Problem Solving in Computer Science

A course dedicated to PhD students
and to research-oriented Master students

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Course Objectives

- hone the problem solving skills of young researchers in computer science.
- explain the "research enterprise" in computer science to beginning doctoral students.
- apply the creative and scientific skills of the participating students to an embedded system engineering problem.

Course Organisation

Three interleaved parts

- 3 group projects (size 3-4) of 3 weeks length each.
- Lectures and exercises on
  - How to define a problem.
  - How to write a proof.
  - How to write a paper.
  - How to have a career in academia.
  - How to referee a paper.
  - How to give a presentation.
- Design of a common engineering artefact.

Lecture contents

- **How to formally define a problem.**
  - imprecise description in mind
  - neccessary to explain problem in paper/thesis
  - enhances understanding
  - eases finding solution & explanation

- **How to write a proof.**
  - claims must be proven
  - proofs must be correct and complete

- **How to write a great research paper.**
  - convey your idea from your head
    to your reader's head
  - language and style

Lecture contents (cont.)

- **How to have a bad career in research/academia.**
  (and alternatives)
  - writing tactics
  - selecting topics
  - performing the research

- **How to referee a paper.**
  - quality control
  - ethics
  - common dilemmas
  - judge technical writing

- **How to give a good research talk.**
  - what to say
  - visual aids
  - giving the talk

Group projects

- driven by final engineering design problem
- comprise foundational and practical aspects
- exploit
  - research interests
  - organsation talents
  - team spirit

Engineering design problems?

