*“If you don’t **explain** what you mean, you can never mean what you say. And a gentleman should always **explain** what he says.” (adapted from Winston Churchill [1])*

Wishful thinking or realistic approach? Rationality and traceability are a virtue!

Apocalyptic predictions, messages of salvation, superforecasting or just common (systems) engineering – any statement about a causal, empirical, or logical relationship between two states of affairs should be substantiated with a traceable chain of rational arguments. Scientific methods and the principles of engineering are fundamental to distinguishing wishful thinking from realistic approach.

1. Systems engineering

Engineering is the applied science employed to design a new system or to modify an existing one. The goals of engineering include defining the function(s) and optimizing the efficiency of the system.

The term “systems engineering” emphasizes the inclusion of the whole life-cycle of a system from idea to design, construction or manufacturing, testing, commissioning, maintaining and finally aborting, recycling or reusing.

It is also used to point out the challenge with high levels of innovation and the difficulties with complicated, complex or chaotic systems (see appendix, fig. 11 for definitions).

2. Uncertainty vs. wishful thinking

"It is hard to make predictions, especially about the future.” (Mark Twain)

But without a traceable chain of arguments, it is even harder to figure out how realistic the prediction may be.

Uncertainty is inherent in engineering

Engineering contradicts comprehensive knowledge about the (future) behaviour of a system. Prediction is needed.

Accurate models have to depict the spectrum of system behaviour. Assumptions can be derived from experience with known systems under similar conditions or ascertained from simulation.

Models tend to become more extensive the higher the level of innovation, the more complex the system, the longer its life span and the more volatile its boundary conditions are. These often result in a greater number of assumptions as well.

Wishful or fearful thinking

Wishful thinking is not only common in political debate; it is also known in science and engineering, although this might not reflect self-perception.

Signs of wishful or fearful thinking are:

- *inconsistent definitions of*
  aggregated figures, systems and models;
  system boundaries with input and output;
  subsystems, elements and functionalities;
- *unsubstantiated* claims,
  incomprehensible arguments,
  unclear or contractionary use of terms;
- *lack of* plausibility checks,
  reproducibility of results or transparency.

All of these deficiencies result in the lack of a stringent /compelling chain of arguments.

To achieve better and more judgeable descriptions of reality and predictions, a realistic approach is needed. The basis can be found in the principles of science, engineering and rational argumentation.

3. Rational argumentation

“Ideology knows the answer before the question has been asked. Principles are (..) different: a set of values that have to be adapted to circumstances but not compromised away.” (George Packer)

A rational approach is driven by recognition. Motivations for wishful or fearful thinking may grow from ideology and affect.

Triple criticism of argumentation

The triple criticism of argumentation proposes to examine one’s argumentation in order to make it more reliable and to distinguish realistic arguments from invalid claims (from [2]).

1) Requirement for recognition:

- Validated cause-and-effect-relations
  based on evidence (data and facts);
- methodology according to scientific standards.

2) Renunciation or disclosure of ideology:

- Cultural values and legitimations;
- political convictions;
- religious beliefs.

3) Critique of affect:

- idealism, interests and individual motivations;
- emotions and moods;
- sympathy, distance or fear;
- distortion, bias or repression.

The triple criticism of argumentation is also helpful for detecting hidden agendas.

Eight rules for rational argumentation

The eight rules for rational argumentation are proposed for the context of projects in education [3], but they are also valid for scientific projects and in (systems) engineering.

1. Comprehensibility: All terms used in the argumentation that are important for their understanding must be clearly explained.

2. Objective arguments: All claims and all statements used to defend a claim must be substantiated.

3. Allow all arguments: No argument made by any interlocutor from the outset may be excluded without further examination and justification.

4. Willingness to criticise yourself: Each participant in an argumentation must be prepared to have all of their beliefs be reviewed and to give them up - however attached to them she or he may be.

5. No sanctions (corruption): Giving or refusing consent to an argument must not depend on reward or punishment (positive or negative sanctions).

6. No unchecked previous knowledge (nepotism): The reasoning must not rely on an unchecked common understanding.

7. Common agreement: If, to the best of the knowledge of all those involved, an argument has arrived at a justified conclusion, it should be checked as to whether everyone would be able to agree with this result.

8. Expertise and goodwill (social behaviour): Participants in an argumentation are required to have a) expertise and b) goodwill.

4. Traceable chains of arguments

Ceteris paribus: A way to master complexity

Ceteris paribus is a way to master complexity. The Latin phrase means "all other things being equal" or "other things held constant" or "all else unchanged".

A ceteris paribus assumption is most often key to scientific inquiry, as scientists seek to screen out factors that perturb a relation of interest.

