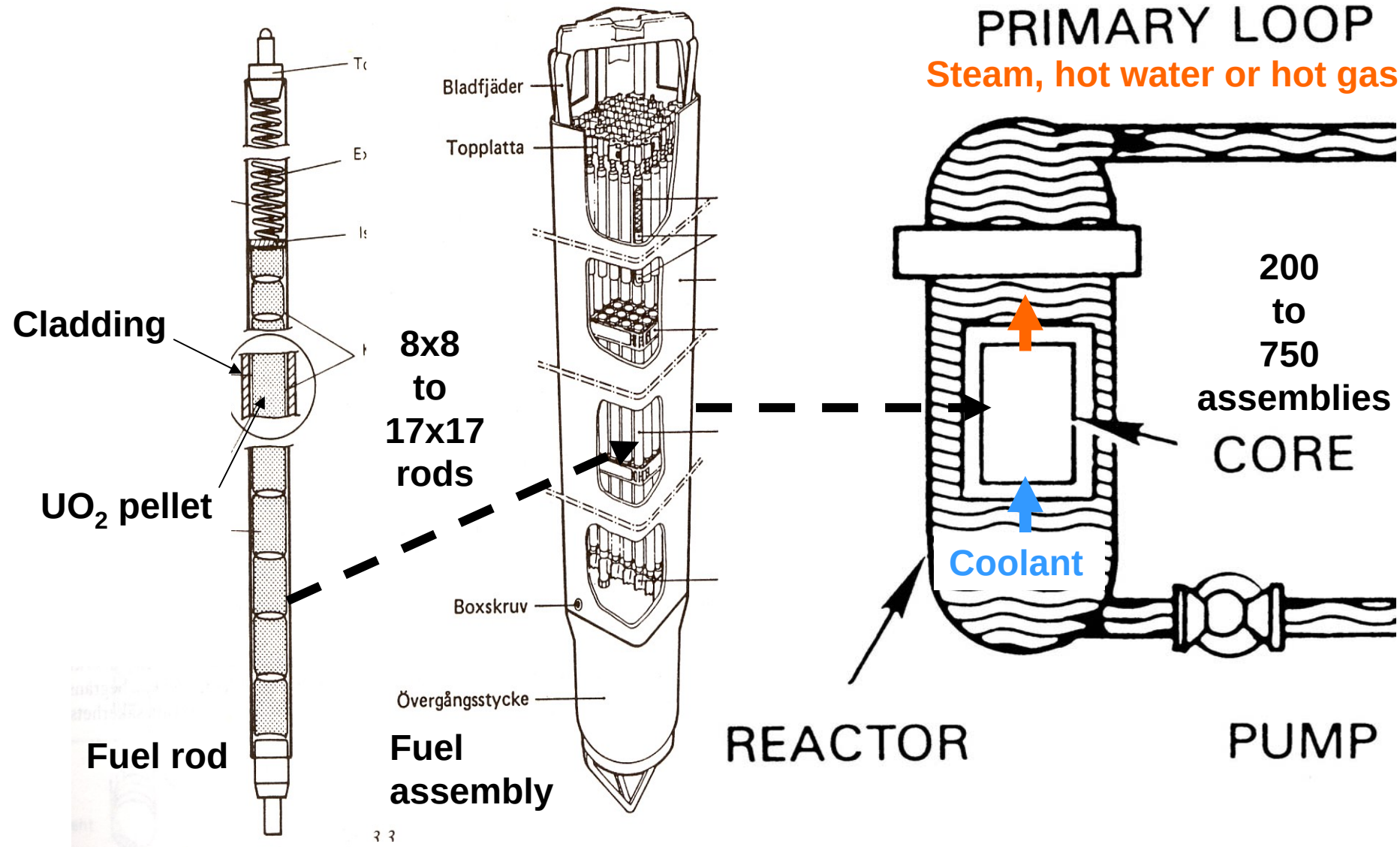


The challenge is to control and utilise the process in a safe way

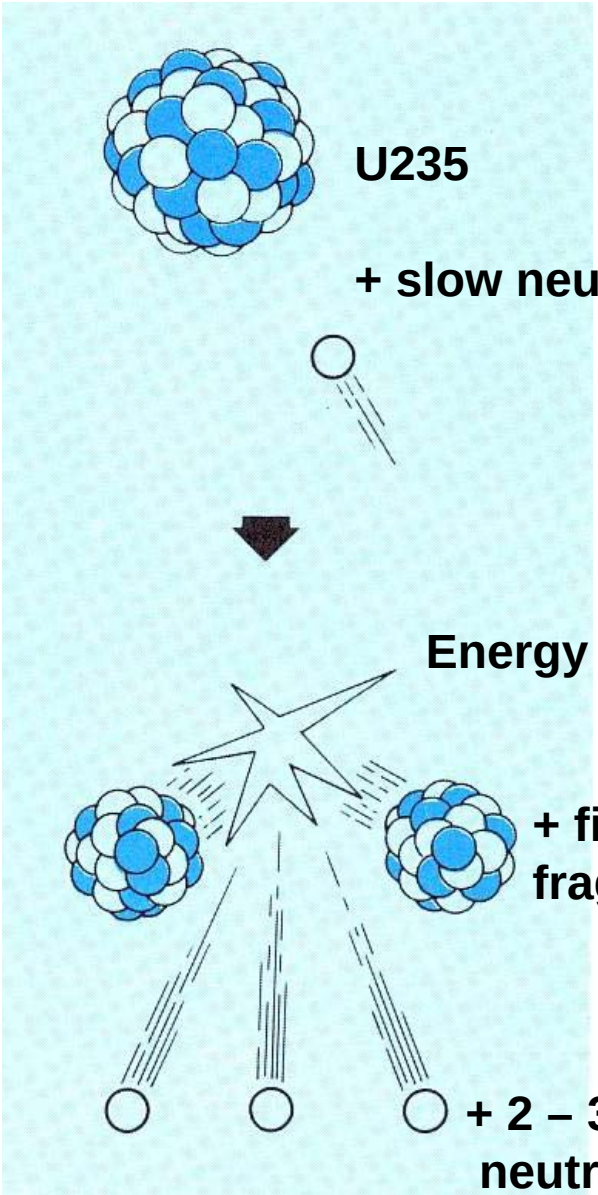
Radioactive

Continued heat generation

Engineering principles



Nuclear fission of uranium



Initial research needs:

- **Nuclear reactions**
- **Neutron economy**
  - **Moderation**
  - **Absorbtion**
  - **Reflection**
- **Cooling**
- **Materials**
  - **Radiation damage**
  - **Corrosion**
- **Control of thermal output**
- **System design and optimisation**
- **Radiation protection and safety**