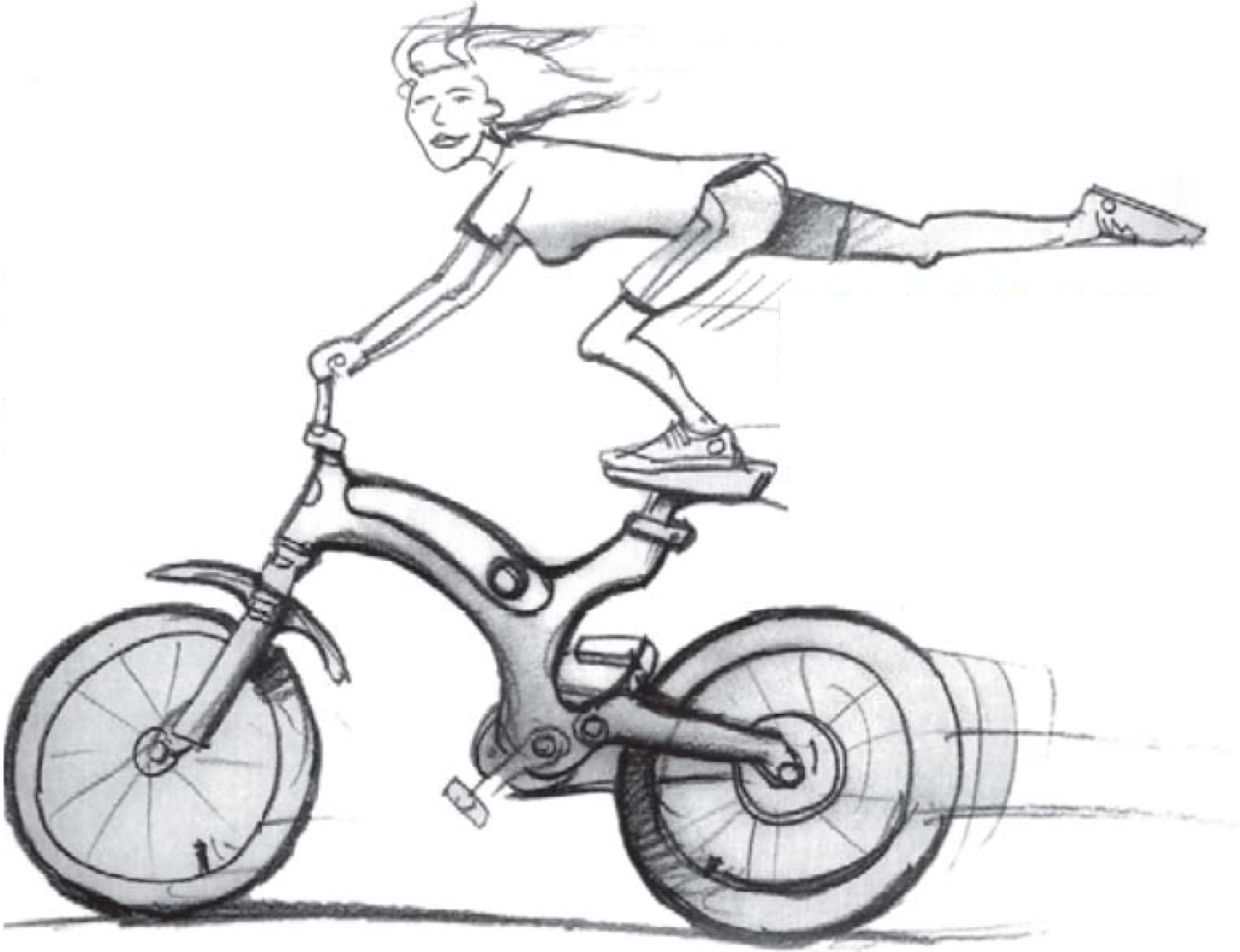
It‘s all about energy

and about embedded systems

A large embedded system design problem

A large embedded system design problem

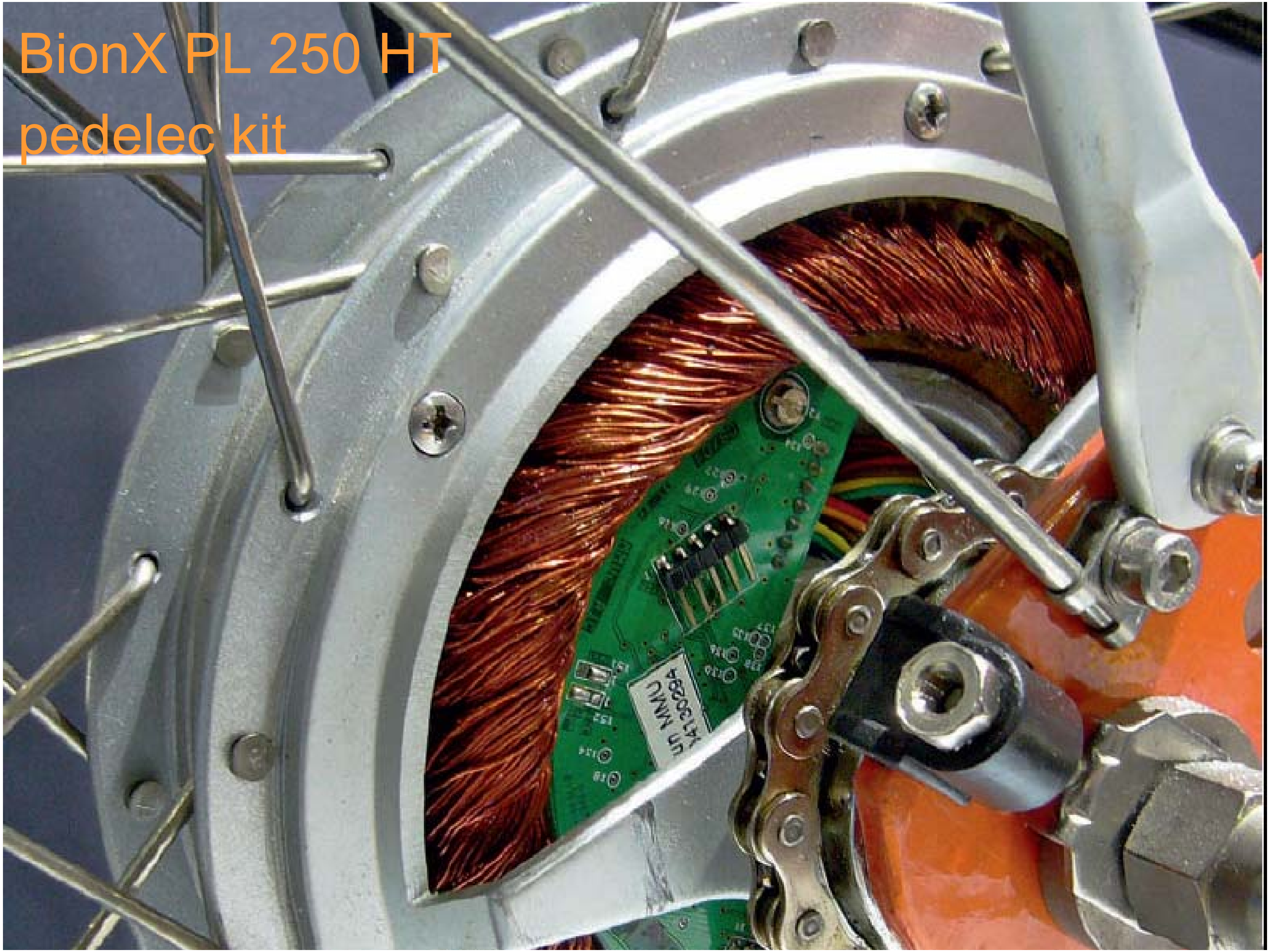
A small embedded system design problem



Pedelecs

Pedal assisted electric bikes

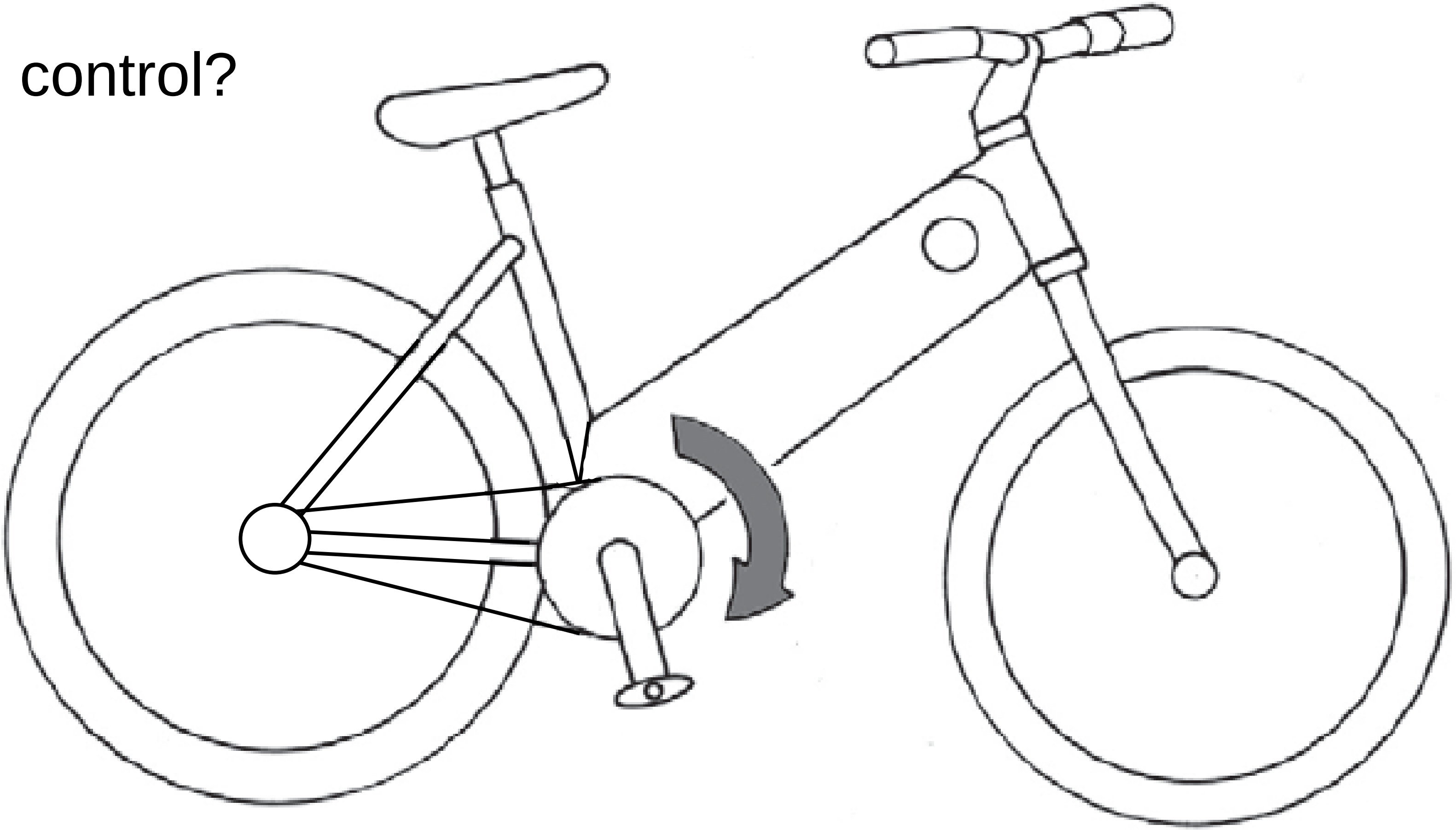
BionX PL 250 HT pedelec kit



A small embedded system design problem: Pedelec

- Where to put the components
  - Motor, battery pack, control unit, sensor

- How to control?



