The future supply of electrical power to the ferroalloy industry

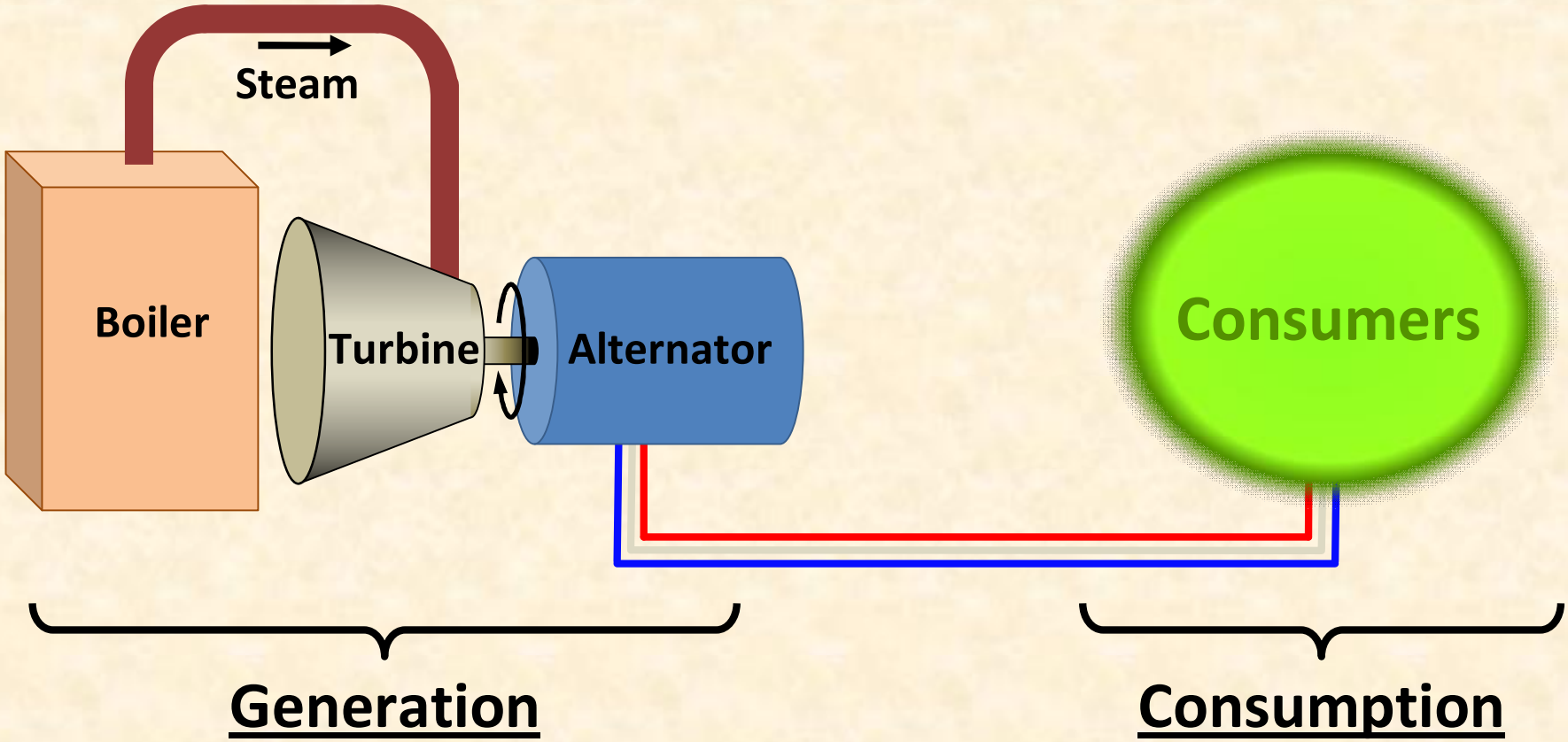
By I J Barker

School of Chemical and Metallurgical Engineering,
University of the Witwatersrand

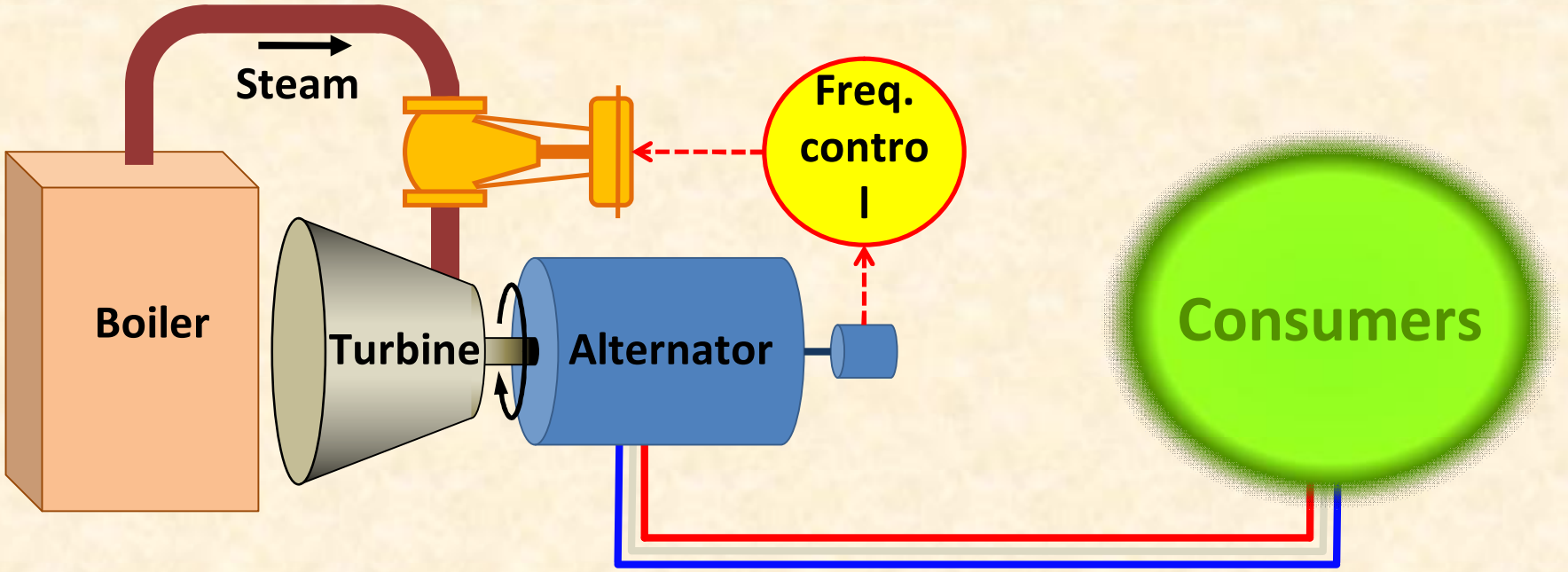
The future is coming...