R1 reactor at Drottning Kristinas väg KTH

Research reactor
built 1951-1954

Natural metallic U
Al-cladding
Heavy water moderated

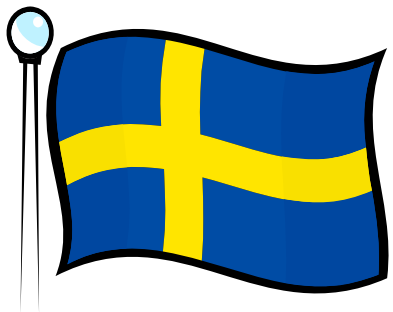
Thermal power:
initially 100 kW
increased to 1000 kW

1955-1965 The Swedish approach -

Goals:

National independence for energy supply

Nuclear weapons capabilities

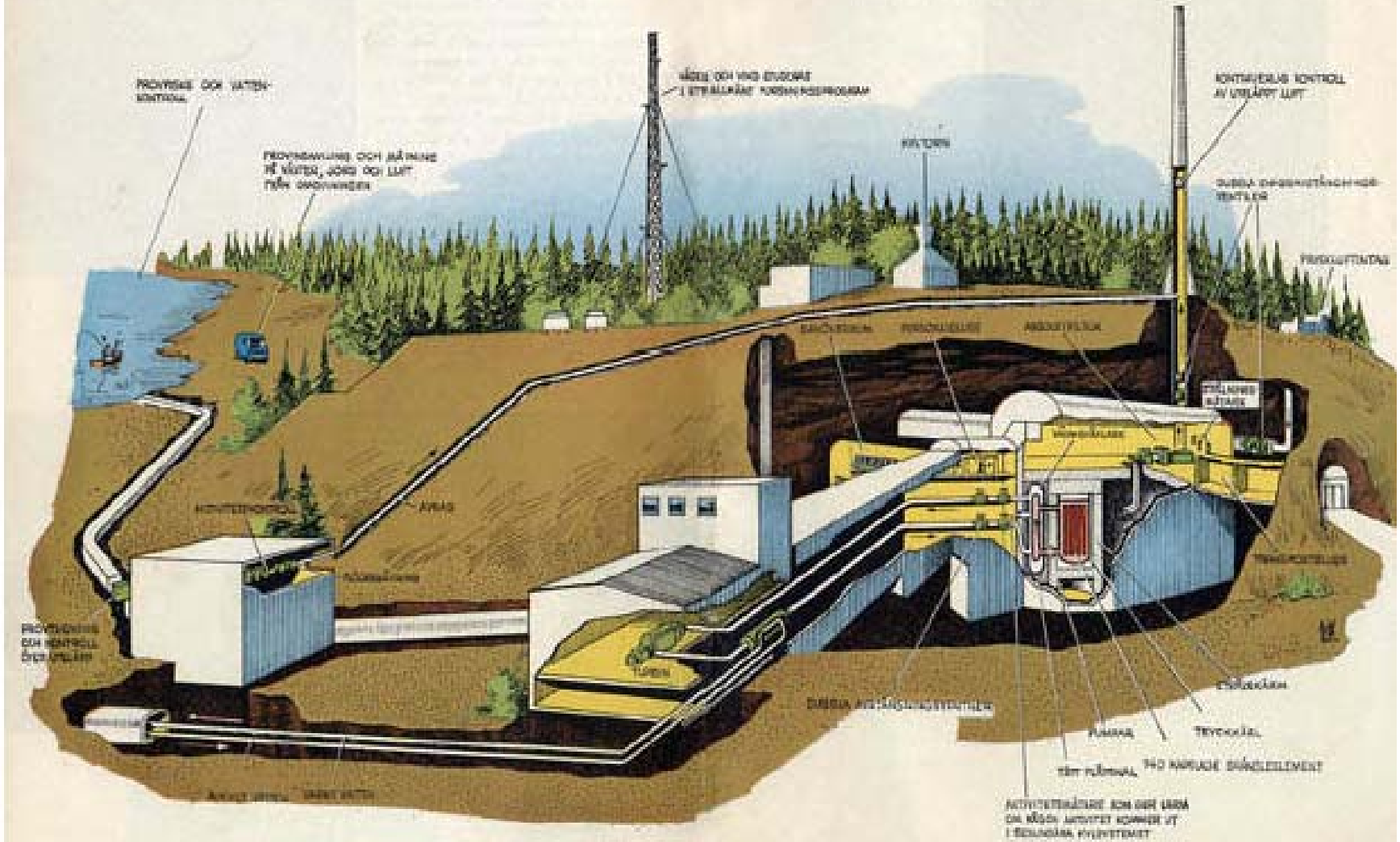


- **Natural uranium as fuel (uranium mine at Ranstad)**
- **Heavy water as coolant and moderator**
- **Indigenous engineering know-how and industrial capacity for introduction of the technology**
- **Combined heat and power generation**

Ytterligare information om Ågesta Kraftvärmeverk lämnas av AB Atomenergi, Informationsbyrån, Stockholm 5V, tel. 010/19 02 60.