Next Generation

A small embedded system design problem: Pedelec

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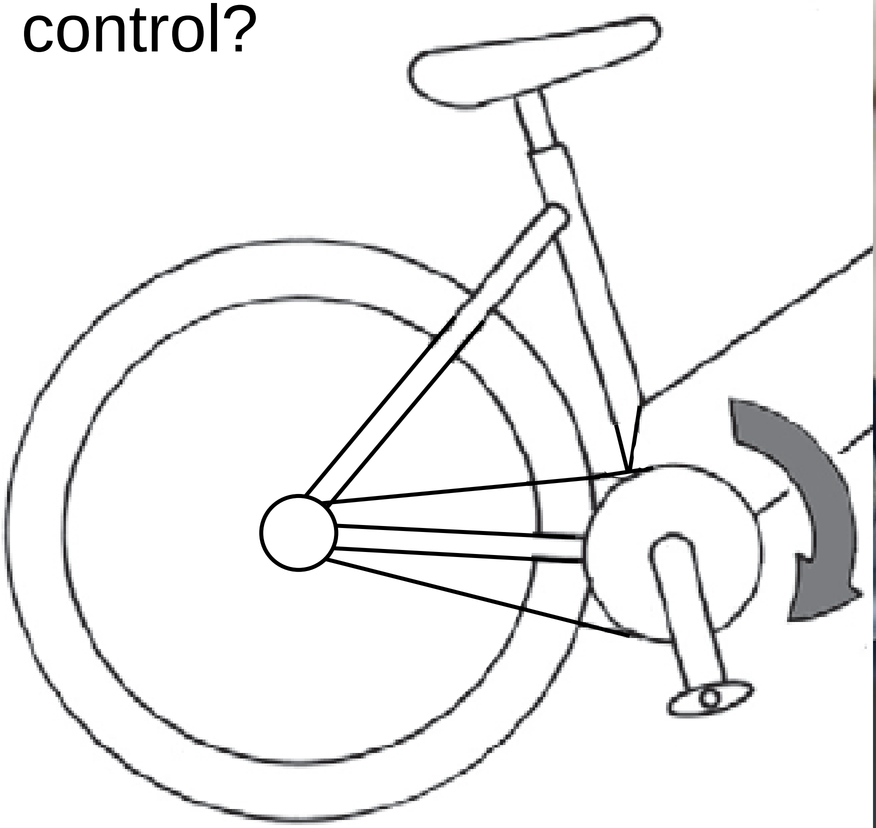
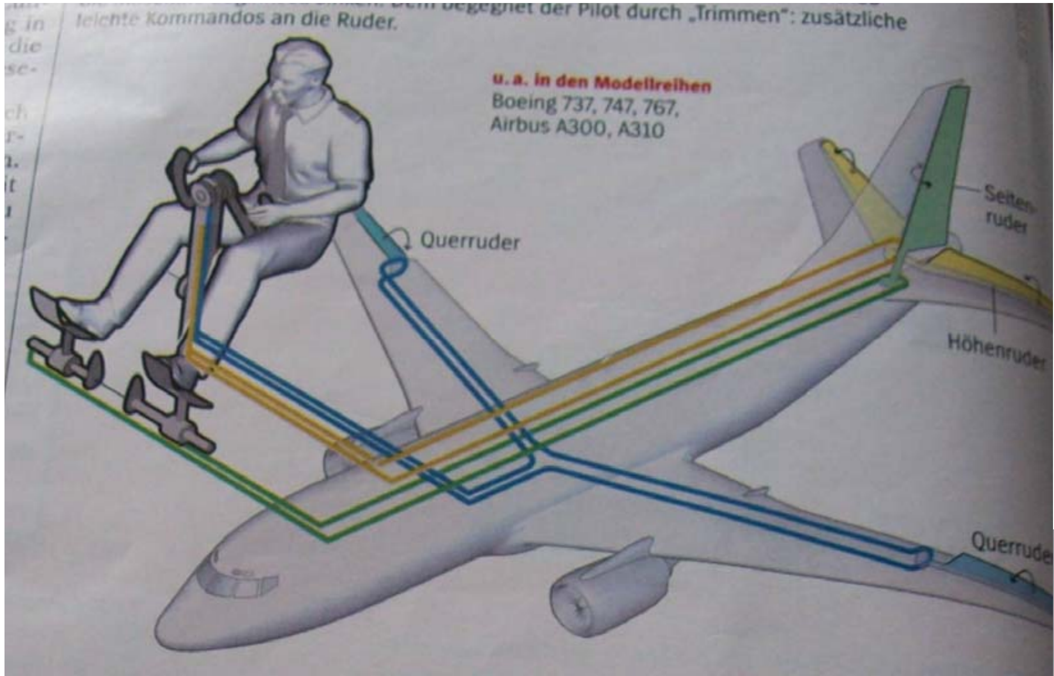