E.g.: Finding basic relationships in physics

If physicists wanted to find the basic relationship between the weight of a ball and its movement on an inclined plane, they would need to repeat the same experiment several times and only change one parameter at a time, while holding all other parameters constant – e.g. the inclination (angle) of the plane *or* the weight of the ball.

Otherwise, it is impossible to determine whether it is the weight of the ball or the inclination of the plane that is responsible for a change in velocity of the ball rolling down the plane (or both).

Principles in systems engineering

Some of the most basic principles in systems engineering are (from [4] and [5]):

- Depiction and examination from rough to detail
- Splitting up systems into subsystems, driven by self-contained (independent) feedback-loops or cause-and-effect relationships
- Stepwise modification of a system and prediction of its behaviour, meaning the evolution of a system by applying reversible modifications at a controllable level of innovation

  To build up a traceable chain of arguments, the idea of ceteris paribus can be interpretated as a guideline for stepwise modification of systems and prediction of its behaviour.

  This means changing only one parameter of a system at a time, while all others are held constant. To depict variety, several variations of one parameter at a time can be examined and depicted.

  Documentation will then cover a variety of stepwise or alternative changes in a transparent way – including depiction of summed up changes based on management, engineering, boundary conditions etc.
- Thinking in variety, using methods like the morphological box, combinatorics and variants.
- Taking into account change over time

All of these principles are inherent to science, too.

Demasking manipulative techniques

How can one distinguish wishful thinking from ambitious goals? Borders may be fluent, but in any case, it is prohibited to use inconsistent definitions to manipulate results of comparison or prediction, e.g. to shift system boundaries or to ignore (“forget”) parameters of importance (see paragraph 2).

One manipulative technique is to set ambitious parameters for wished systems or variants while setting conservative parameters for unwished systems or variants. Such tendentious assumptions are not allowed, unless they are declared and balanced with scenarios heading in the opposite direction.

Transparency is a virtue!

On the other hand, it is permitted to transparently differentiate into ambitious – realistic – conservative assumptions. The discussion of the results may then even take into account some (transparently stated) ideologically motivated goals or wishes.

Requirements for traceable chains of arguments and realistic (or at least judgeable) results are:

- Consistent definitions of
  aggregated figures, systems and models;
  system boundaries with input and output;
  subsystems, elements and functionalities;
- Substantiated claims,
  comprehensible arguments,
  clear and consistent use of terms;
- Plausibility checks,
  reproducibility of results
  and transparency.

Declaration and justification of assumption is needed in any case – including neglect of parameters, e.g. justified by their minor scale, i.a.

5. Building transparent and resilient models

To make statements about a causal, empirical or logical relationship between two states of affairs, modelling is indispensable. In engineering, the function and behaviour of (existing) systems are most commonly described by

- Linguistic models to describe,
- Graphical models to visualise,
- Operational models to operationalise,
- Mathematical models to quantify
  (including aggregated figures).

These models make a particular part or feature of the world easier to understand, define, quantify, visualize or simulate by referencing it to existing and usually commonly accepted knowledge.

Imperfection is inherent in modelling

Modelling requires selecting and identifying relevant aspects of a situation in the real world. Thus, valid models must be based on evidence.

Simplifying assumptions permits illustration or elucidation of concepts thought to be relevant within the sphere of inquiry. But these assumptions must not affect the result or the findings of the inquiry.

Pareto principle

The principle specifies that 80% of consequences come from 20% of the causes, asserting an unequal relationship between inputs and outputs.

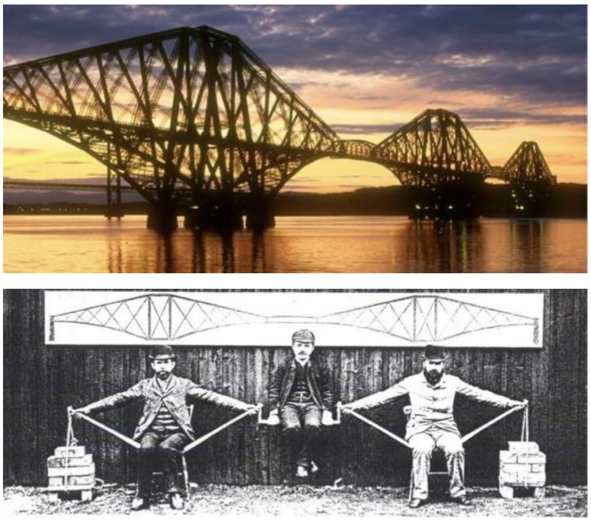


Fig. 1: Accurate models should be as elaborate as needed and as vivid as possible (railroad bridge over the Firth of Forth).