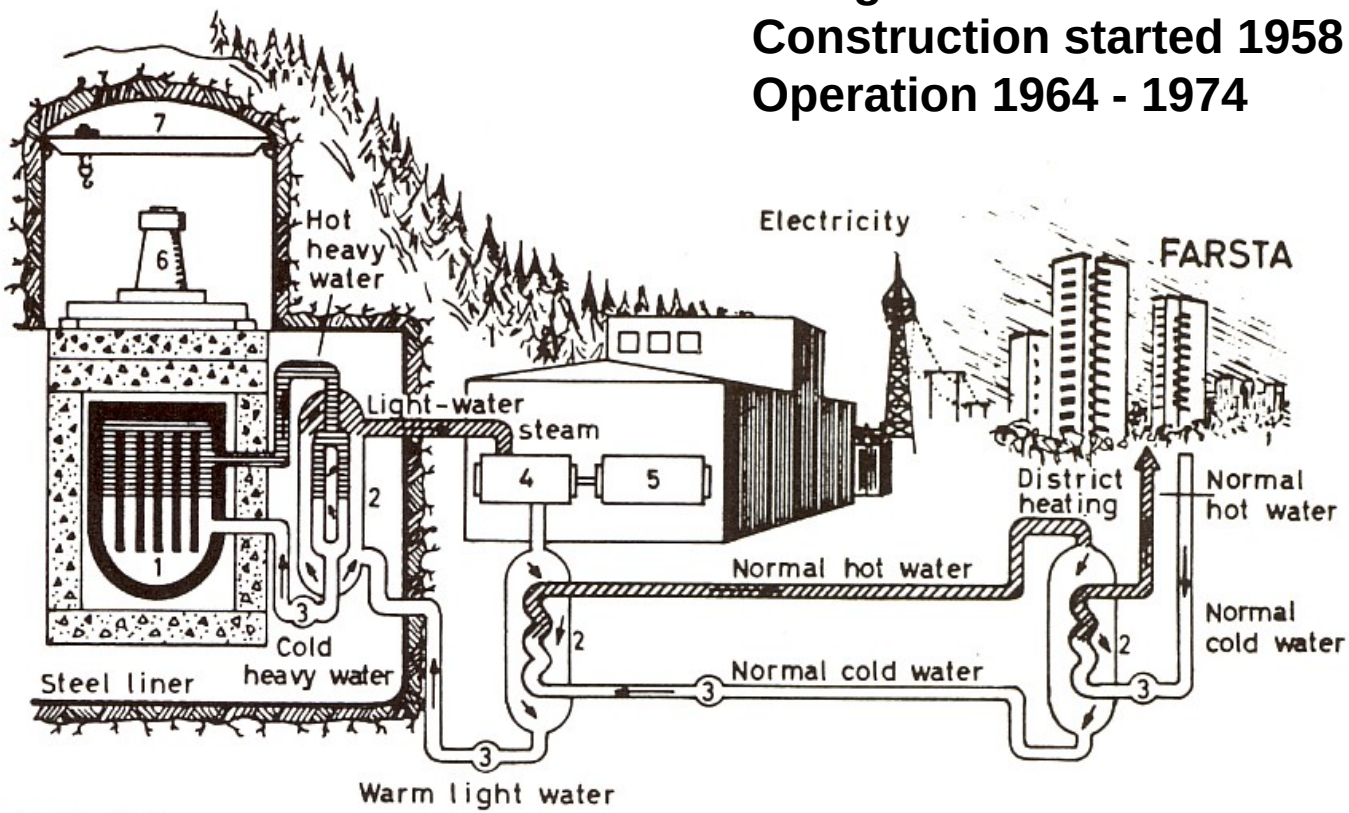
ÅGESTA

kraftvärmeverk



The Ågesta power plant

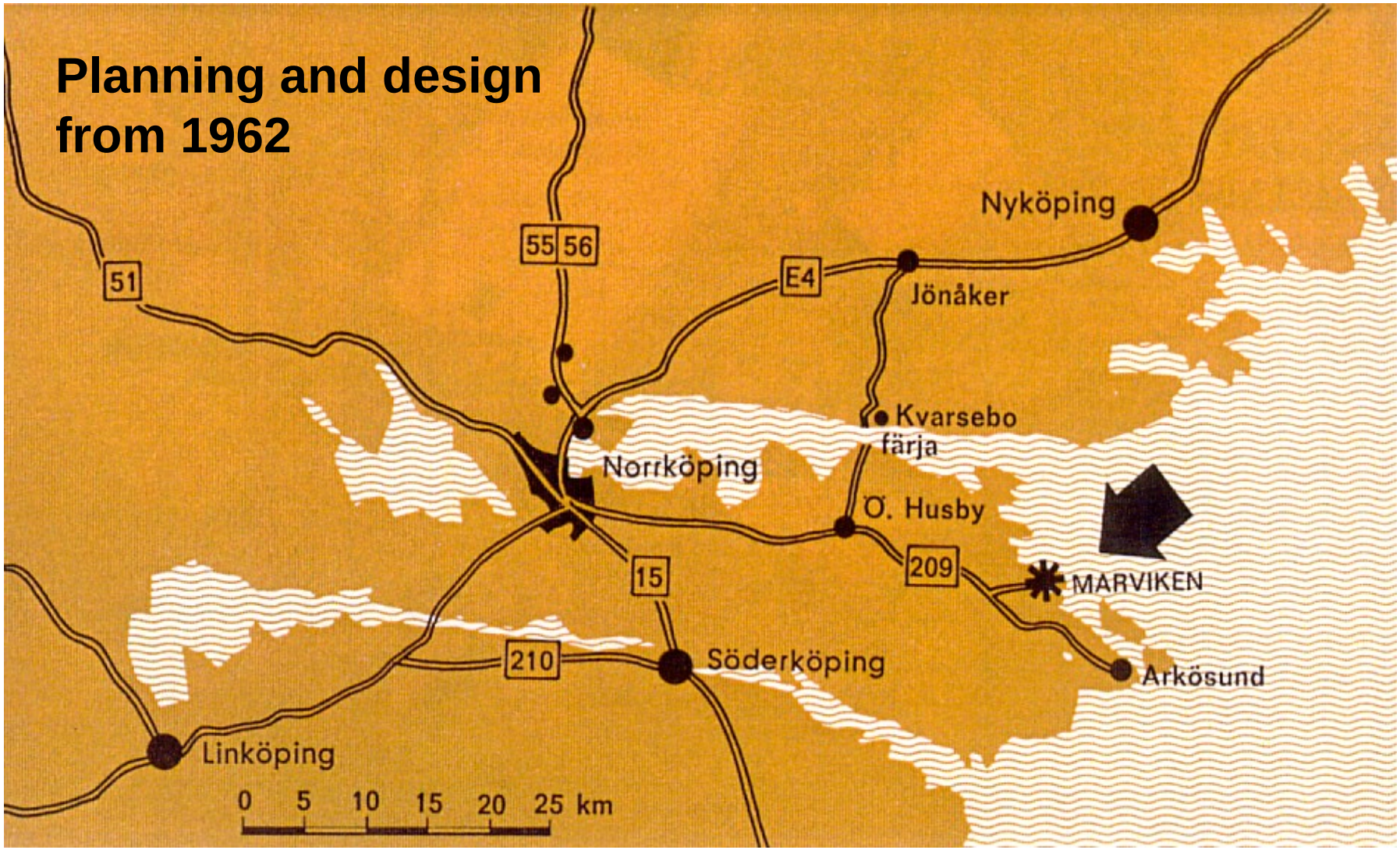
Design started 1956
Construction started 1958
Operation 1964 - 1974