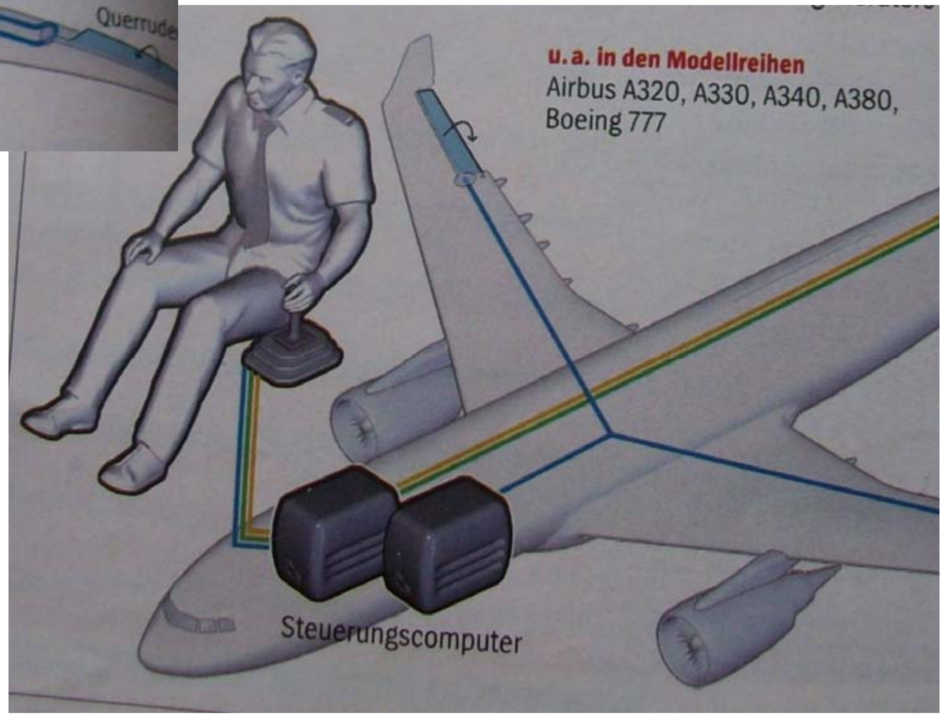
- Bye-Bye-Wire Bike!

