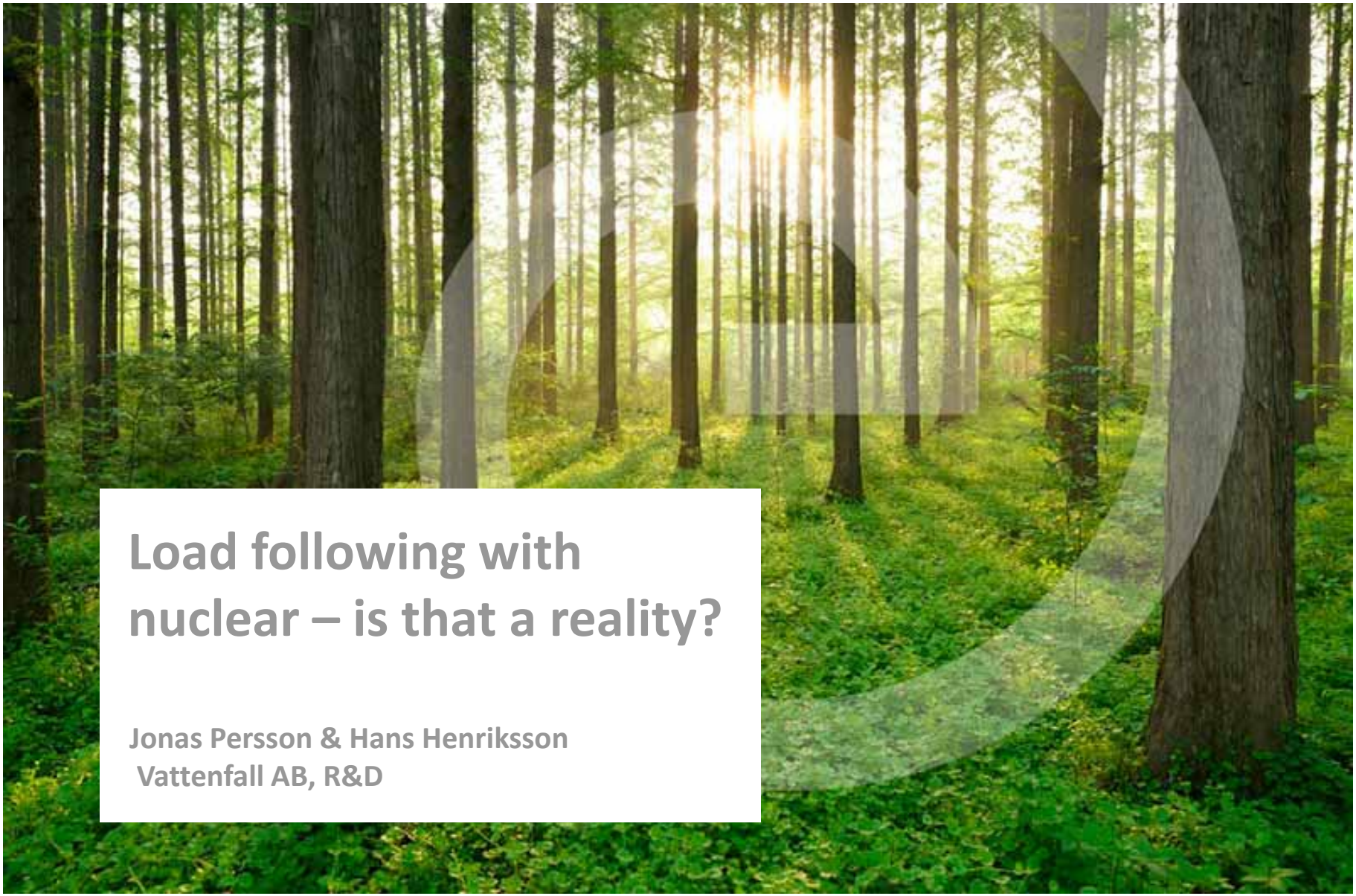


# Load following with nuclear – is that a reality?

Jonas Persson & Hans Henriksson
Vattenfall AB, R&D

Energiforsk

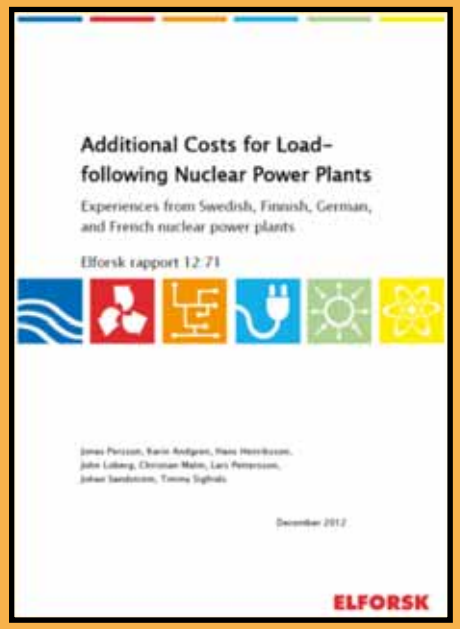
# Conclusions

- Feasible to use nuclear power as regulating power
- Examples of good experience from Sweden and other countries
- Focus on day,- or week-scale, but possible as primary control (sec-scale)
- Further study of problematic working points
- Plant-specific issues to be verified
  - Turbine optimisation
  - Pump status
  - Fuel load pattern
  - Power ramping performed according to specifications

# Load following with nuclear – Studies carried out 2011-2012

First study already 2011 about possibilities to load-follow with nuclear (in Swedish): Elforsk 12:08