- Big concerns about the future supply of energy
- Ferro-alloys use large amounts of electrical power
- How is the energy scene likely to affect the industry?
- What can we do now in preparation?

Basic present arrangement

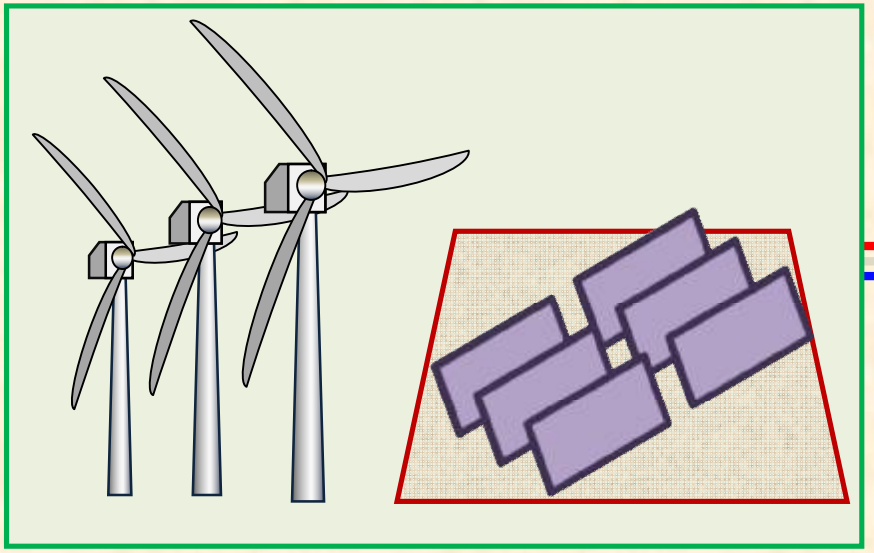


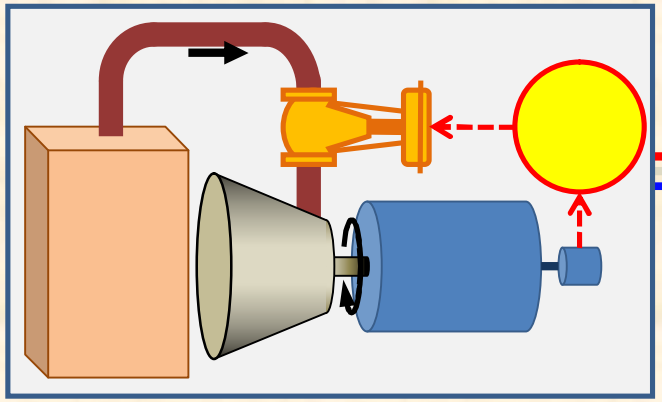
Adjustment for load variation



Typical variation of phase with time

Diversification of generation





Consumers

Consumption

Storage

Generation

Prognosis so far...

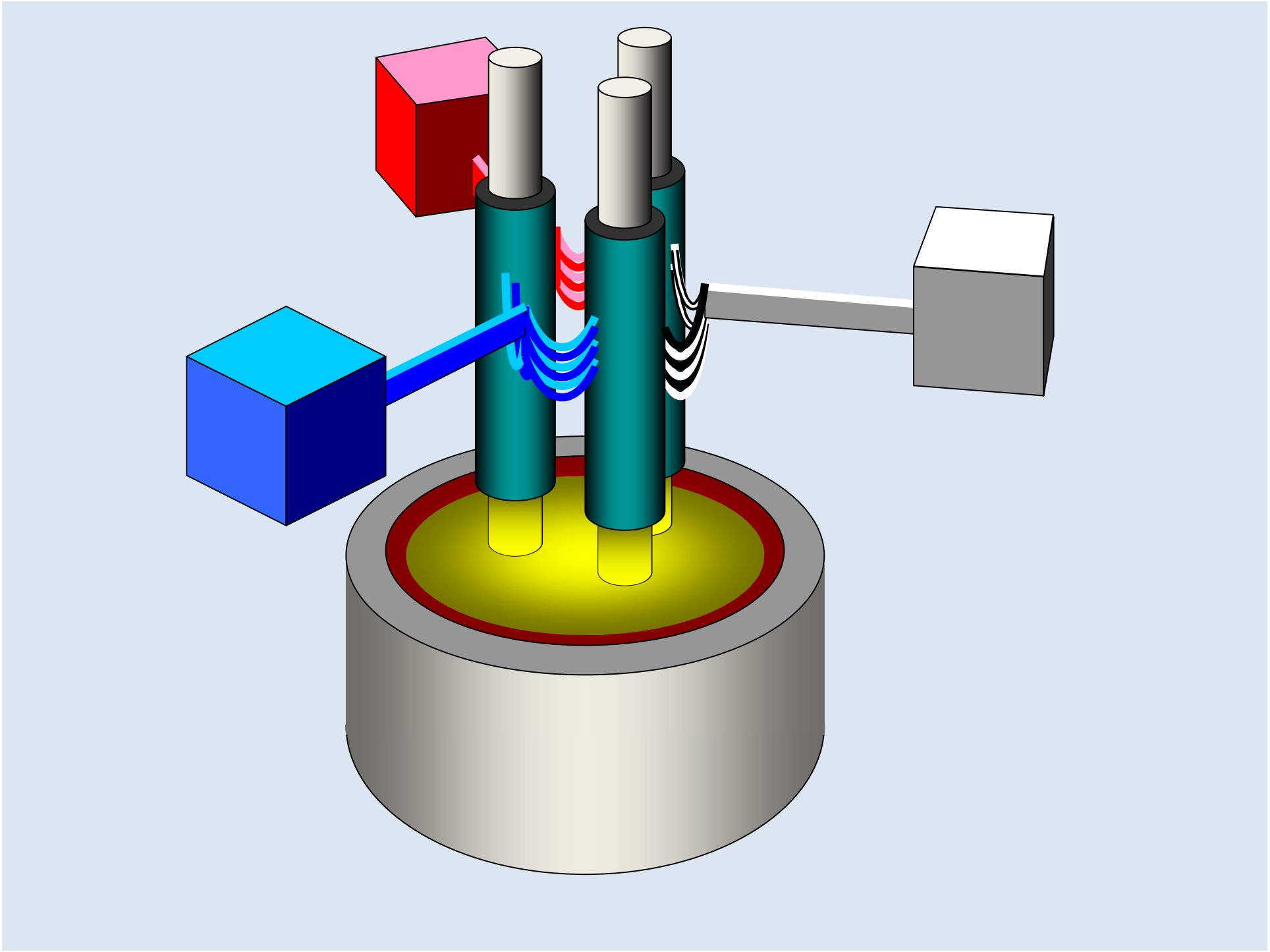
- There are going to be unavoidable variations in the quantity of electrical power available.
- Has *got* to be matched by variation in demand.
- There will have to be huge incentives to encourage users to adapt their demand. (Pricing?)
- Average prices will probably get higher.