A large embedded system design problem revisited



hydraulic

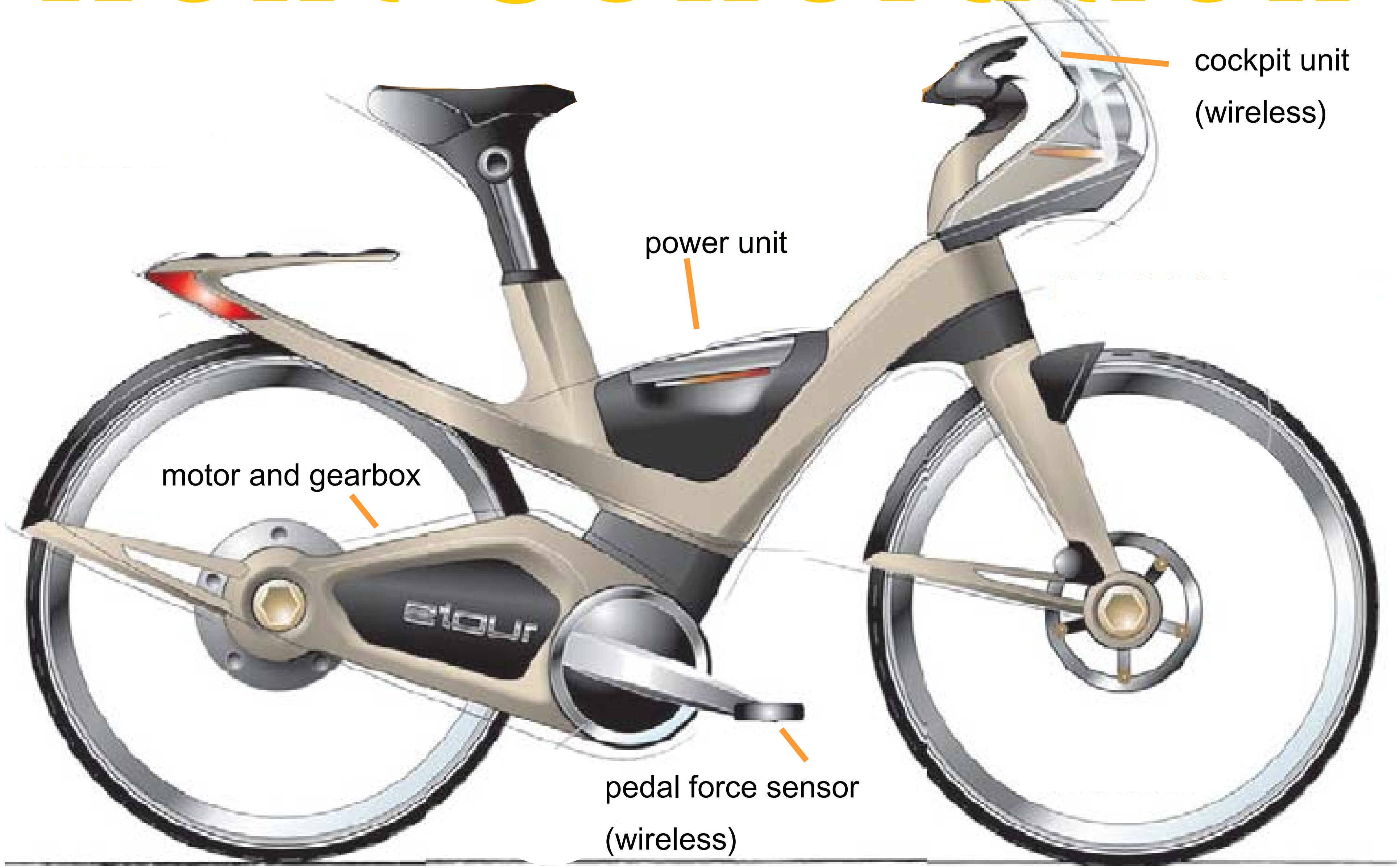
control



fly-by-wire

Shimano Dura Ace 7970 electronic gear shift

Next Generation



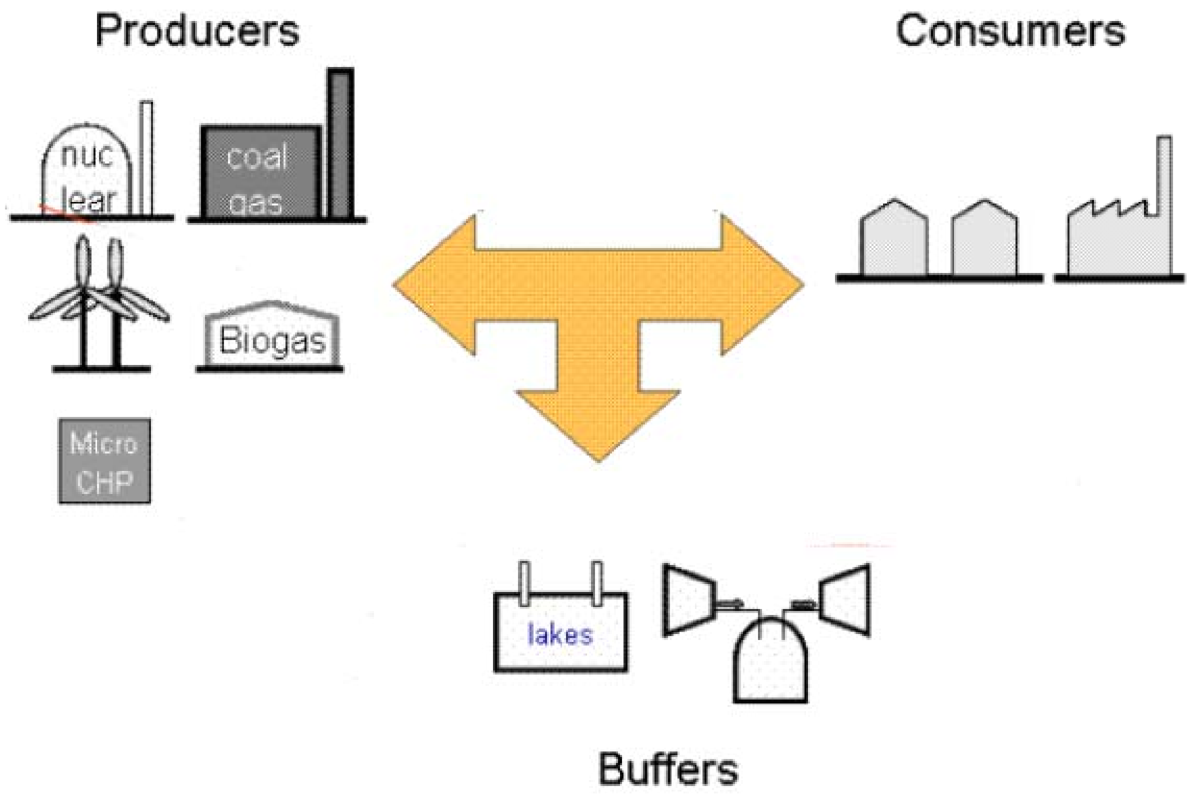
Another large embedded problem

A large societal problem

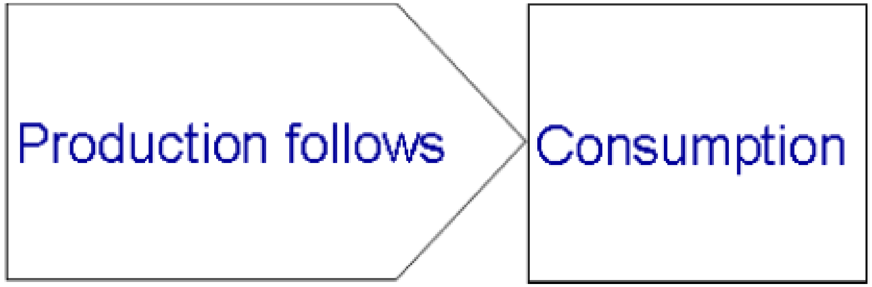
Principal Electricity Market Participants

Producers
 - thermal:
      nuclear,
      gas,
      coal
      cogeneration of
                heat/power

- renewable:
      wind, solar, biogas,
water
      geothermal



Principal Electricity Market Considerations



Production follows Consumption

Base assumptions:

- the electricity demand never exceeds the potential offer

- the producing entities are fully controllable

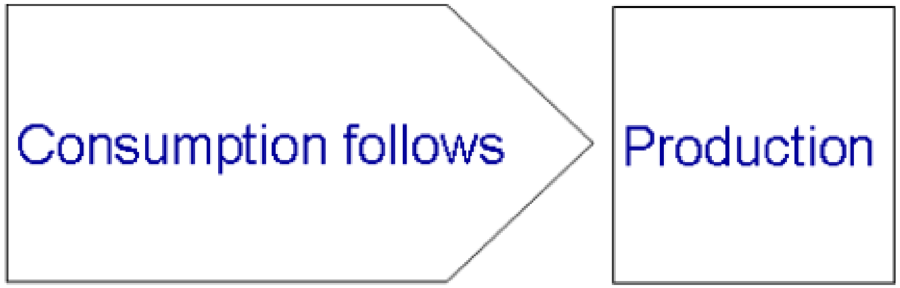
Features:

- barely any regulation on the consumer side

- producers are structured and coordinated in such a way that they satisfy the fluctuations in demand.

- consumers are charged for the costs incurred by the energy they consume

Principal Electricity Market Considerations



Consumption follows Production

Base Assumptions:

- electricity can only be consumed if it is available

Features:

- production entities are hardly controllable

- frequent interruptions of energy availability on the consumer side

- often comes with the allocation of electricity quotas to consumer

- mechanisms to control the consumer side characteristics

Principal Electricity Market Considerations

Production follows → Consumption

How?

Example: Germany

- currently divided into 4 so **control areas.**

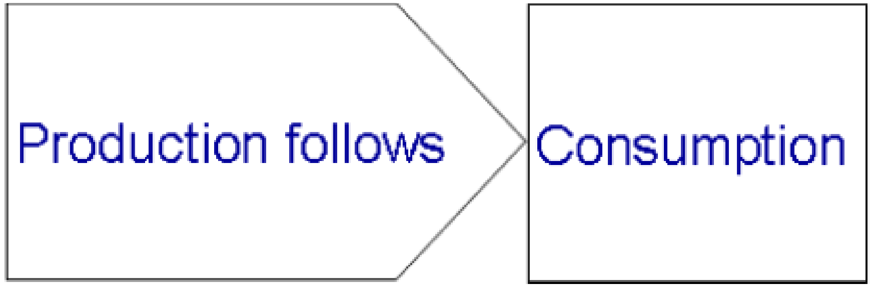
Inside a control area, traders and network users form so-called **accounting grids**.

Each consumption and production unit belongs to a single accounting grid.

Each grid has a responsible **grid coordinator** who interfaces traders and users.
Prime responsibility: maintain the electricity flow inside the grid in balance.
Deviations need to be corrected within pre-specified time bounds

Accounting grids are tightly interwoven by physical entities (cables, transformers) so they form a virtual structure on top of the electricity network.