Follow-up study with focus on costs realted to load-following, Elforsk 12:71 www.elforsk.se/Rapporter/?rid=12_71




**Summary:**

- Load-following (LF) operation means only minor additional costs. In the case the operation is planned, no additional cost is foreseen.
- Increased fuel cost in case of unplanned LF: up to 4% increase of total production cost in a BWR (4-7 % in a PWR).
- Increased need for maintenance in control rod mechanism and lower availability seen in France during primary (frequency) control.
- It is recommended to use several reactors in series to avoid larger power decreases, below 60% nominal reactor power
- Some work ranges for pumps and other components need to be identified.



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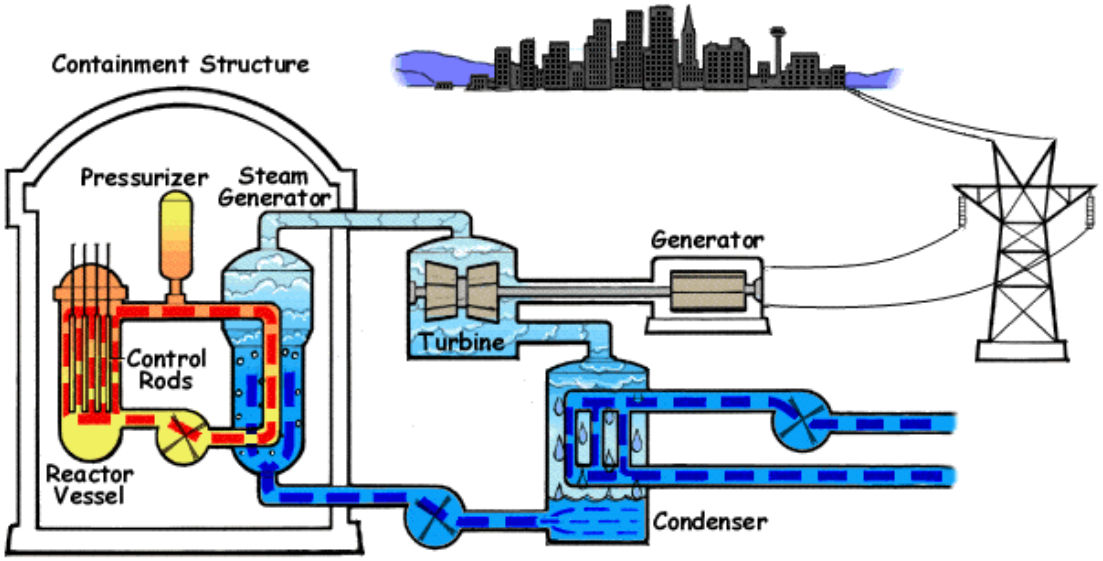
# Introduction