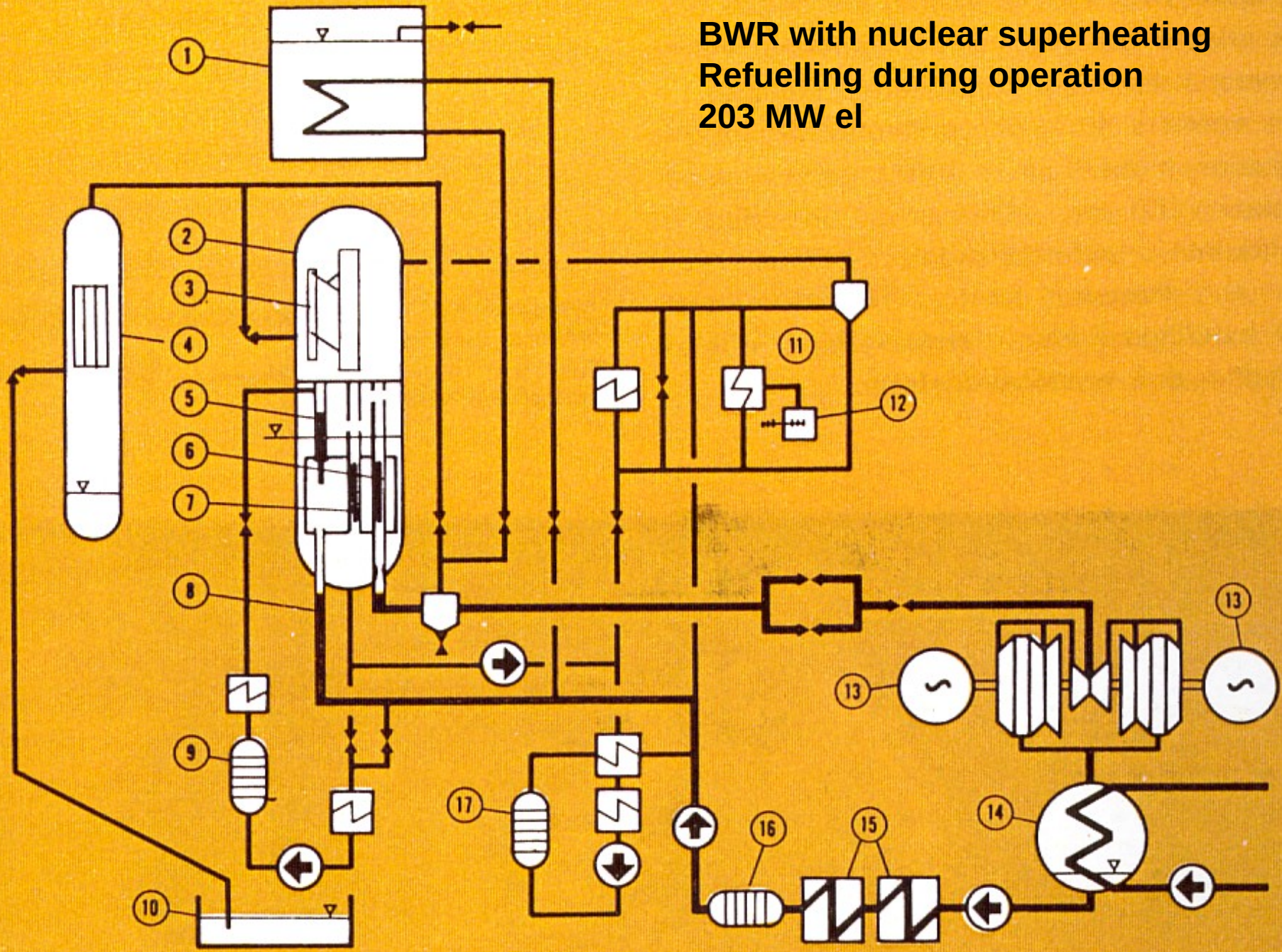
1 Reactor
2 Heat exchanger
3 Pump
4 Turbine
5 Generator
6 Charge machine
7 Overhead crane

12 MW el
68 MW heat

Marviken – the most ambitious reactor project the World had seen

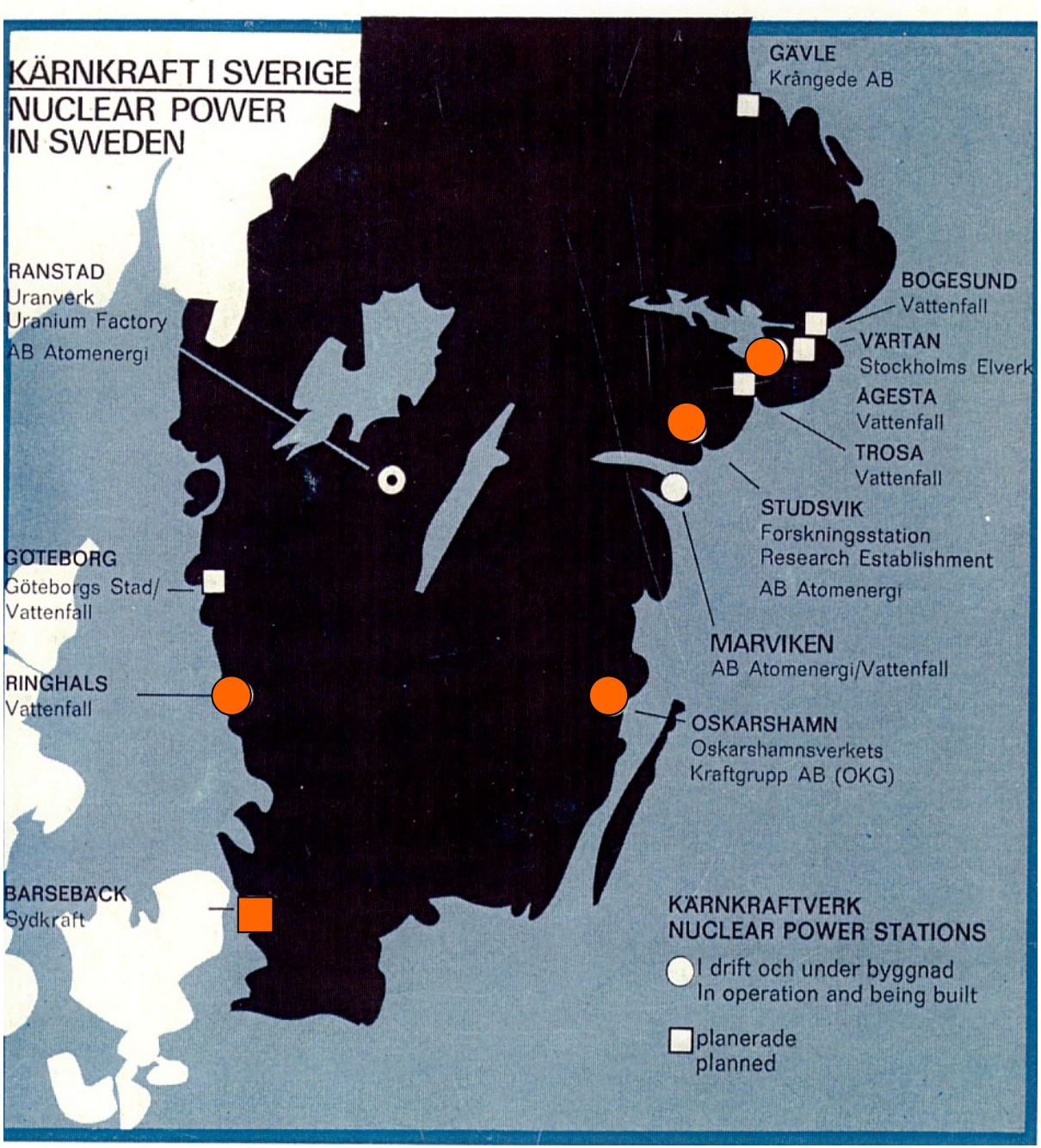


BWR with nuclear superheating
Refuelling during operation
203 MW el



Growing industrial capacity in 1960´s
Massive support from Gov:t

- **AB Atomenergi (gov:t owned)**
  - **Design and engineering of Ågesta**
  - **Design and enginering of Marviken (until 1964)**
  - **Research and development**
  - **Exploratory uranium mining at Ranstad**
- **ASEA from 1968 Asea-Atom (50% gov:t)**
  - **Design and enginering of Marviken (from 1964)**
  - **Design and engineering of Oskarshamn 1 and 2**
  - **Ringhals 1, Barsebäck 1 and 2**
- **Uddcomb**
  - **Manufacturing of large pressure vessels**