Evidence is known from categorization in logistics (ABC analysis), health (20 % of hazards account for 80 % of injuries), computing (fixing the 20 % most important bugs eliminates 80 % of the related errors and crashes) and others.

This principle also serves as a general reminder, that with 20 % of expenses, 80 % of outcomes are possible. But how can one know what the 20 % most relevant expenses are?

To cope with the difficulty of imperfection, some methods known from systems engineering are helpful: from rough to detail, system demarcation method, black-box-approach and switching layers of system.

From rough to detail

"From rough to detail" means to start with, to see and understand the whole picture before going into (too much) detail.

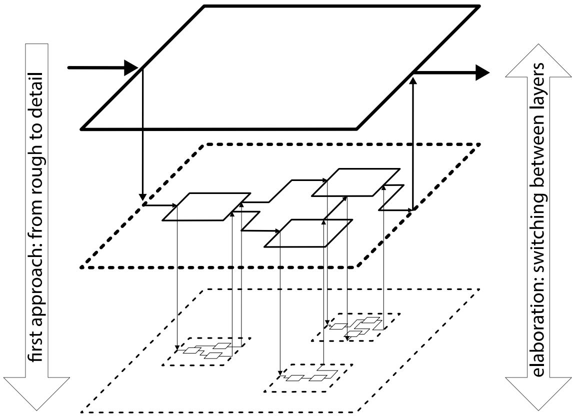


Fig. 2: Principles of systems engineering: from rough to detail / switching between layers.

Switching between layers of a system

Switching between layers is useful or necessary in order to understand, examine and consider dependencies within a system from the top layer (system) to subsystems (layer 2) or elements (layer 3), e.g. if element X is chosen, then the design of the whole system has to be changed.

Switching between layers is also needed if the function of some single key elements is crucial for the whole system, e.g. the "detail" of fixing the main cable on the pillar of a suspension bridge.

Switching between layers is done throughout the whole problem solving process (see fig. 28-30).

Black box approach

The black box is a means of reducing complexity:

- Focusing on the input and output (fig. 4a),
- Ignoring or simplifying the inside of the box, thus the complexity of the system itself, and focusing on the transformation (fig. 4bc).

Input and output can be flows of materials or people, information, energy and money (figs. a-c).

System demarcation method

The system demarcation method from [6] helps to define the problem and its demarcation from the environment by analysing the relationships and dependencies within (or outside) the system.

1) Easy collection of ideas for the system, its parts and its surroundings to be investigated
2) Depiction as a grid of elements or subsystems with their dependencies or interferences
3) Analysis of the dependencies: strong, medium, loose.
4) Demarcation of the problem

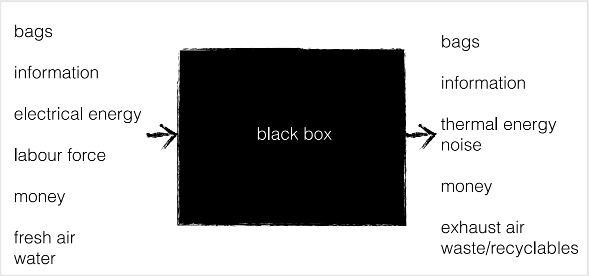
Demarcation has to include strong dependencies of elements or subsystems. Dependencies or relationships of minor interest and importance can be "cutted" and then captured as input and output (see fig. 4d/27).

Zooming out (the power of ten)

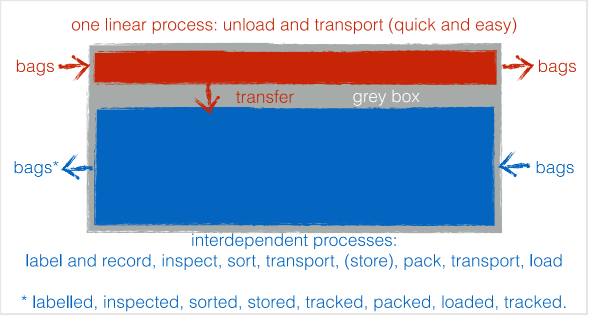
Zooming out is an important mechanism for moving from rough to detail and finding the right demarcation of a system. It means zooming out from the original sketch of a model and then enclosing and demarcating until an appropriate understanding is arrived at.

Fig. 3: The power of ten: zooming out 10 times.