- Future requirements could demand a more flexible generation at our Nuclear Power Plants (NPPs):
  - The variation in production and consumer load will be much larger and faster than before.
  - New electric grid code with tougher demand on regulating power.
- A flexible power control of NPPs could, with increased intermittent energy production, be a valuable asset.



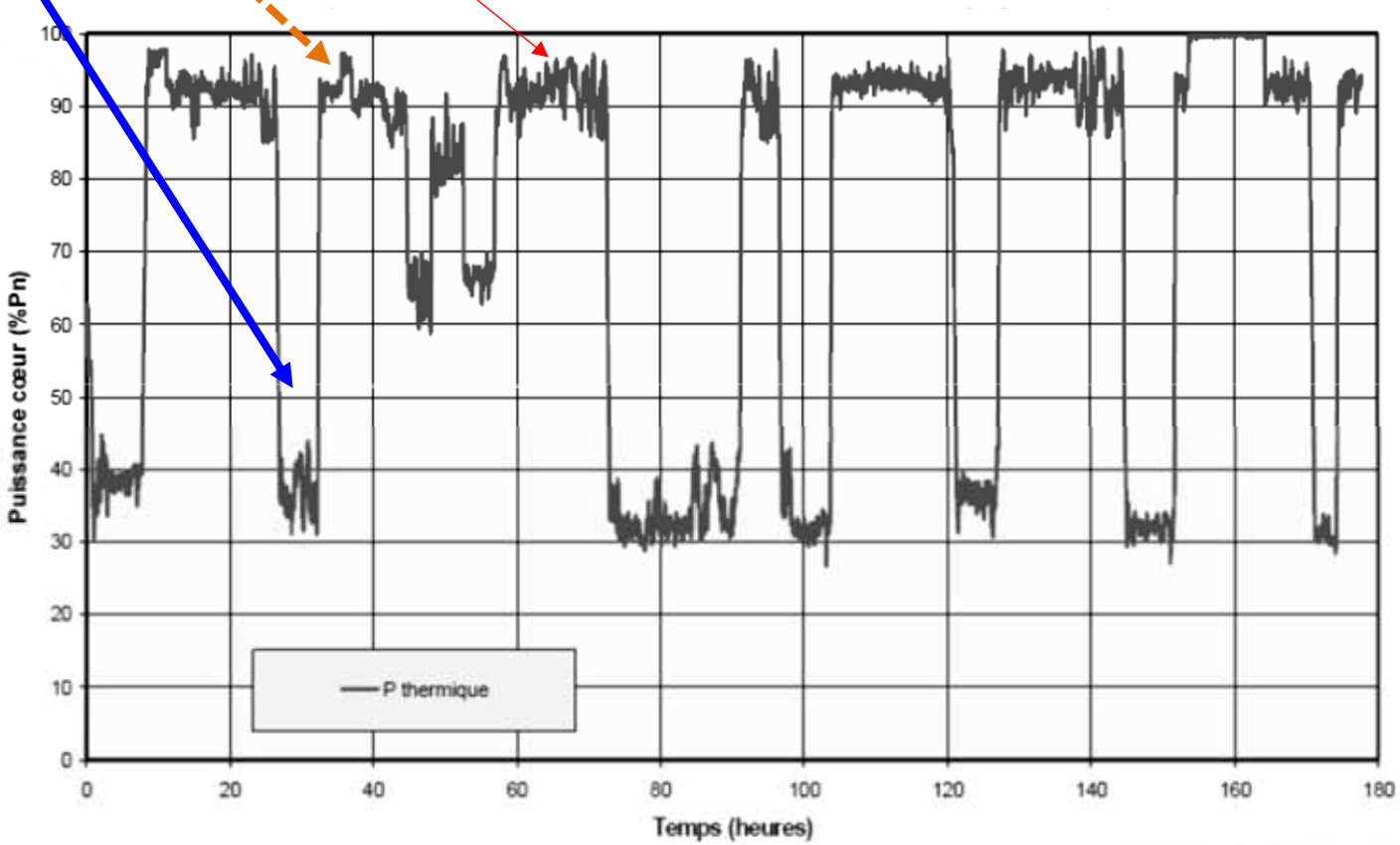
# Background

**Why load-following?**

- More intermittent power in the grid
- New grid requirements
- Differentiated market (four market regions in Sweden)
- New transmission links to other markets
- Trading opportunities