Plans for nuclear energy in Sweden 1969

Several proposed sites close to large population centres

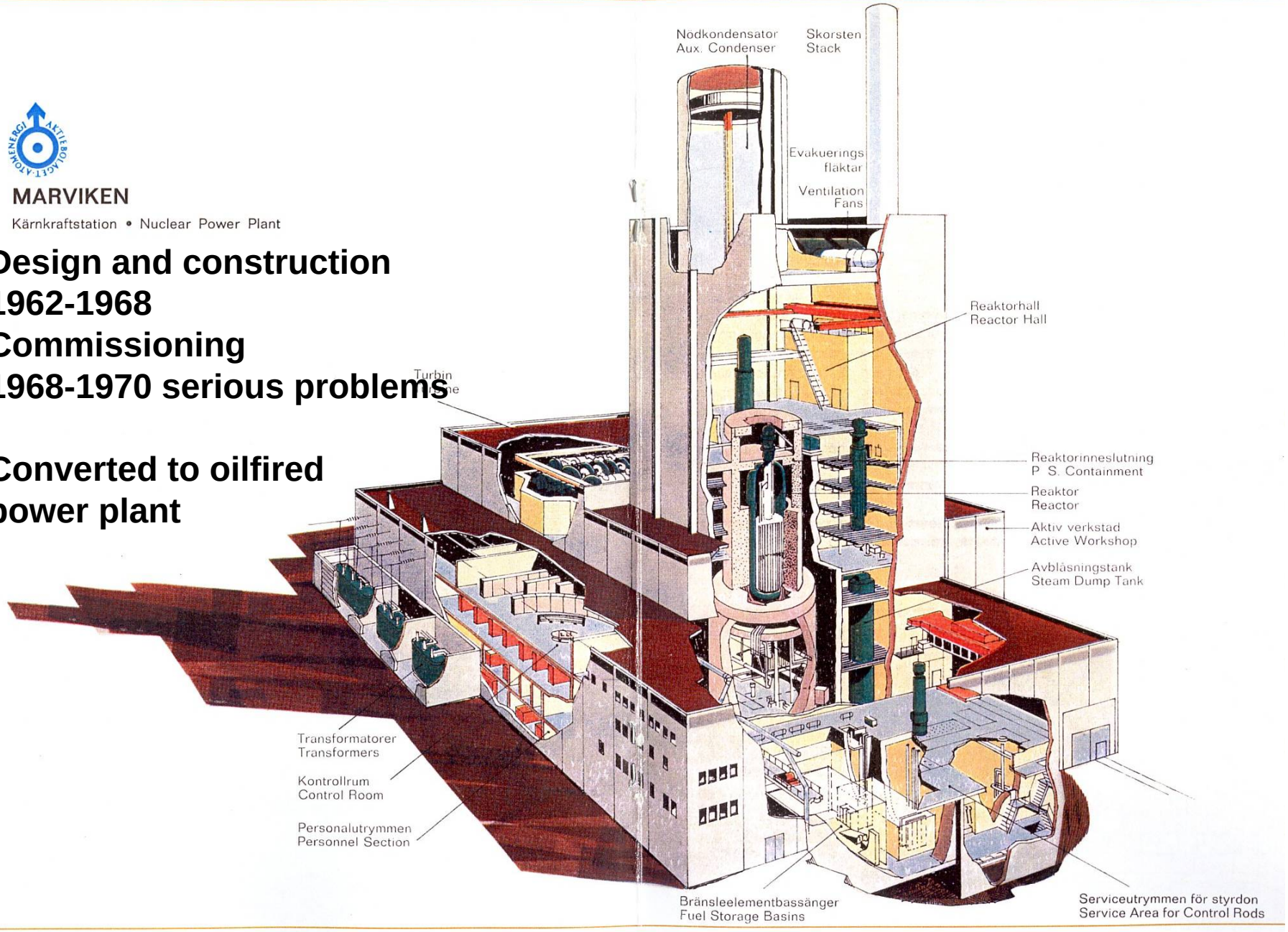
Realised projects

MARVIKEN

Kärnkraftstation • Nuclear Power Plant

Design and construction
1962-1968
Commissioning