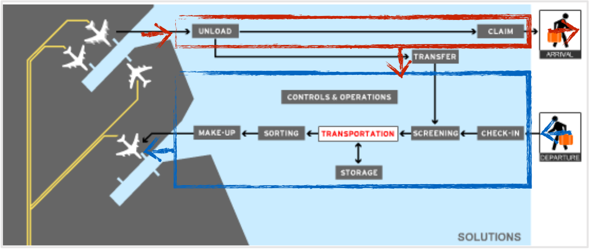
a. Input and output -> contextual view (black box)



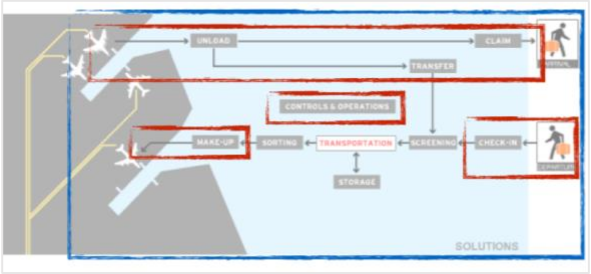
b. Function -> transitional view (grey box)



c. Function and processes



d. Demarcation of system and subsystems



e. Function, processes and structures in more detail

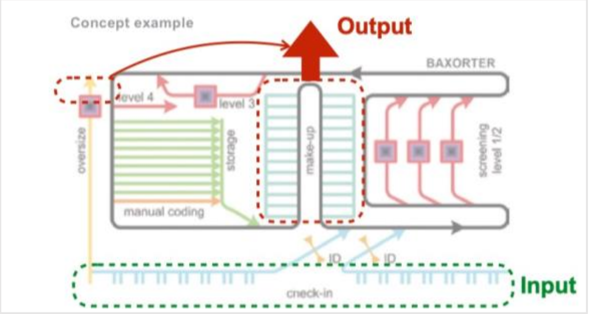


Fig. 4a-e: Systemic approach to systems, ex. baggage systems from rough to detail.

Criticism of models

The following list of questions helps to derive appropriate and meaningful models (from [6]).

Is the model appropriate with regard to:

- Scale and level of detail,
- Section and boundaries,
- Input and output?

Is the model complete, including and depicting

- Relevant aspects on different layers,
- Dependencies,
- Cause-and-effect relationships?

Does the model meet the needs:

- Do the results meet the requirements of the receiver of the results?
- Are the expenses and benefits in a reasonable relationship?

Is the model realistic:

- Possibility of calibration on present situation,
- No self-delusion (the impression of clarity where chaos and uncertainty rule),
- Plausibility, lucidity and reasonability of the explanation by the model?

This list complements the principles of systems engineering and verifies the application of those in science.

6. Case study: “Energy revolution Switzerland”

A matter of great importance and lively debate

The energy system of Switzerland and its reliability is a matter of supreme importance to all economic, social, cultural and political systems.

Its (r)evolution has been subject to lively debate over a long period of time, starting more than a century ago: Ever since its building up from run-of-river plants to storage seas, nuclear energy plants and to more decentralised wind and solar energy plants.

A complex system with a tendency for unclarity

The energy system of Switzerland is a rather large and complex system. A description of the system as a whole has to take into account:

- Many possibilities for the definition of system: incl./excl. grey energy , i.a.
- Well-defined system boundaries equating to the national borders: import of raw materials (uranium, fossil fuel), export of waste, import /export of electrical energy;
- Boundary conditions of stochastic nature (weather), relevant both for production and consumption of energy.

Description of the system then comprises:

- Many layers of the system with a large number of elements on each layer: From system to several layers of subsystems to elements;
- Large differences in the scale and nature of each layer and each element: functionality, robustness against fluctuating (boundary) conditions like weather, market prices i.a., availability and reliability of aggregated figures;
- Scheduled or predefined behaviours and processes on the production side, interfered with by stochastic incidents such as disruptions or malfunctions;
- Stochastic behaviour of participants, in particular of consumers and industry.

Prediction of the effects of modifications of the systems depend on:

- High costs and benefits, high number and long life cycles of subsystems and elements;
- Large differences in the nature and level of development of used or intended technologies including evolution of availability, costs, efficiency and side-effects;
- long life cycles and duration of fundamental changes and transition for remarkable impact on the system over several generations.

All of these characteristics of the system make it challenging to find adequate description and reliable prediction.

“Energy revolution Switzerland”: replacing uranium and fossil fuel by renewables

”Kraftwerk Schweiz – So gelingt die Energiewende.” [7] (Engl.: Powerplant Switzerland – this is how the energy revolution succeeds) describes a ***R***evolution of the energy system of Switzerland.

The primary intention of the author is to show that:

- It is possible to reduce the input of primary energy by ~ 67 %
- It is possible to replace generation of electricity by nuclear power plants with renewables, in particular wind, solar and biomass by 2035
- It is more efficient (and also possible) to replace almost all fossil fuels with electrical energy plus geothermal heat:

  combustion -> plug-in hybrid / electrical drive,

  heating oil and gas burner -> heat pumps*

  The transition will be completed by 2035.