# Background

- Primary control (frequency compensation to establish 50Hz).
- Secondary control (return to daily average of 50Hz in grid).
- Load-following: Adjusting power to demand.



# Experience in France

French PWRs are flexible in operation (all modes of power control)

One transmission system operator (in France) and one operator (EDF) simplifies demand-response.

Load-following is carried out in the power range 37%-93% during the first 85% of the fuel cycle.

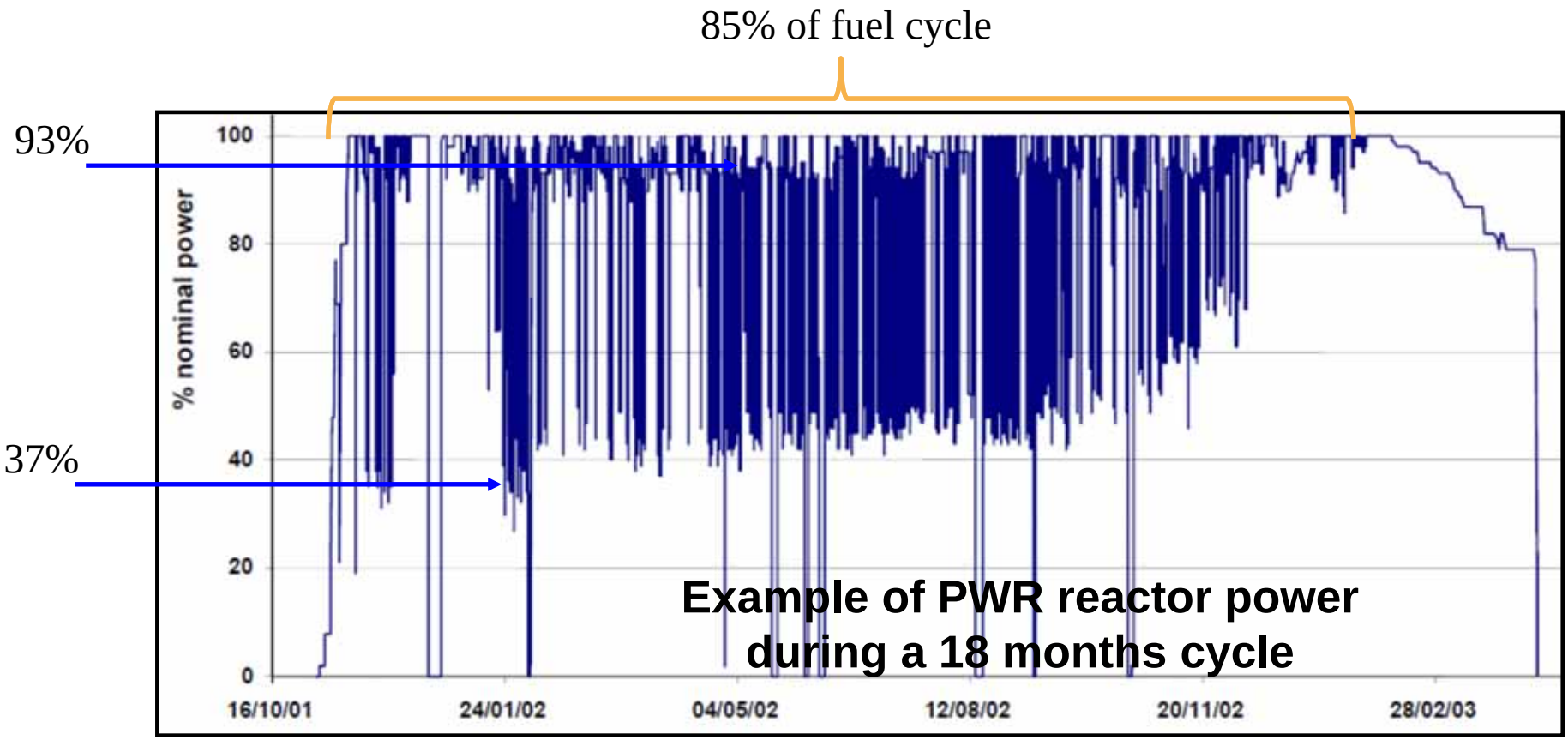
Primary/Secondary power control performed from 93% power:
2% margin for frequency compensation,
5% margin to secondary control.