1968-1970 serious problems

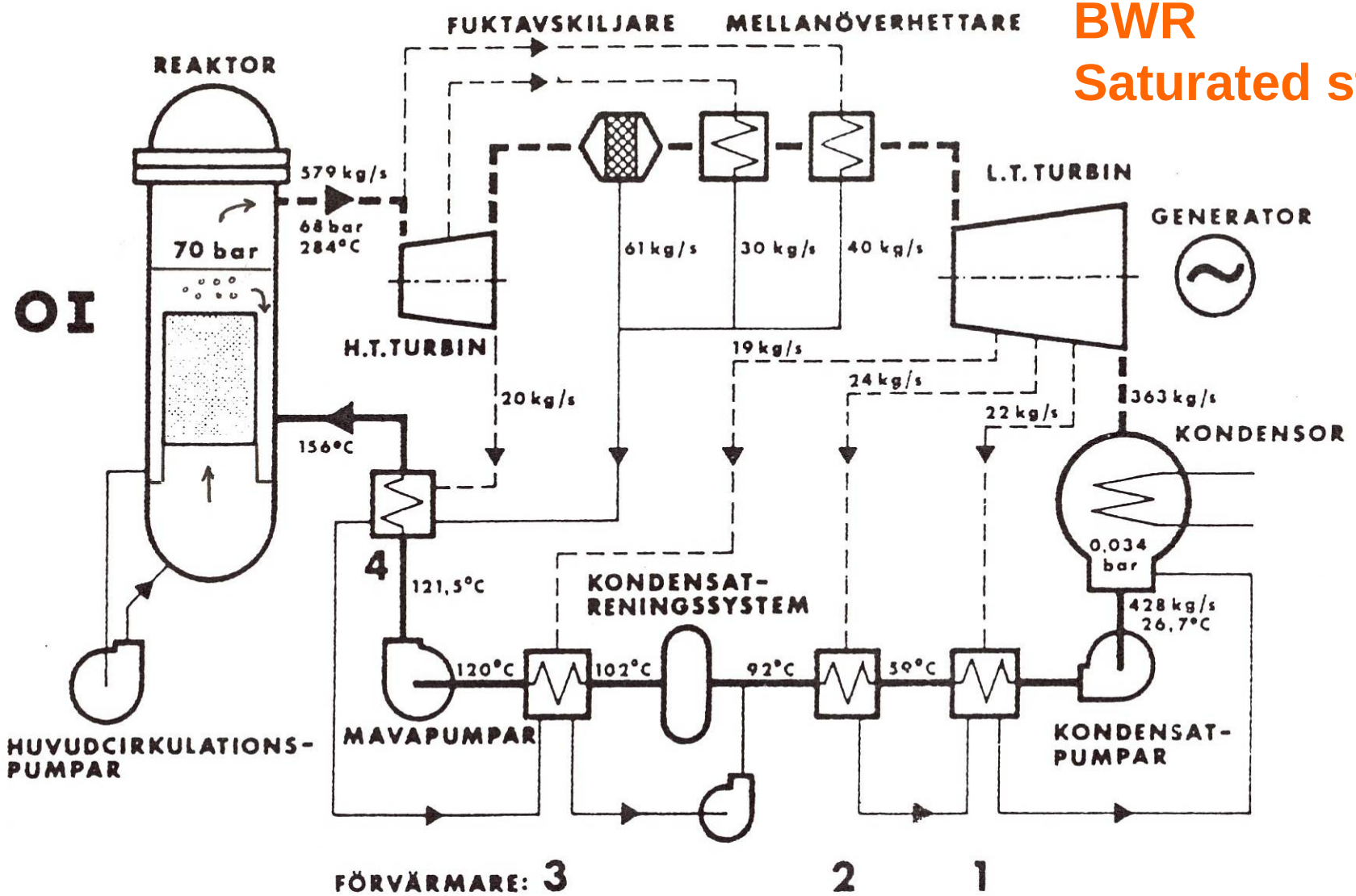
Converted to oilfired power plant



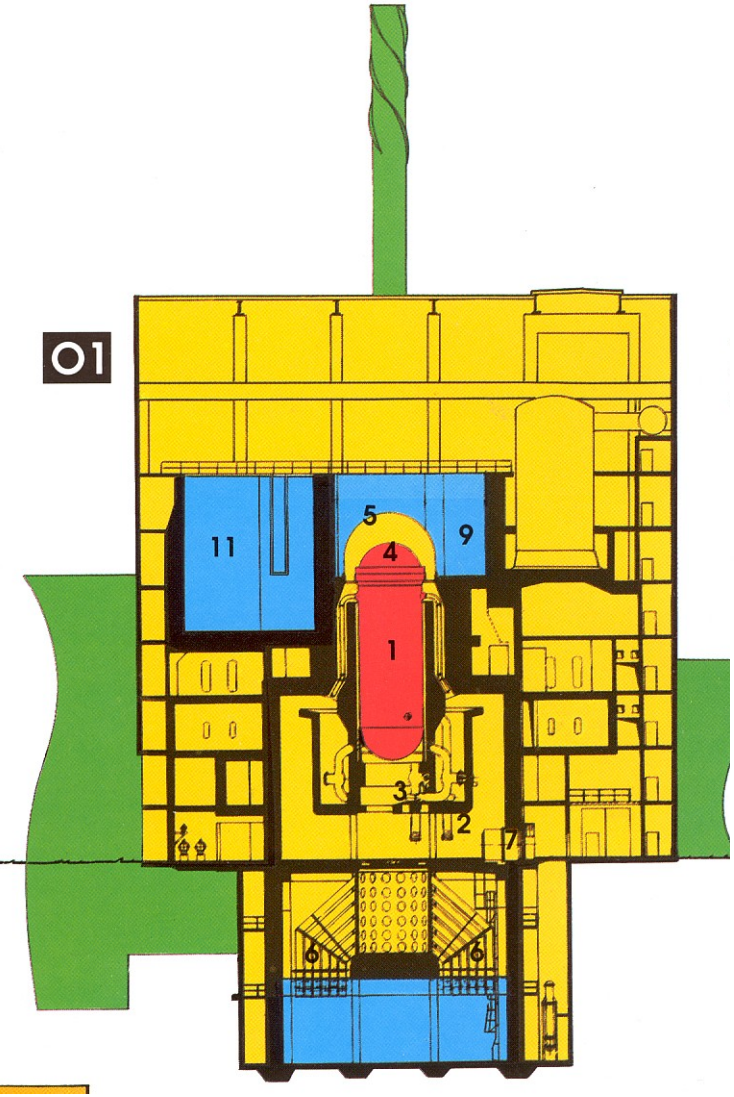
Oskarshamn nuclear power plant site

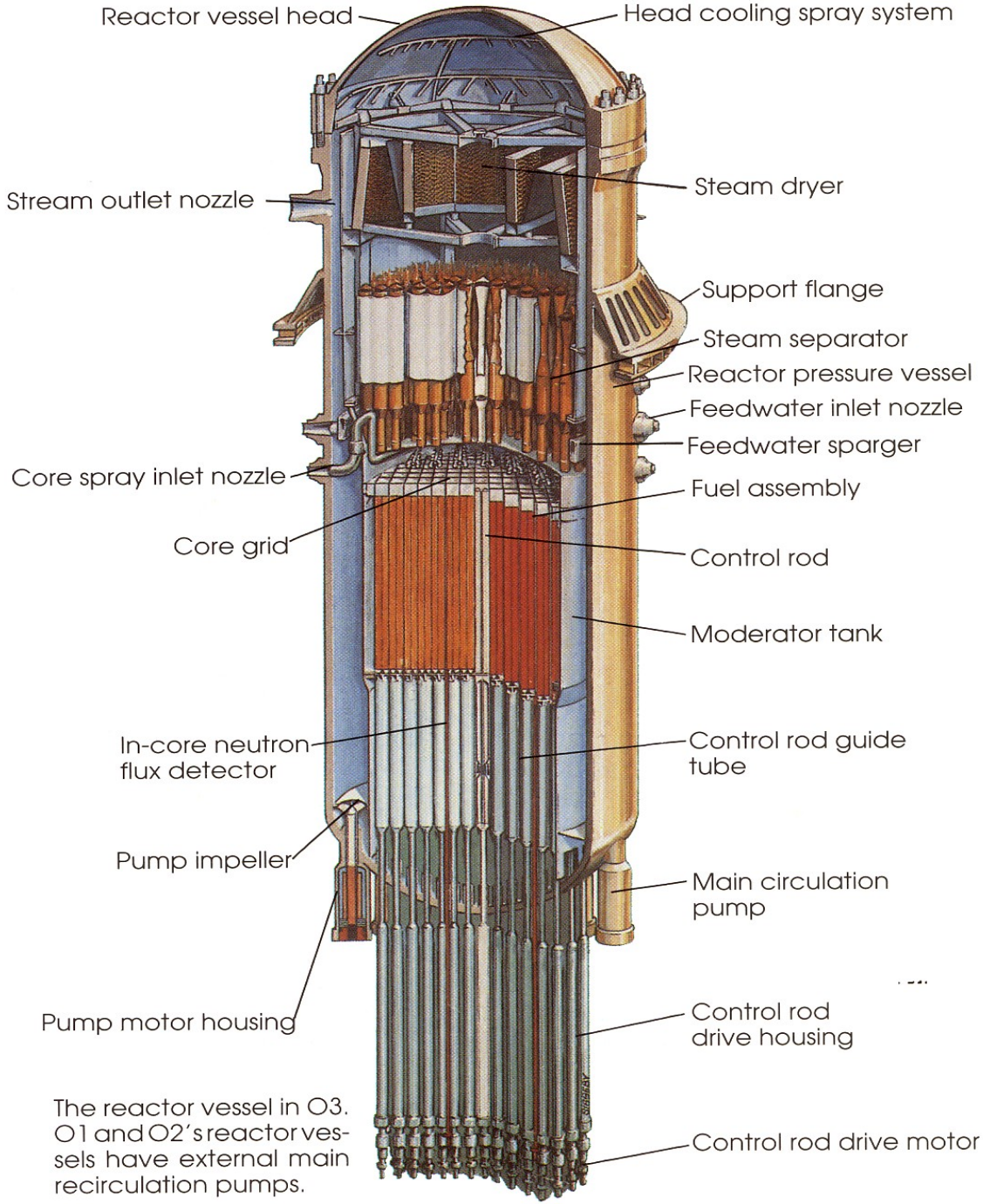
Oskarshamn 1 – first commercial power reactor in Sweden