Principal Electricity Market Considerations



How does the grid coordinator act?

- based on daily load schedules that each grid coordinator has to announce
(at 14:30 the latest for the following day)

- load schedules can be adjusted on an hourly basis with a 3 hours deferral period,
unless network bottlenecks result.

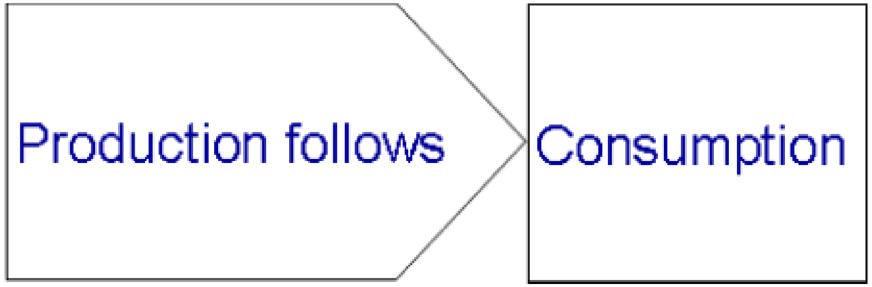
- implies that the grid coordinator
  - needs to forecast the aggregated expected consumptions in his grid,
  - must match this consumption with production capacities
(bought on the stock market, or produced in power plants),
scheduled on the same timeline.

This balance is essential for stable and reliable network operation:

Overprovisioning (or underconsumption) results in frequency drops,
underprovisioning results in frequency jumps.

Too excessive frequency deviations : malfunctioning on consumer side.
chain reactions may lead to network collapse ('blackout').

Principal Electricity Market Considerations



How does the grid coordinator act on short term?

- use of the concept of **control energy**.

  - electrical power that can be added to or substracted from a grid by the grid controller almost instantaneously.

Technically often realised with the help of pump-storage plants
subtraction amounts to pumping up water
addition turns water downflow into electrical power

about 10% of peak consumption.

Control energy can be traded across grids,
this is a characteristic feature to maintain stability on the German market.

Notably, there is a considerable energy loss because of ineffectiveness of pump-storage.

So, what's the challenge?

The integration of renewable energy.

Renewable energy production has a drastically higher volatility and this volatility is uncontrollable.

This asks for increased efforts related to network stabilization.

The drastic increase in volatility will at some point excess the available control energy.

To say it strikingly:

A squall on the north sea might blow out the lights in Palma.

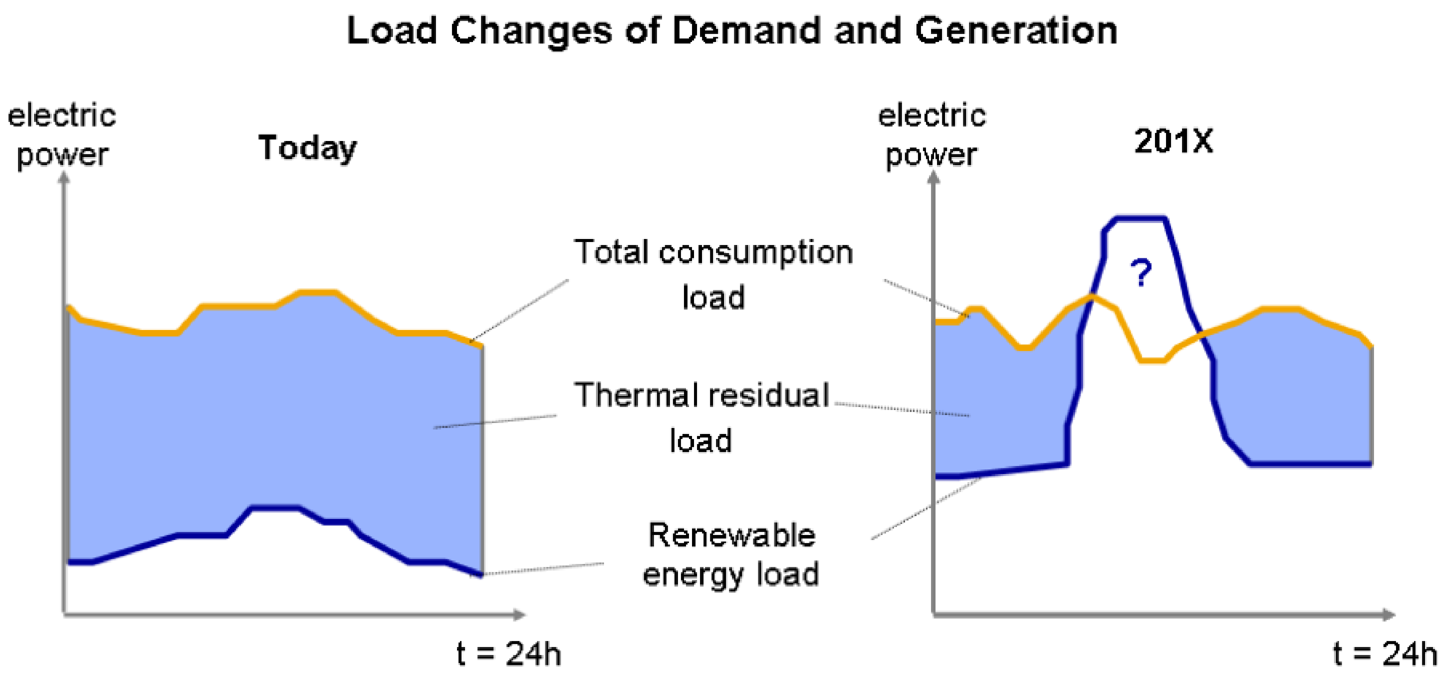
similar to what has happened on November 4, 2007 in large parts of Europe
after a manual shutdown of a landline in northern Germany.

The main focus of this presentation is not on network stability.

It is about the changes needed to address the upcoming challenges
which are related to economic energy usage.

Challenges for Economic Energy Usage?

Increase in renewable energy induces
- volatility effects on the stock market pricing for short term electricity,
- change in workload characteristics of traditional, thermal power plants.



So far: base load power plants have low marginal costs
should operate most suitable all the time (running river, nuclear or lignite fired).

Concerns:

- What happens in situations when renewable energy production is higher than total consumption?