Power variation (load-following) about 2-5%/min (25-65 MW/min)

Primary control: 1%/s (26 MW variation)

# Overview of study

Example of PWR fuel cycle with primary and secondary power control



# Fuel costs: Modelling 6 fuel cycles

Additional fuel costs. Different scenarios with ”unplanned” load-following were considered during one cycle followed by 5 ”normal” cycles:

1. Reference fuel cycle 100% power,
2. 1st fuel cycle 100% power but 20% shorter cycle length
   a) BWR
   b) PWR
3. 1st cycle operated at 60% power during first half of the cycle (BWR only)

Case 1: Reference case (72.94 EFPH/FA)

Case 2a: 5% cost increase

Case 2b: 17% cost increase

Case 3: 25% cost increase

Costs due to unplanned (forced) load-following:

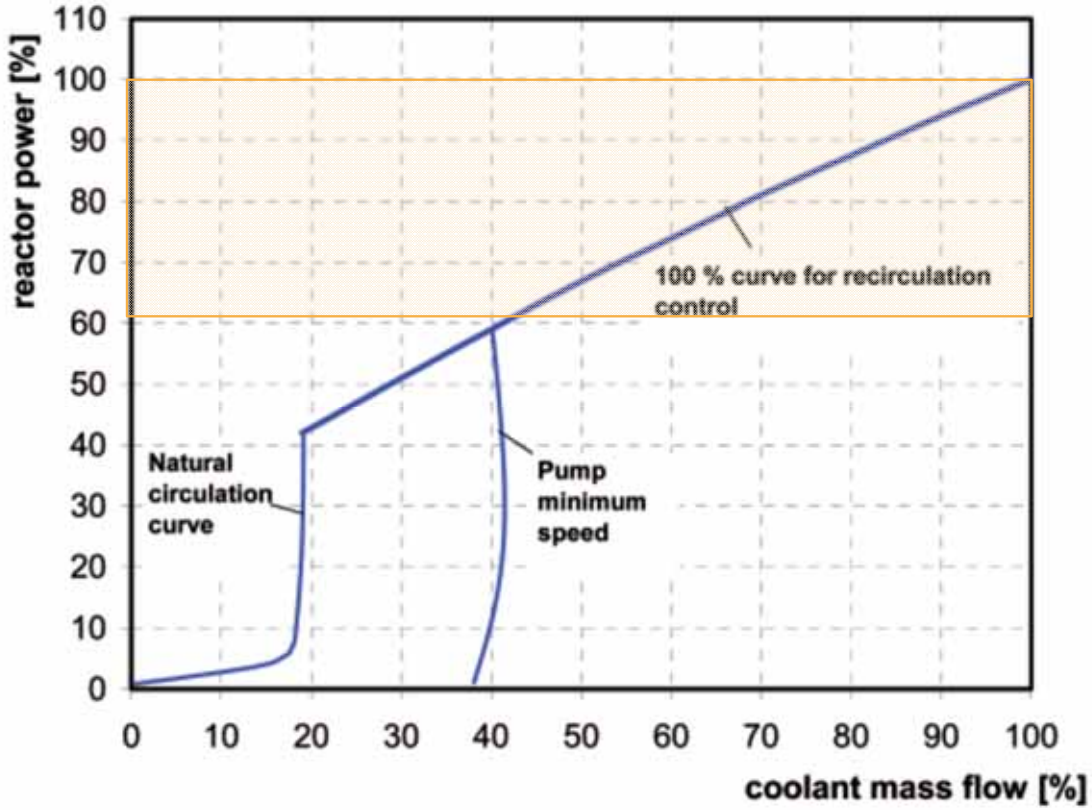
– The additional production cost for BWRs could be 1-5%.
– For PWRs, the additional production cost could be 4-7 %.