BWR
Saturated steam



Reactor design





The reactor vessel in O3. O1 and O2's reactor vessels have external main recirculation pumps.

1966-1976 – From enthusiasm to political controversy

- **Nuclear weapon plans officially abandoned 1966**
- **Planning and construction work on power plant sites in Oskarshamn, Ringhals, Barsebäck and Forsmark.**

  Growing public concerns from late 1960´s.

  Concerns about waste management raised in parliament 1972.
- **Ågesta closed, Marviken converted to oil-firing.**
- **Parliament election 1976 – Center party gained largely on opposition to nuclear power. Change of government. (New non-socialist majority split over nuclear issue)**

The controversy over nuclear energy

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+ Relatively small environmental impacts under normal operation of power plant
+ Relatively cheap

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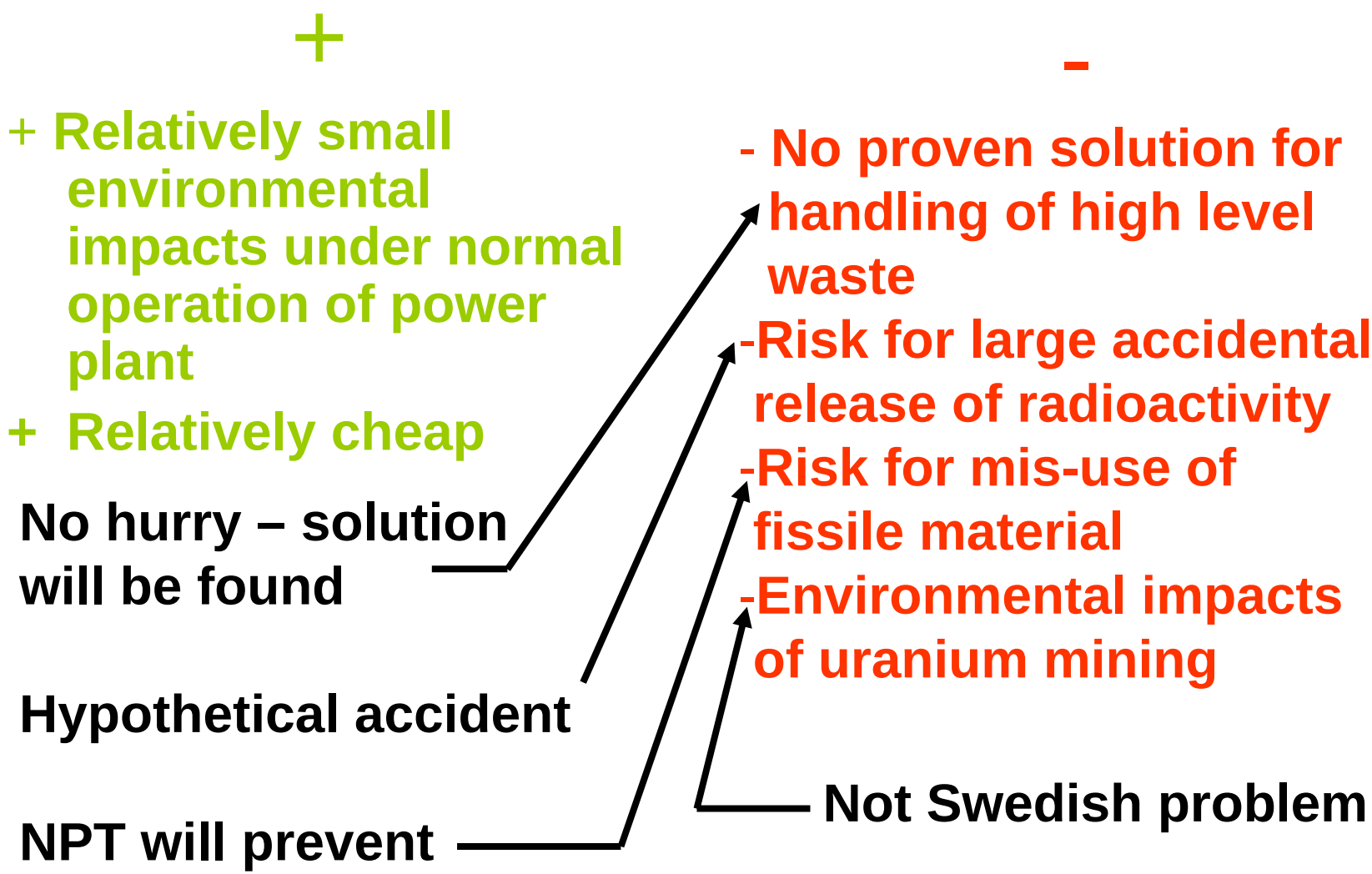
- No proven solution for handling of high level waste
-Risk for large accidental release of radioactivity
-Risk for mis-use of fissile material
-Environmental impacts of uranium mining