* Heat pumps need ~25 % to 30 % electricity + ~70 % to 75 % thermal energy from air /ground to produce 100 % thermal heat for houses.

These replacements are treated and calculated separately. The effects are not summed up. Thus, no proof can be found for the claim that they can all be implemented together.

The author is providing some well- examined insights into selected subsystems as well as rather synoptic overviews on some other aspects. He switches between complete and incomplete depiction, using selected exclusion or inclusion of relevant aspects. He makes some bold assumptions with great impact pointing in the right direction, too.

Wishful thinking vs. transparency and resilience

This case is an especially interesting one to examine, because of the

- Implications of supreme importance for all economic, social, cultural & political systems;
- Contradictory interests from any side;
- Diverse fears and emotions;
- Scale and complexity of system (see above).

All of these characteristics tend to allow or evoke wishful or fearful thinking.

The intention of the case-study is to distinguish wishful thinking from transparent and resilient argumentation on the basis of engineering science.

Additional calculations are carried out to close gaps in the chain of arguments or to point at tendentious assumptions – using different assumptions.

The focus is on the most important and most striking aspects of the book.

7.1 Energy system Switzerland

Fig. 5a depicts the amount of energy as circles proportionally.

The information given is a mix of energy content of raw material and production of energy for 2010 (reference). (See fig. 13)

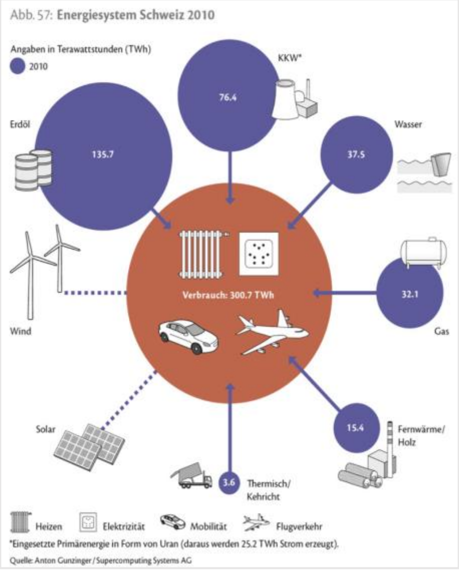


Fig. 5b depicts the same information as fig. 5a for the target state in 2035.

The information about grid losses is absent. The assumptions regarding savings (50 % less consumption in automotive) are omitted. The deficits in production of electrical energy resulting from transition from fossil fuels to renewables and electricity are ignored. See paragraph 11 for bigger graphics and tables with all figures used.

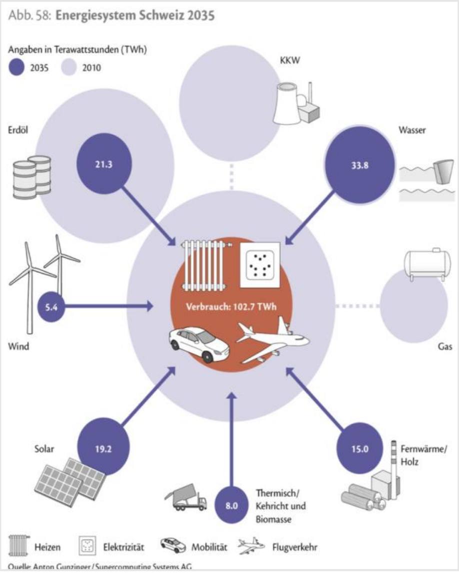


Fig. 5a (above) and b (below) from [7].

Systemic approach and criticism of models

Fig. 5c depicts the information from fig. 1a and 1b as energy flows for “2010 reference” and “2035 wishful”. The black framed boxes point out the actual information from the left. It is distributed over several layers of production, distribution and consumption and it does not completely depict them. The greyed-out parts of fig. 5c show the completed information for the layers production, distribution and consumption. (See fig. 19 / 20).