( Fuel costs account for about 20% of total production cost)

# Limited experience of load-following operation in Sweden

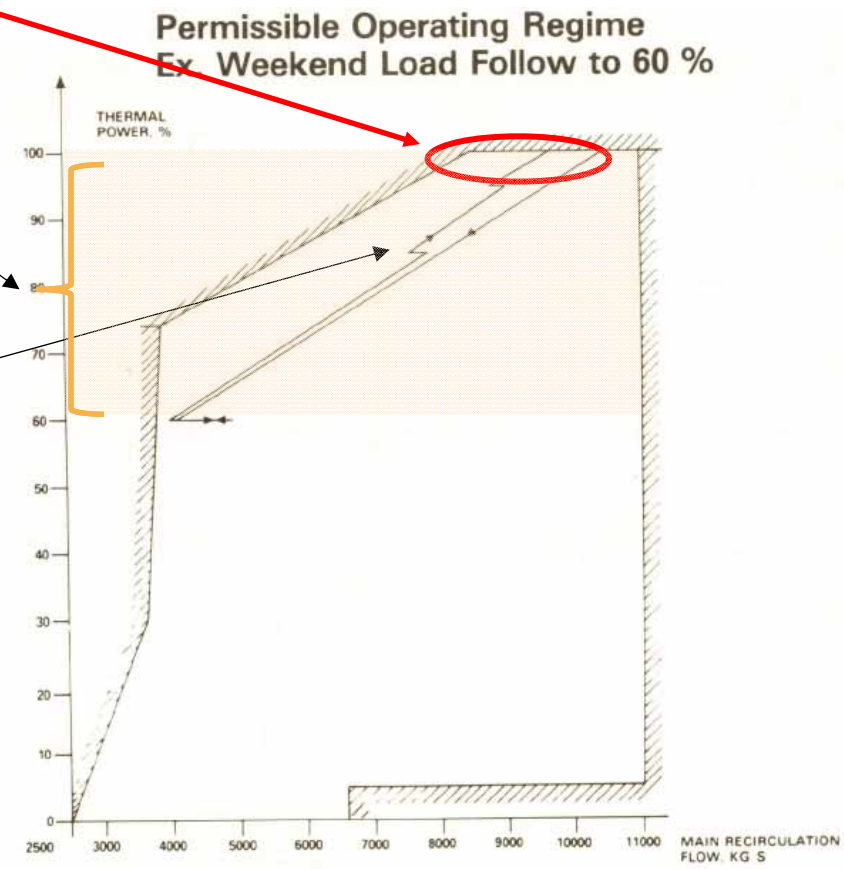
Swedish NPPs are co-owned: power decrease is compensated per MW to the other owners due to possible wear and tear.