The controversy over nuclear energy



My personal shift of attitude

- **Intil 1972 entusiastic. Busy developing design basis for normal operation. Thought critics were badly informed.**
- **1972 engaged by Nuclear Inspectorate to review performance of safety systems. Identified numerous weaknesses in design basis – gradually more concerned.**
- **1974 Experienced how alarming results from ”Urban siting study” were withhold from the public and political decision makers – Fought from inside for more open attitude without success.**
- **1976 Left job at AB Atomenergi with ambition to stop further nuclear expansion until problems had been resolved**

Major nuclear reactor accidents

- **1957 - Fire in the gas cooled Windscale reactor (England). Large release of radioactivity.**
- **1969 – Coolant malfunction in gas cooled Lucens reactor (Switzerland). Underground site – no radioactve release.**

Large accidents in water cooled reactors - hypothetical

- **1979 – valve failure in Three Mile Island reactor (USA) caused partial core melting. Small release of radioactivity. Hypothetical accident became reality.**

Swedish parliament decided to arrange national referendum on future of nuclear power in Sweden

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The 1980 nuclear referendum

Three options:

1. **Nuclear power will be phased out at a rate that does not risk employment and social benefits. Maximum 12 power plants shall be commissioned. 18,9%**
2. **Nuclear power will be phased out at a rate that does not risk employment and social benefits. Maximum 12 power plants shall be commissioned. 2010 presented as target year for phase-out. 39,1%**
3. **Nuclear power shall be phased out before 1990. Only the 6 completed reactors in operation. 38,7%**

After this, the parliament decided to limit the number of reactors to 12 and to phase out nuclear power completely before 2010

Development after 1980

- **Reactors in Ringhals (2 units) Forsmark (3 units) and Oskarshamn (1 unit) that were in different phases of completion were brought into operation.**
- **Proposals for final storage of spent fuel deep in dry stable rock developed.**
- **Filters for reduced release of radioactivity installed.**
- **1986 – Accident in Chernobyl reactor (USSR) caused a very large release of radioactivity.**
- **1987- Government proposed starting phase-out 1993-1995. Final year would still be 2010**
- **2004 – Both reactors in Barsebäck closed. Socialdemocrats, centerparty and ”communists” agree to continue phase out at a rate that will not lead to disturbances of energy supply or increased CO_2 emissions. No final year.**

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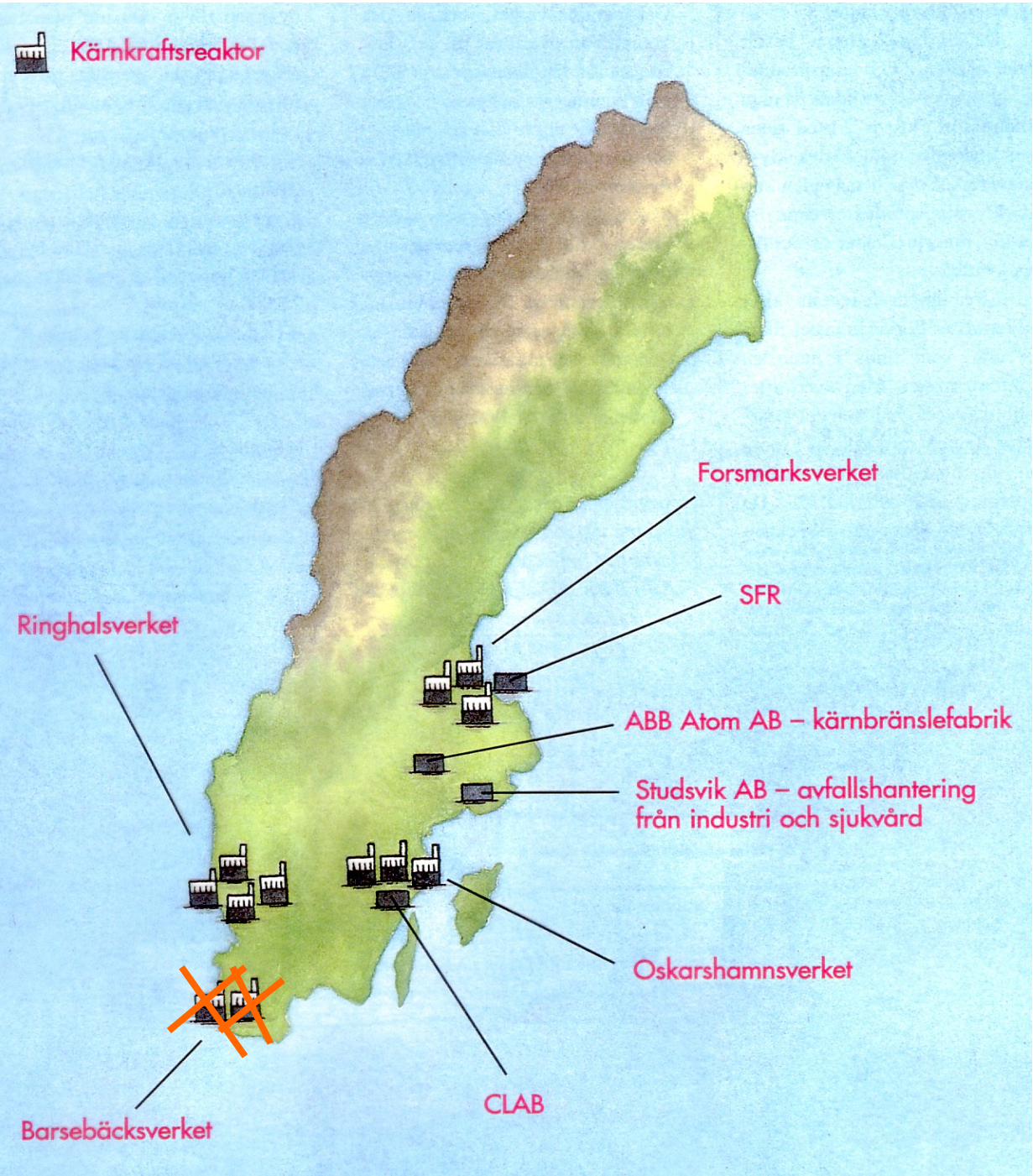

The present situation

- Siting studies for final storage of spent fuel
- Two units closed but output from the other is being increased
- Fundamental problems remain

Is there a future for nuclear power?

- **Nuclear energy opens great possibilities for energy supply.**

- **The fundamental problems remain.**

- **Further development of the technology will be necessary for sustainable public acceptance.**

  Limit the amount of fission products that can be released under extreme conditions.

  Develop designs that are less sensitive to interruption of cooling of the fuel

Lessons learned – personal level

- **An engineer must take moral responsibility for the consequences of technological systems he is working with**
- **Make sure to check the facts before you take conflict with the establishment**
- **Do not attempt to suppress negative information about new technologies – there will certainly be a back-lash**