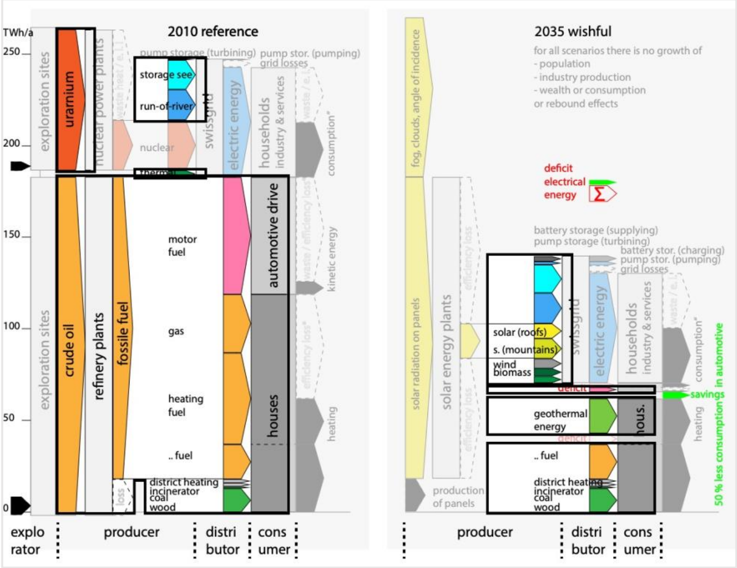


Fig. 5d depicts the same information as fig. 5c arranged for:

- Losses and waste (above): A most remarkable reduction of waste and efficiency losses is the result of investments for more efficient housing and a completely new fleet of automotives as well as the transition from fossil fuel to geothermal and electrical energy. This results in a remarkably high deficit of production of electrical energy.
- Constant output consumption (below): It is assumed that there is no growth in population, industry production or wealth, no reduction in consumption and no rebound effects.

The graphic divides the layers from production to consumption.

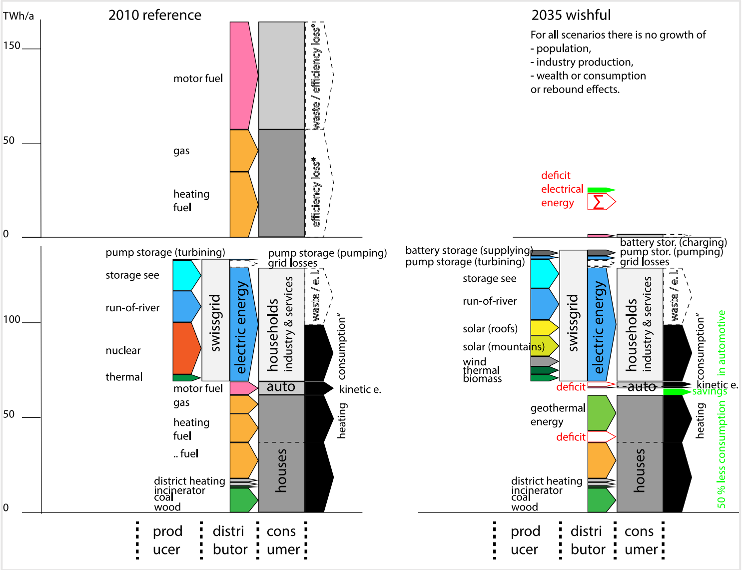


Fig. 5c and d (below) “Translation” to a more systemic approach.

7.2 Renewables replacing nuclear power plants

Statements and intentions by the author of [7] are in *italics.* Comments and criticism of models are in non-italic letters.

It is possible and reasonable to replace the production of electricity by nuclear power plants with renewables by 2035 for a year with average weather conditions.

It is best to promote and install a mix of new resources: solar, wind, biomass and battery storage as well as storage sea (already existing) – instead of focusing on solar or solar and wind energy only. Pump and battery storage play an important role in the transition while storage capacity is limited. Minimizing storage of electrical energy is key to the calculations made for the different scenarios and it is the reason why a "solar -only" strategy would fail.

Realistic approach and criticism of models

Depiction of different scenarios from solar only to solar+wind+biomass+battery storage goes into quite some detail, and calculations seem to be accurate (see paragraph 11, fig. XX). However, there are some major issues:

1) The new regime for production of electrical energy fundamentally changes the system characteristics. The base-load capacity of nuclear power plants covers about 40 % of production. Omission of nuclear power means that run-of-river production is the only base-load capacity left during all seasons of year. This makes the production more vulnerable to weather events. No proof can be found, if the results from [7] are applicable for years with greater or lesser deviations from average weather statistics.

2) Consumption and production of electrical energy varies over the four seasons. It is about 30 % higher in winter than in summer (fig. 6a on the left). This is why storage seas are empty in spring and full in autumn (see paragraph 11, fig. X). It is assumed that this fluctuation is partly levelled out (fig 6b). There is no evidence as to why this should occur.

On the other hand, production of solar electricity is highest when consumption is lowest and storage capacity is limited.

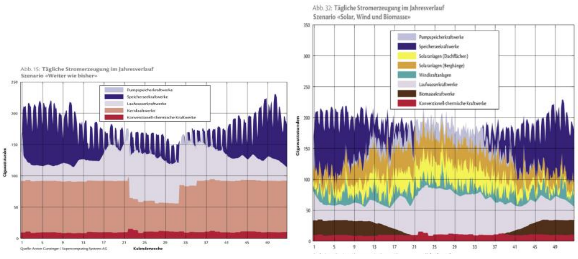


Fig. 6a and b Daily energy production over an average year for 2010 (left) and 2035 (right).