BWRs are mainly power regulated by main re-circulation pumps (to 60-70% power).



# Load-following pattern, BWR

- The optimal working point cannot always be reached, resulting in lower turbine efficiency.
- The optimal (and less demanding) power range is 60-100% power.
- The power increase is hampered by new thermal equilibrium of fuel, xenon-poisoning, et c.
- Usage of several reactors in a fleet (to avoid larger power decreases).



# Risks

- Damaged fuel
  - Limits in operation and flexibility when having damaged fuel
- ”Under-loading” fuel
  - Would affect fuel cycle length and/or coast-down period.

  *With strong seasonal variations in the Nordic countries, outage is preferable in the summer, hence 11 month fuel cycles*
- Component wear
  - The power ramps need to be performed according to specifications to avoid wear.

  *As long as no design transient specifications (DTS) are ”used”, no risk of additional wear is seen*
- Increased risk of operational disturbances
  - Every change to steady-state operation could case disturbance

  *No indications of such situation has been given.*

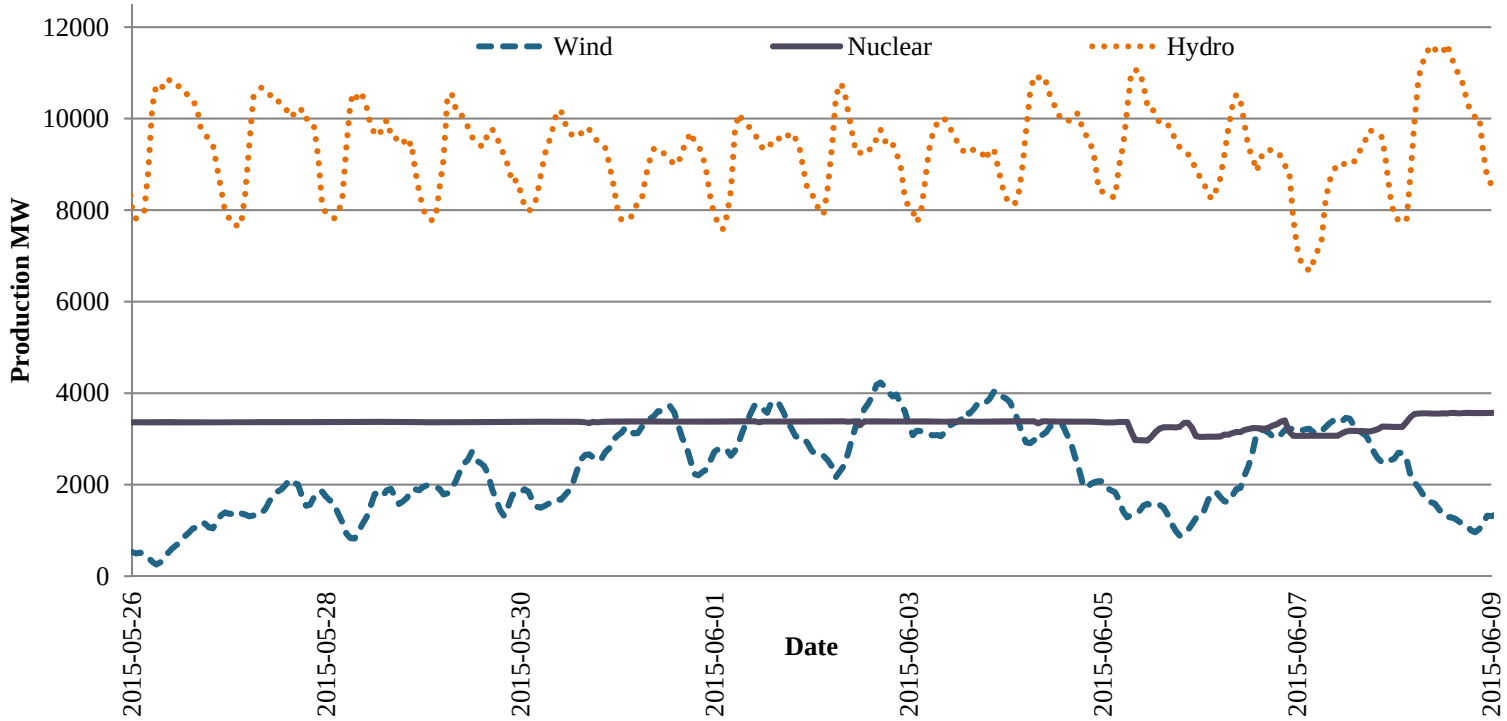
# Price areas in Sweden

- A large new intermittent power production, i.e., wind power that influence the power system and the market. Intermittent power production demands more regulating power.

- Therefore, can NPPs also provide flexible power production to the market such as primary and secondary control?

# Variation and wind power in Sweden

- The production from wind power 2010 was 3.5 TWh.
- The production from wind power 2014 was 11.6 TWh.
- In 2015, Sweden has 5.4 GW of installed wind power.
- Wind power production varies with 0 - 4 GW (se below).