Choices for the ferro-alloy industry:

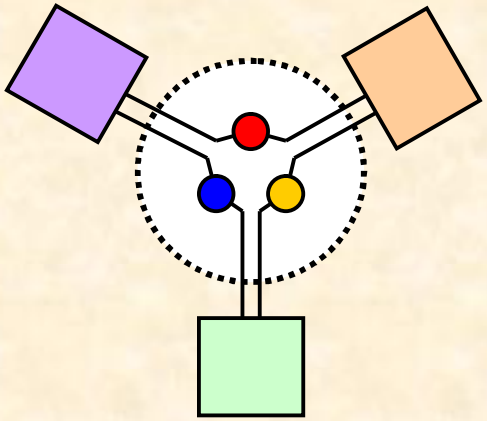
- **Carry on at a fixed level of demand & pay the resulting high prices.**

OR:

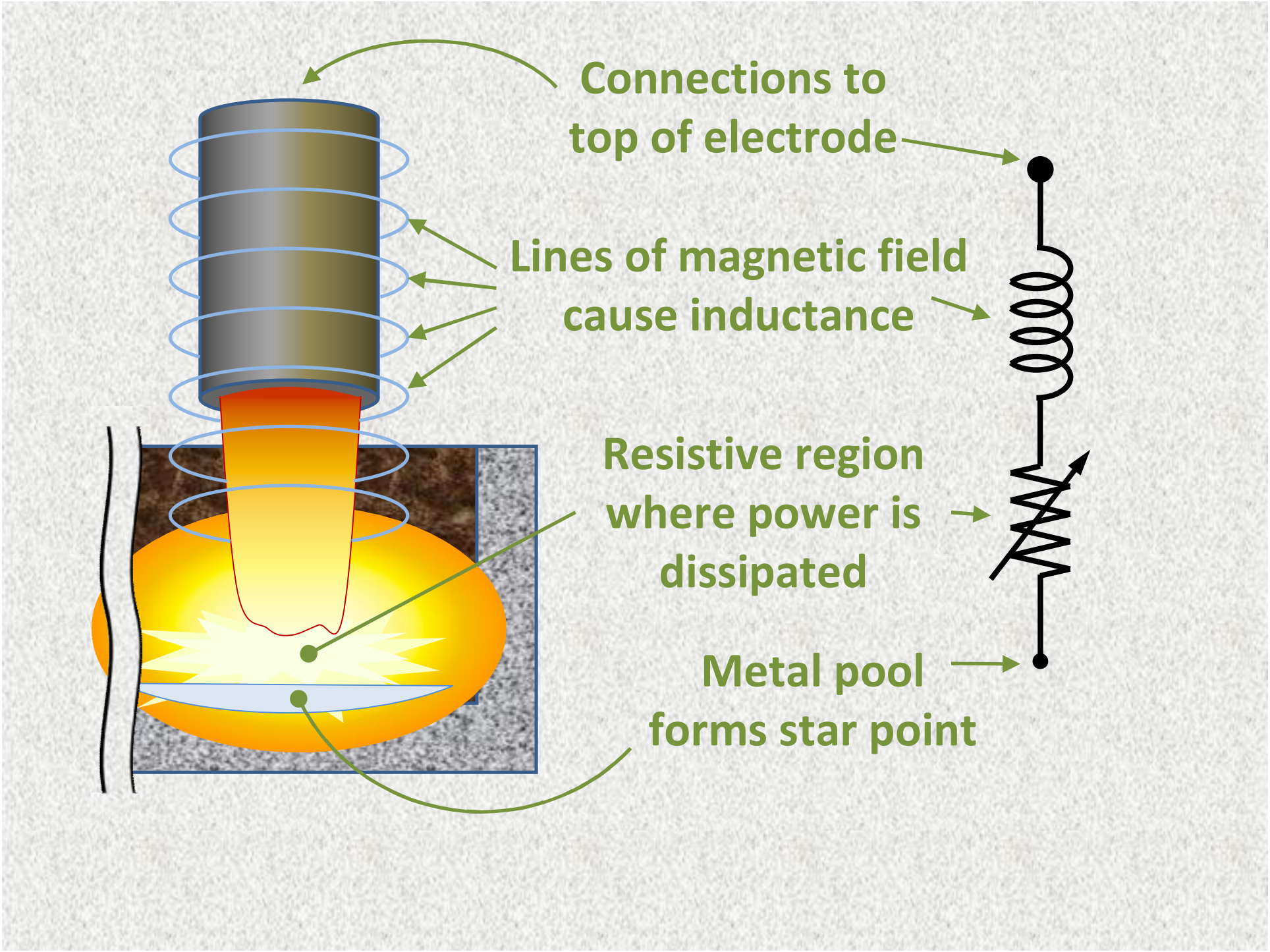
- **Evolve the technology so that plants can cycle between high and low levels of demand.**