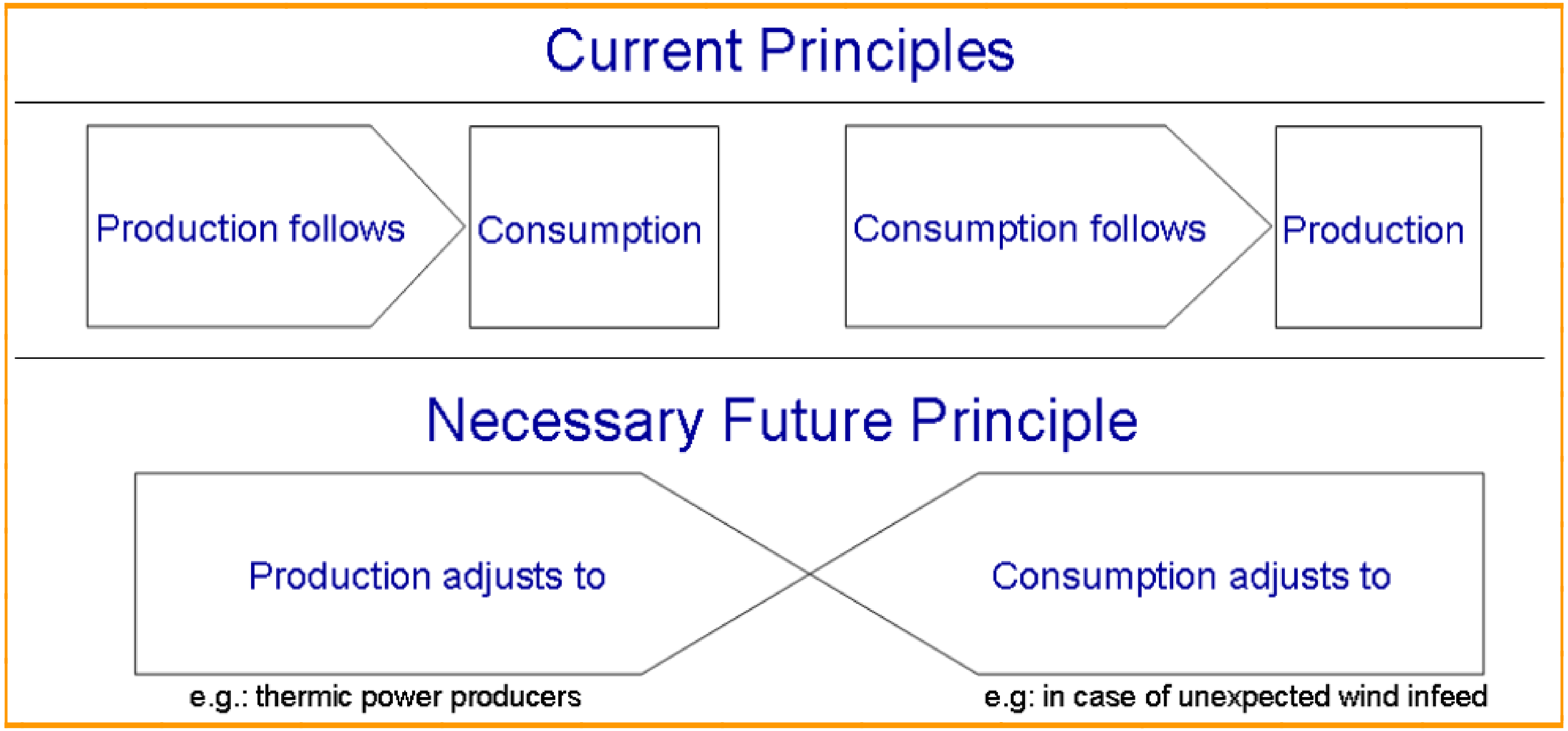
- What production entities are needed,
if all the base consumption load is covered by renewable energy?

Challenges for Economic Energy Usage?

Our claim:

Economical and ecological reasons will dictate a shift away from the

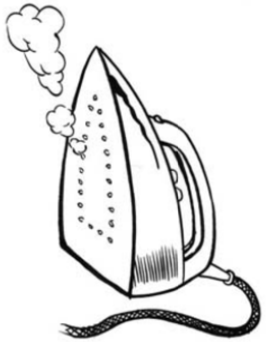
Production follows consumption principle.



What to Control on the Consumer side?

~~Light bulbs?~~

~~Ironing?~~



~~PC?~~

~~TV?~~

Electrical water warming?

Climate control?

Cooling control?

Air pressure applications?

Off-peak storage heating?