Conclusion from 1) and 2): There seems to be no proof as to how renewables could replace nuclear power plants if calculations were based on the reference fluctuation over the four seasons and/or if weather conditions deviate from the statistical average.

3) The calculations are based on an exponential growth of installations. Fig. 7a gives suitable, regionally distributed locations with strong and somewhat stable winds. For installation of 4GW, 2,000 wind turbines of 2 MW each are needed.

For comparison: This is

57 * 70 MW (all installations so far) = 4 GW

108 * 37 MW (Mont Crosin, biggest plant) = 4 GW

For transition within 25 years there is a need for ~ 4 turbine parks the size of Mont Crosin (the biggest plant so far) per year or new turbine parks installed each year at twice the size of existing ones.

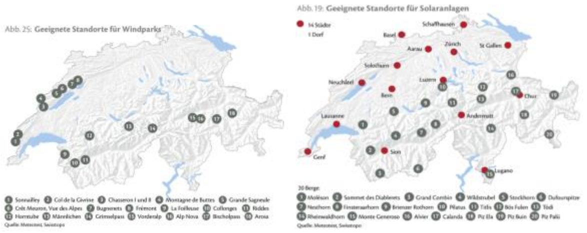


Fig. 7a and b: Locations for wind turbine parks (left) and large areas or solar panels (right).

Fig. 7b gives suitable, regionally distributed locations, partly "above the fogs" in winter. The area of photovoltaic panels for 20 TWh/a is ~ 100 km^2

for comparison: area of roofs (Σ) ~ 400 km^2

Production of electricity from 2010 to 2020 has linearly grown from 0.2 to ~2 TWh/a. With a similar growth per year, the goals will be reached in ~ 100 years.

4) There is an ongoing political and juridical debate about installation of photovoltaic installations on roofs and about installation of wind turbines. However, progress can be seen, and installations are growing slowly but constantly.

Conclusion from 3) and 4): This transition seems to be more than just an ambitious goal. It expresses a good portion of wishful thinking.

Obviously, importing electrical energy would be an alternative or an inevitable consequence if

- Renewables did not cover the deficit from shutting down all nuclear power plants;
- Energy consumption were to grow due to growth of population, industry production or wealth.

However, in the event of success, it would probably take much longer than by 2035.

Tendentious depiction of system

Nuclear power plants are exterminating *energy. The energy content of uranium is 77 GWh/a while the electric energy gained is 28 GWh/a.*

Efficiency losses and waste are inherent to any system by nature:

- Energy content of uranium remaining at the end of the burning process can be seen as waste, but it still exists.
- Power plants emit waste heat and are (relatively small) consumers of energy as well.

The common term used to describe this is *efficiency*, while *exterminating* is not appropriate.

Efficiency of electricity from solar radiation is 100 %.

Photovoltaic installations suffer efficiency losses as well, of course. To claim an efficiency of 100 % is nonsensical. The annual energy input from solar radiation varies from below 1.1 MWh/m^2 (midlands) to ~ 1.6 MWh/m^2 (peaks or 4000 m a.s.l.). Electrical energy generated from this is 10 to 25 % (see paragraph 12, fig. 22 on the right). These factors are of great importance for calculation of areas on roofs or mountains needed to install a certain capacity.

7.3 Electricity replacing gasoline for vehicles

It is possible and reasonable to replace the fleet of automotives driven by combustion engines with a fleet of electrical and hybrid-driven cars by 2035. This leads to overall savings of primary energy > 90 % compared to 2010.

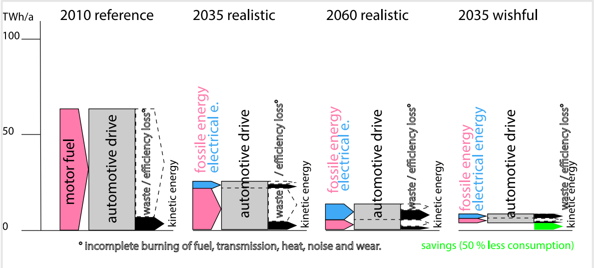


Fig. 8 Scenarios for energy consumption of automotive. (see fig. 26)

There is a remarkable reduction of waste and efficiency losses as a result of the transition from combustion to electric and hybrid drive for automotives (see fig. 8/26, “2010 ref.” and “2035 wishful”). However, there are some major issues with this.

Tendentious depiction of system

1) It is possible and reasonable to reduce consumption of automotive transportation by half.

There is little doubt about the reasonability of such a reduction. However, sufficiency has rarely been observed in developed or emerging economies.