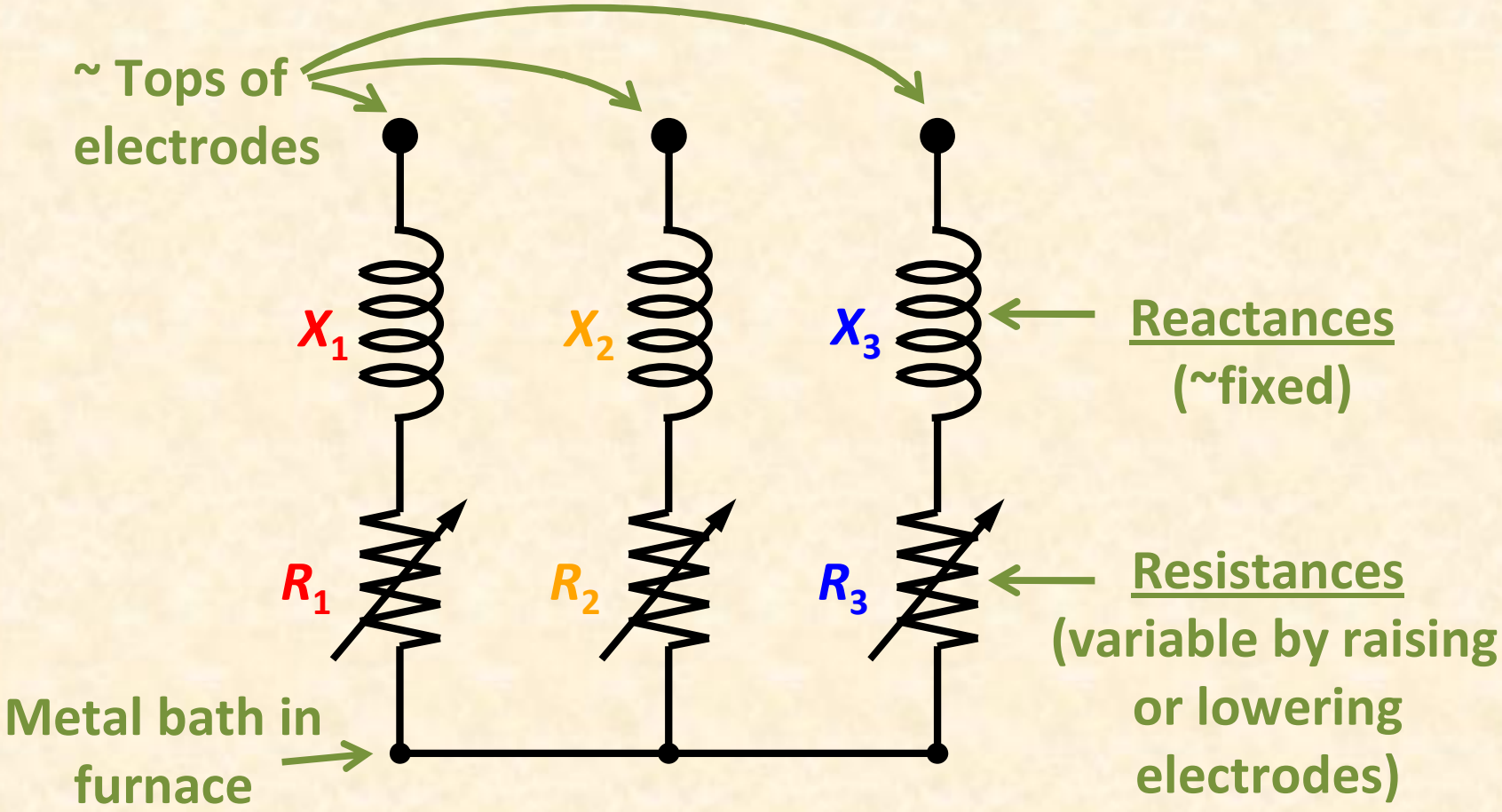
Problems with existing furnace design



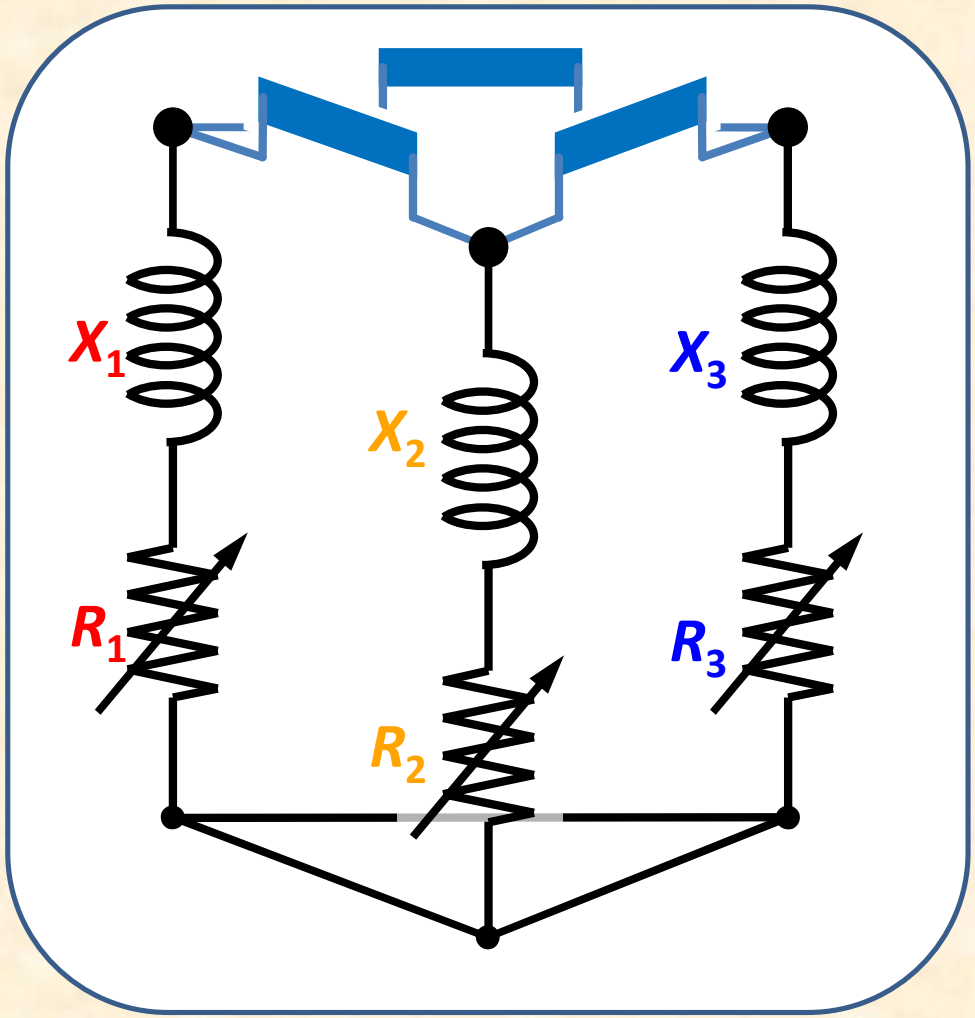
1. **Electrodes are highly inter-dependent (problem for 1 → problem for all 3).**
2. **Doesn't run at low loads easily.**
3. **Unwise to switch off for ≥ 3 to 4 hours (i.e. time *is* an issue; cannot take only a snapshot viewpoint).**
4. **Cannot scale up much beyond present largest units.**
5. **Present largest electrode size seems to be near limit (about 2.0 metres).**


Connections to top of electrode
Lines of magnetic field cause inductance
Resistive region where power is dissipated
Metal pool forms star point