- The consumption in Sweden varies during a normal day with 5 GW.



# Remaining issues

- How precise can power production variations be in present nuclear power plants?
- Examination of the NPP's possibility to deliver reactive power to the grid (voltage stability) and if this is affected by any mode of operation.
- Is this only hypothetical for old/present reactors? Is it feasible for new plants? Specific needs for BWRs and PWRs to be further studied regarding present NPPs.
- What are the manpower and competence needs for flexible power production? Possible constraints in operation during flexible power generation? (maintenance, safety,…)

# Thank you for your attention!

**Contact details:**

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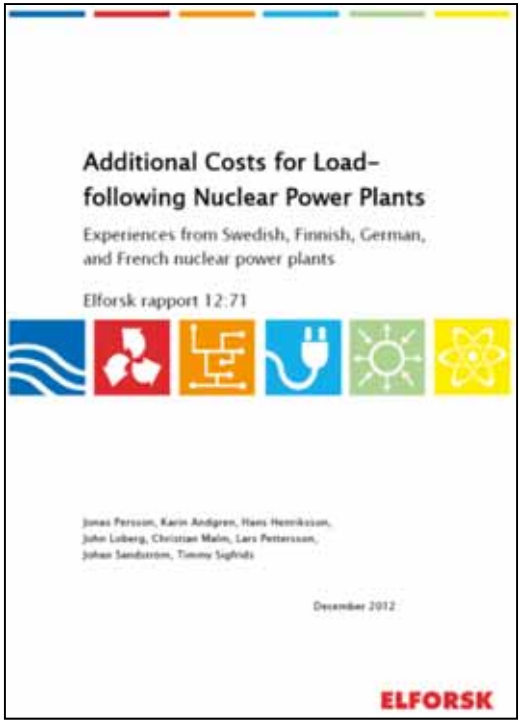
Additional Costs for Load-following Nuclear Power Plants

Experiences from Swedish, Finnish, German, and French nuclear power plants

Elforsk rapport 12:71

Jonas Persson, Karin Andgren, Hans Henriksson, John Lidberg, Christian Malm, Lars Pettersson, Johan Sandström, Timmy Sigfridz

December 2012

ELFORSK

Please read the report: Elforsk report 12:71

## Conclusions:

- Load-following would mean only minor additional operational costs. If planned properly, these costs may even be avoided.
- Fuel cost increase in unplanned situations (up to 4% increase of production price in a BWR). Slightly higher relative fuel cost in PWRs.
- No wear of components detected due to load-following
- Additional maintenance in control rod drive mechanism decreased availability (<1,8%) in France (due to primary control operation).
- It is recommended to use several reactors in series to avoid larger power decreases, below 60% nominal reactor power.