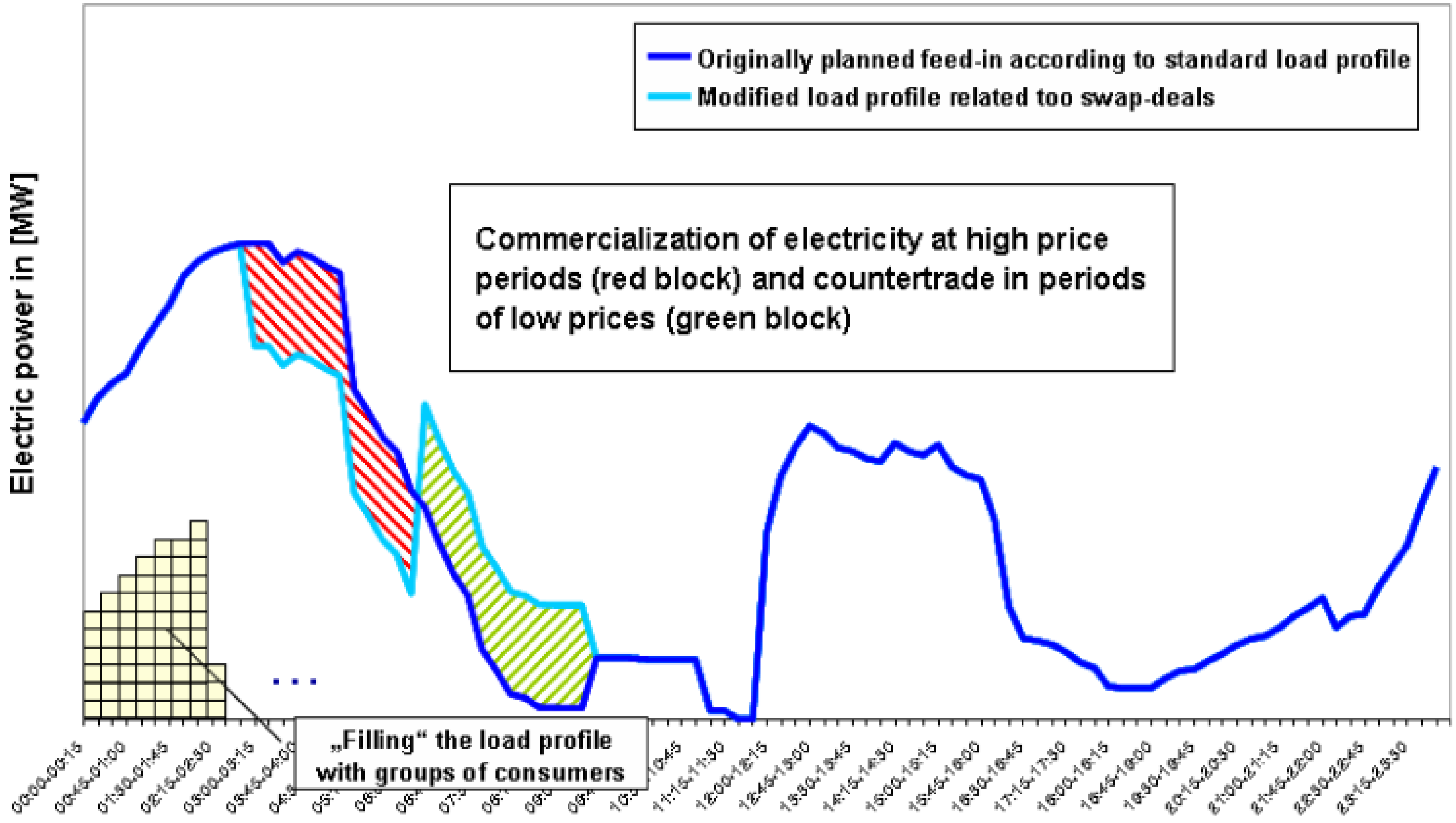
Geothermal heating?

Electrical and hybrid electrical vehicles?

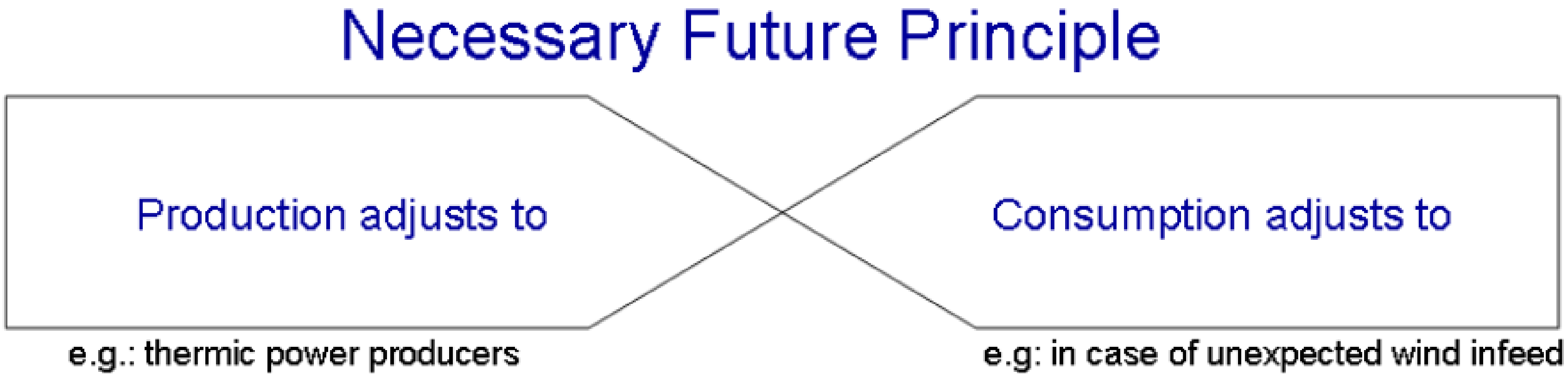
The segment of 'schedulable' consumers in Germany is in the order of a few ten thousands of MW.

How to make profit from this?
And stabilize the network ?

The Principle of electrical Swap-Deals (schematic account)



Talking a bit of mathematical models



So far, the ***producer*** behaviour was modelled as *deterministic and controllable process*, while the ***consumer*** behaviour was a *stochastic process* with well-known characteristics.

In the future, the ***producer*** becomes more and more *stochastic*, and in return the ***consumer*** model must become more *deterministic and controllable*.

We call this the resulting challenge the

Stochastic Energy Balancing Problem

What can we derive as requirements for models supporting the decision process?

Modelling and Analysis

Requirements for a proper modelling and analysis framework:

1) **Time** plays a crucial role in the model (load profile, schedules, timing of swap deals)

2) Need to keep track of the **global state** of the accounting grid
(superposed from component states)

3) To assess the economic effectiveness, model must be decorated with **costs or rewards**
that incur on state changes and are accumulated with time

4) Need to support **composition and orchestration mechanisms** for schedulable consumers

5) The **stochasticity** inherent to ordinary consumers and
renewable energy producers needs to be reflected.
Not on an individual basis, **stochastic dependencies** must be properly reflected.

6) Schedulable consumer points, especially rechargable batteries,
have **nonlinear dynamics** with respect to charging and discharging.

7) **Nonlinear dynamics combined with random perturbations**
are found in meterological models, as well as stock market models,
both of which are likely influencing the decisions of a grid coordinator.

A design challenge

- So far:
  - Producer: deterministic and controllable
  - Consumer: stochastic and uncontrollable

- Future:
  - Producer: stochastic and partly uncontrollable
  - Consumer: stochastic and … partly controllable

- Needed:
  - Large scale distributed control mechanisms
    - protocols
    - data bases
    - infrastructure
  - Models to predict network behaviour

What's next?

First course: next Friday.

Initial assignement for you:

1) Write 2 paragraphs about you.

- Who are you?
- What are your specific skills and interests.

2) Pick one of the two problems. (If in doubt, pick the pedelec.)

- Sketch how ***you*** would structure this research endeavour
  with a team of 20 gifted students
  that have some 120 hrs to spend each
  in a time span of 3 months
  assuming unlimited financial sources.

3) Send the results of (1) and (2) to `crouzen@cs.uni-sb.de` before next Thursday.