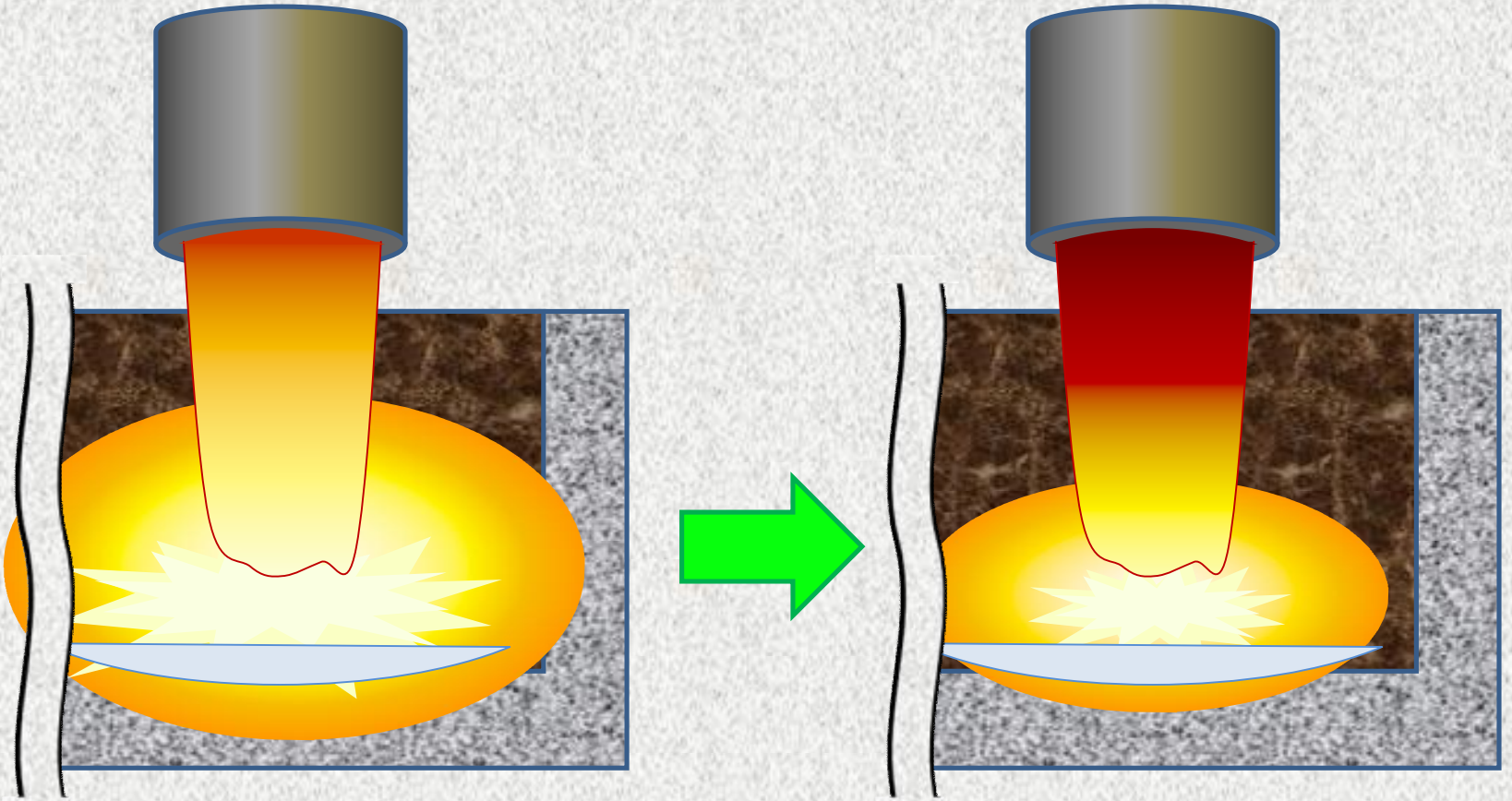
Equivalent circuit of furnace



Circuit connected to 3-phase power source

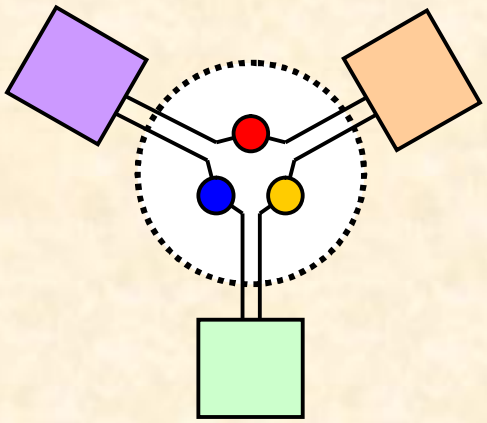


Turn down power level



One quick-fix solution:

= Turn off furnace for 2-3 hours at peak times.



- OK in existing power arrangements, but not if random.
- Can stagger the switch-off periods of the furnaces at a plant (but only if know the availability of electricity in advance).

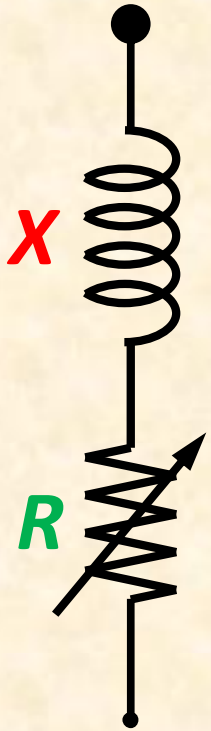
Circuit connected to 3-phase power source

As furnace size gets bigger:

- ***R*** **decreases,**
- ***X*** **increases.**

Eventually *X* dominates everything.

→ Leads to problems with furnace operation.



Duration of switch-outs

$$t \propto d^2$$

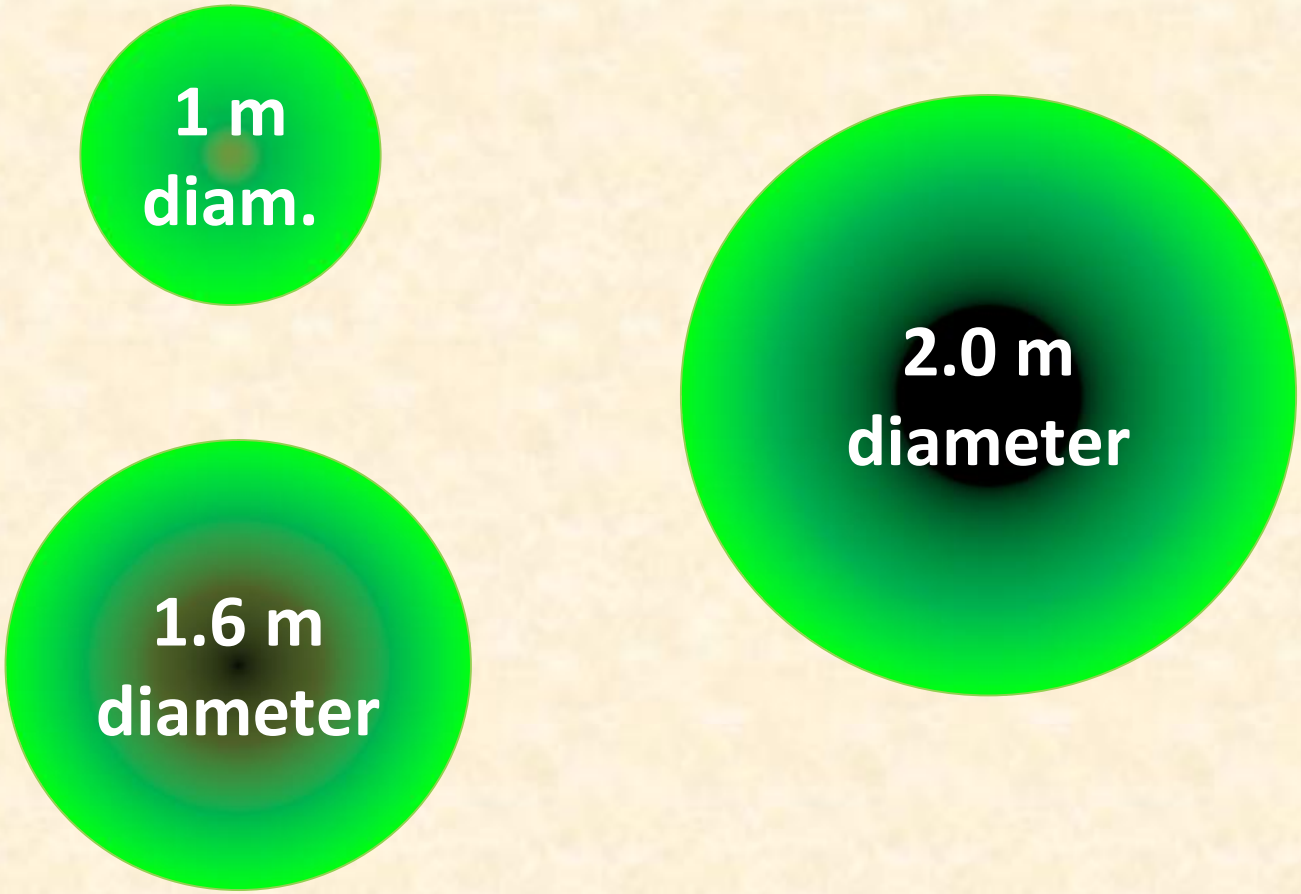
where:

t **= time for heating or cooling**

d **= diameter of electrode.**

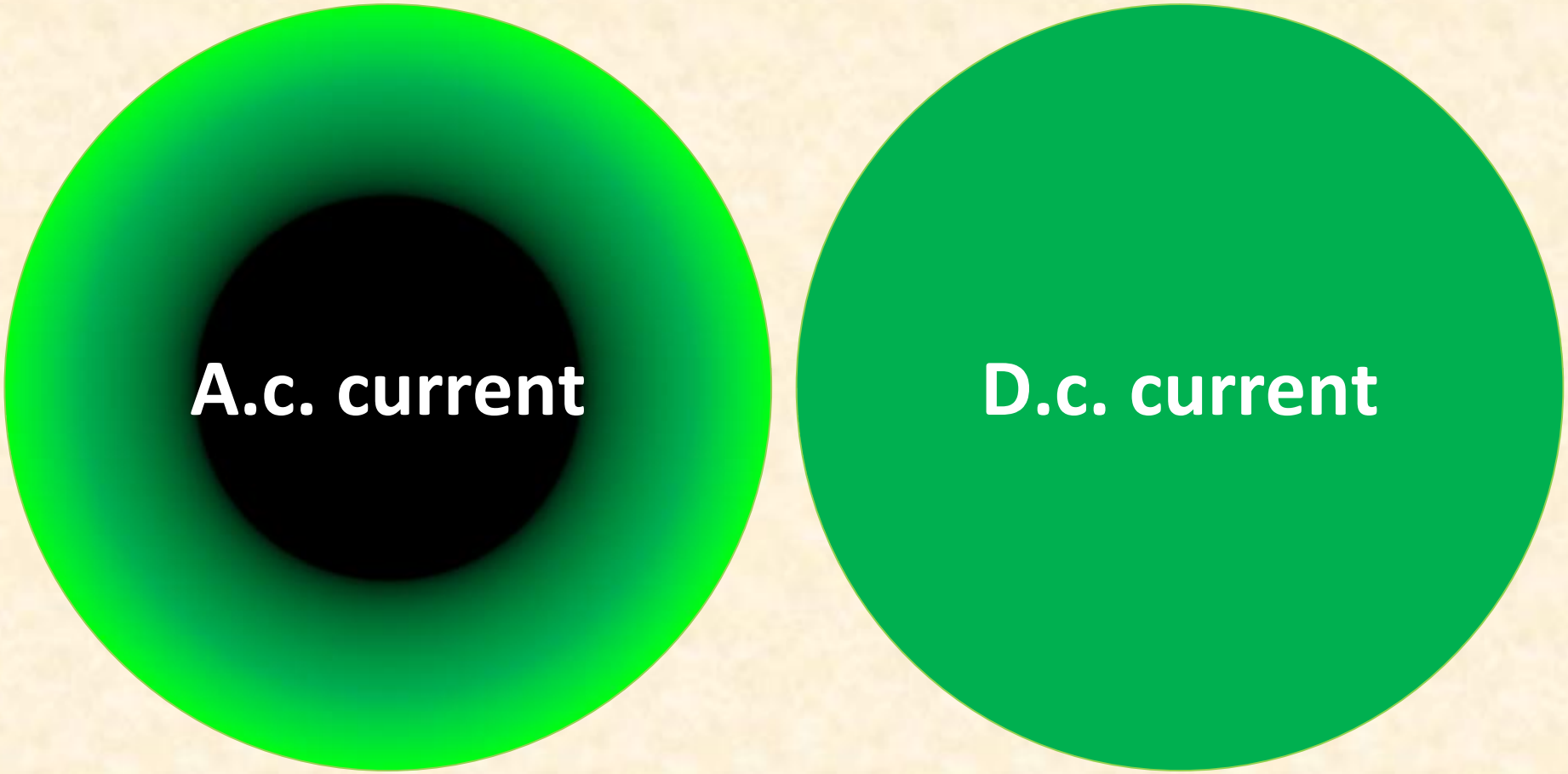
→ Would seem to indicate that big electrodes can be switched out for longer?

Skin effect in electrodes

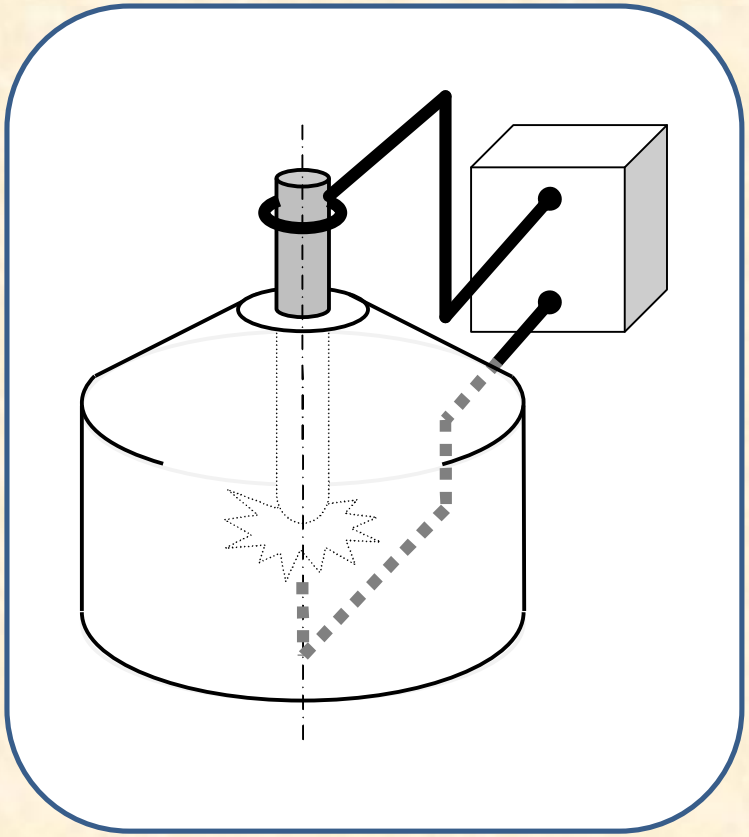


Skin effect: a.c. vs. d.c

For 3-metre diameter electrodes

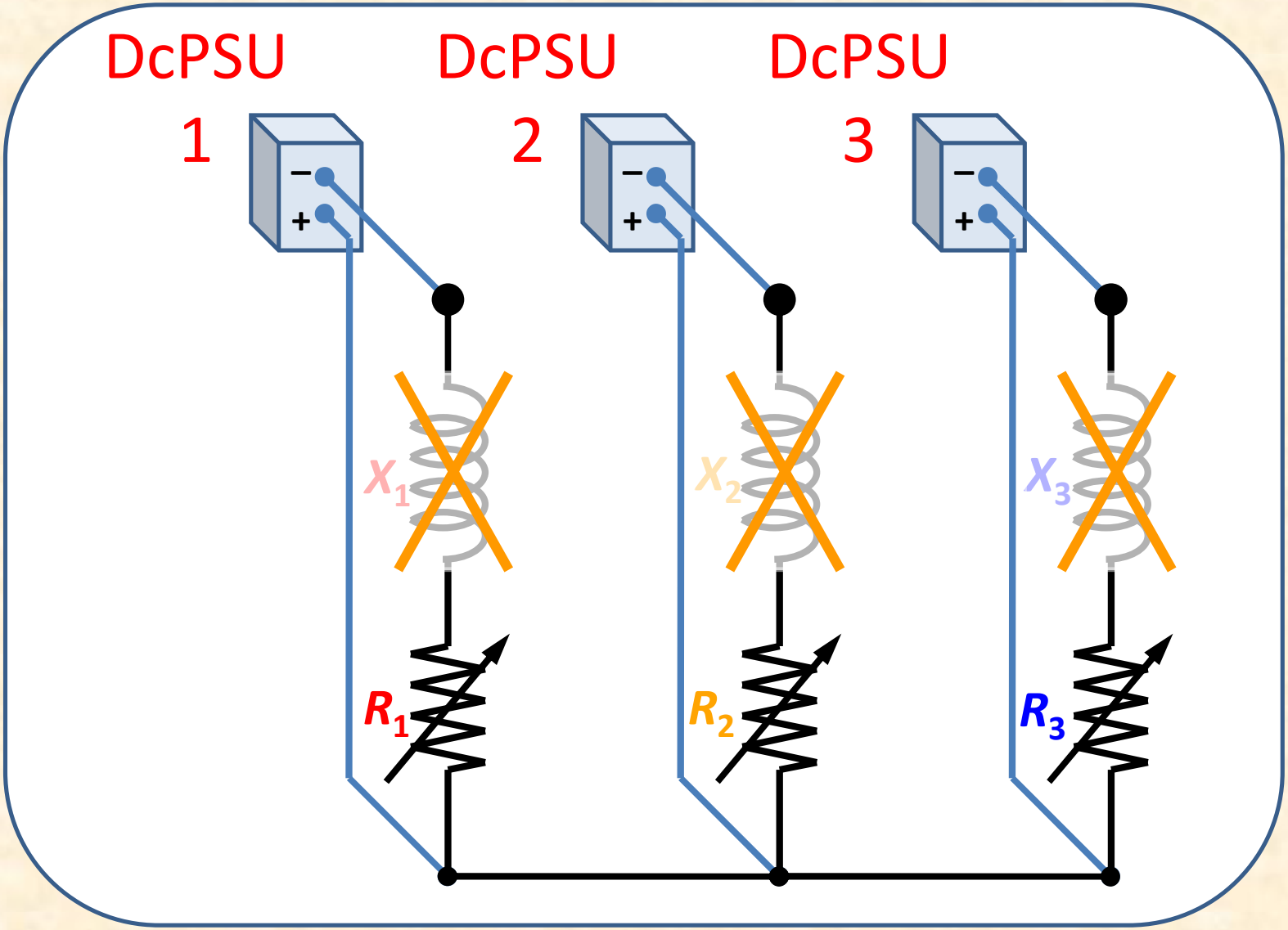


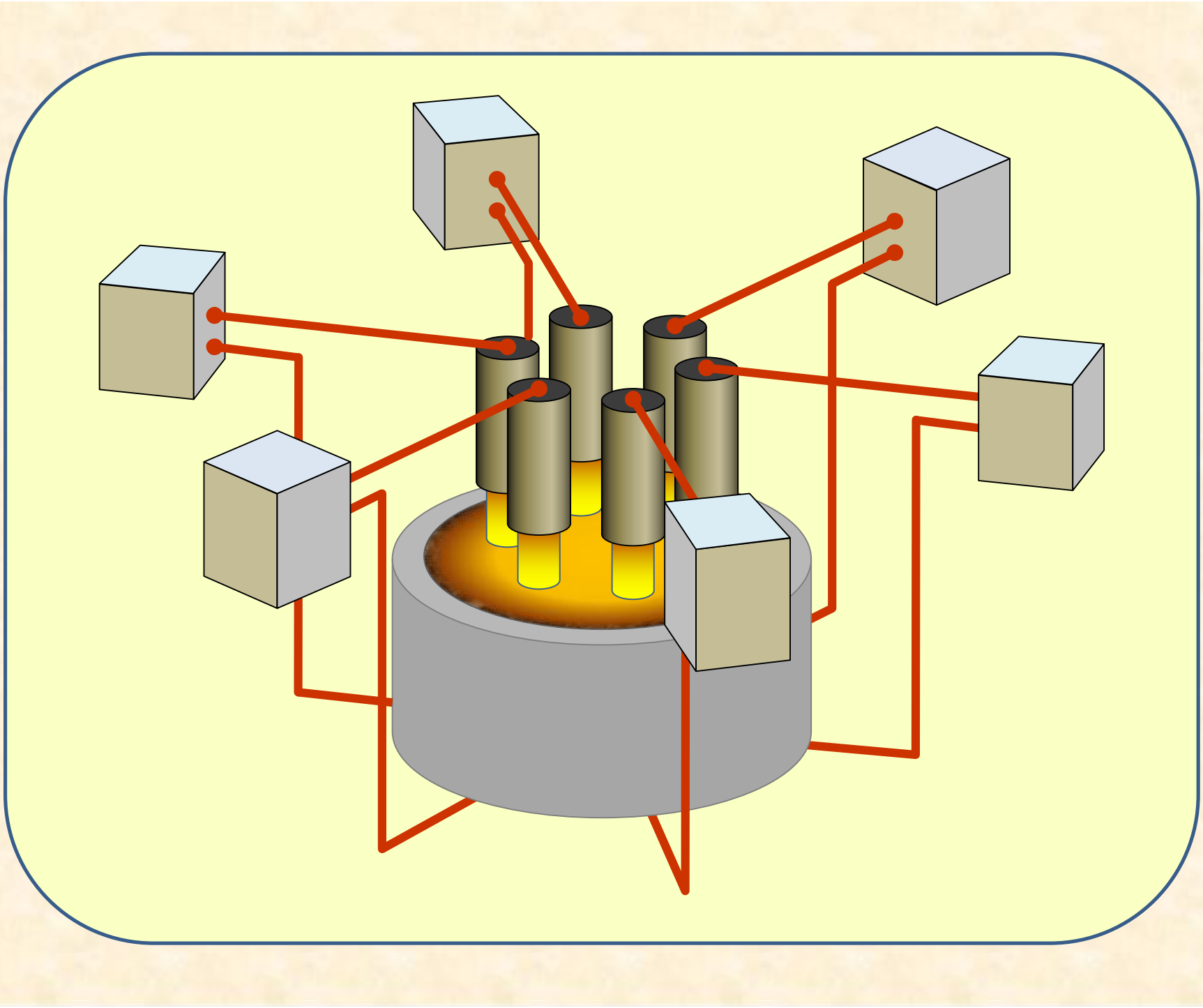
D.c. furnaces: some advantages



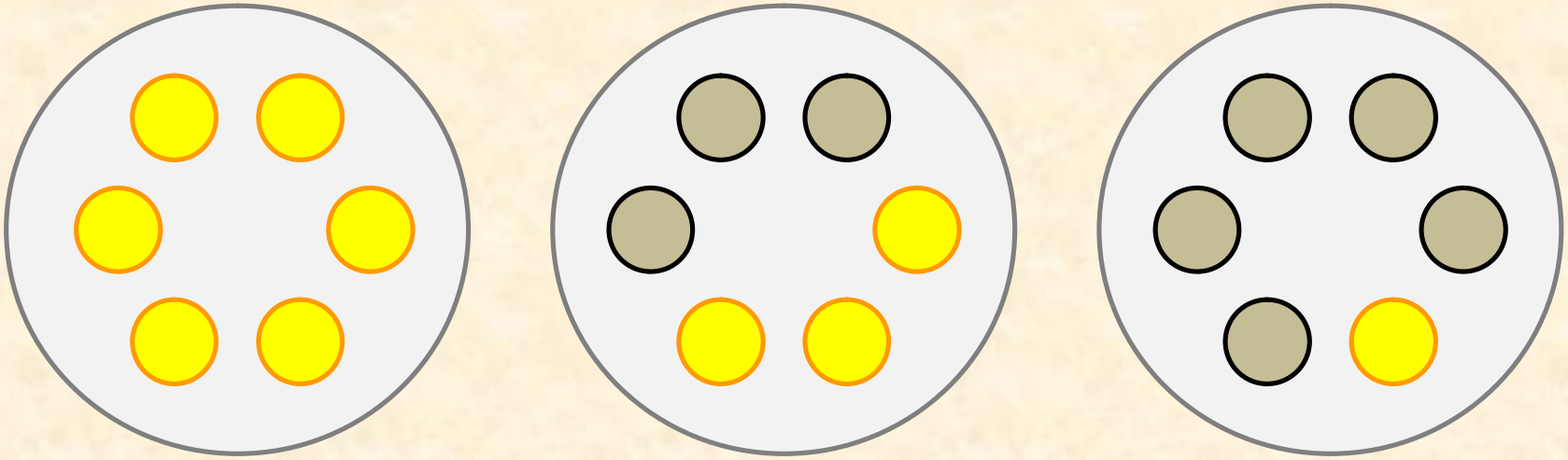
- One electrode on its own.
- No “skin effect”.
- Inductance not a constraint.

3 electrodes each fed d.c. separately:





Levels of switch out



Full power

Half power

1/6 power

Potential scale up

Existing 3-electrode a.c. furnace

- Electrode diameter = 1.6 m
- Resistance = 1.0 mΩ
- Electrode current = 100 kA
- Total furnace power = 30 MW

Large 6-electrode d.c. furnace

- Electrode diameter = 3.0 m
- Resistance = 0.5 mΩ
- Electrode current = 250 kA
- Total furnace power = 187 MW

Conclusions: (a) General

- **Electricity costs are likely to increase dramatically, & availability of supply will become more variable.**
- **We are going to have to find ways to vary the level of electricity demand, or we will have to pay high prices.**
- **Matching supply to demand won't be simple:**
  (1) Political issues,
  (2) Control & feedback concepts not well understood by the general public,
  (3) Time is an issue, in particular the prediction of the immediate future,
  (4) Transmission over large distances.

Conclusions: (b) Ferro-alloys

- **Existing 3-electrode 3-phase a.c. arc furnaces are not really suitable.**
- **One option = multi-electrode d.c. furnaces.**
- **(Another option = solar furnaces?)**

Conclusions: (c) D.c. furnaces

Multi-electrode d.c. furnaces would seem to offer several advantages:

- **Each electrode is independent, so any operating problems won't progress into a full furnace upset.**
- **Can swing load over a much wider range.**
- **Potentially very large electrodes (good for scale-up and for longer switch-offs, but actual viability still to be checked).**
- **More electrodes: particularly 6 in a circle (also good for scale up).**
- **An avenue for scale up to very large furnaces (up to about 200 to 300 MW) → advantages of scale.**
- **Easy progression from existing a.c. furnaces.**

Conclusions: (d) Route of progression

1. **Check technical details (e.g. simulation of large electrodes with d.c. current, high-current power supplies, etc).**
2. **Convert an existing 3-electrode a.c. furnace into a 3-electrode d.c. furnace.**
3. **Develop a supervisory control system to handle a varying load on this furnace.**
4. **Convert an existing *large* 3-electrode a.c. furnace into a *6-electrode* d.c. furnace.**
5. **Scale up from there progressively.**