2) Electrical and hybrid-driven automotives have an efficiency of 95 % while combustion driven automotives only have an efficiency of about 10 % (see paragraph 11, fig. 16).

Batteries add considerable weight to electric cars. For a comparable payload and comfort, such cars become heavier and need more kinetic energy from the drive (+ ~ 20 %). Otherwise, a reduction would result in (additional) sufficiency.

Charging and supplying from batteries in cars result in losses of assumably ~ 10 %.

3) Production of electric energy is a) from solar source only and b) this source is 100 % efficient – while c) exploration and production of fossil fuel is only 70 to 80 % efficient.

a) Any consumption of energy in a communicating system like the power grid results in a mix of production methods by nature. It is impossible to ascribe one’s consumption to a single source.

The deficits in production of electrical energy resulting from transition from fossil fuels to electricity are ignored (see paragraph 7.1). This results in the odd fact that the author of [7] claims to use electrical energy from a source that – according to his own calculations and assumption – doesn’t even exist.

b) Efficiency of the production-sites-and-grid system (the upper level of the “energy system Switzerland”) is calculated by the author as ~ 90 %, due to grid losses, waste and efficiency losses from charging and supplying from batteries as well from pumping and turbining from pump storages. Efficiency of energy production from photovoltaic panels transmitting solar radiation is discussed in the previous paragraph.

These three issues are omitted for “2035 wishful” (fig. 8/26 on the right) but taken into account for “2060 realistic”.

Conclusions: This transition seems to be rather ambitious. Its reduction in the need for primary energy and its reduction of waste and efficiency loss can be remarkably high but most probably less than stated.

In addition, it would probably take longer than 2035 to replace all combustion drives by electrical and hybrid drives. Fig. 8/26 “2035 realistic” shows a transition of 50 % compared to “2060 realistic”.

Last but not least: The deficits in production of electrical energy resulting from transition from fossil fuel to electricity have to be taken into account on the upper layer of the “energy system Switzerland” (see fig. 10. 11. 22, 23).

7.4 Heat Pumps replacing fossil fuel

It is possible and reasonable to replace the existing heating installations (gas and heating fuel burner) in houses with heat pumps and to reduce losses dramatically by replacing or renovating all of the old houses by 2035 to make them more economical.

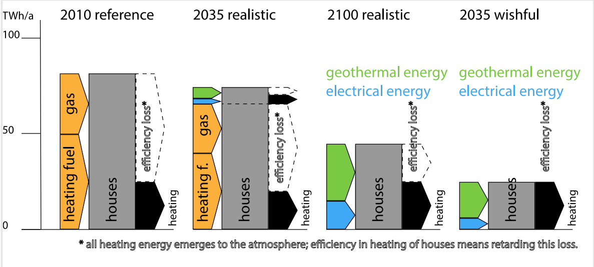


Fig. 9 Scenarios for energy consumption of heating of houses. (see fig. 25)

There is a marked reduction in waste and efficiency losses as a result of both the transition from fossil fuels to geothermal heat and electricity as well as investments in more efficient housing, while the output as heating is held constant for all scenarios.

Improving efficiency in domestic heating means retarding this loss using better insulation i.a. In fact, all heating energy escapes to the atmosphere sooner or later. Fig. 9 depicts "2010 reference" with an efficiency loss of ~ 90 %. On the other hand, "2035 wishful" gives an ambitious benchmark rather than an absolute figure "0" for efficiency loss.

Realistic approach and criticism of models

Depiction of different scenarios for the use of underfloor heating or radiators goes into quite some detail and calculations seem to be accurate (fig. 9/25). However, there are some major issues:

1) It is stated that houses are replaced after a life span of 80 years on average and that any new houses would comply with the most ambitious energy standards for heating economy. It is not pointed out how renovation of existing houses could comply with these same standards.

2) It is assumed that all new heating installations use underfloor heating. This allows one to calculate with a low inlet temperature and therefore a high efficiency of the heat pump, assuming a ratio of ~ 25 % electrical energy and ~ 75 % geothermal heat as input. For heating distribution with radiators, this ratio is ~ 33 % / ~ 67 %.

Conclusion from 1) and 2): This transition seems to be very ambitious. It would seem more likely that

- some installations do not meet the highest standards (radiators instead of underfloor heating);
- transition of houses to the most ambitious standards for heating economy will probably take longer, that is, about the average life span of houses, and not include all houses.

Fig. 9/25 shows a scenario "2100 realistic" as target state, taking into account these assumptions. "2035 realistic" then shows the results of calculations for an intermediate state of the system after 20 % of the transition would be completed.

3) The deficits in production of electrical energy resulting from transition from fossil fuels to electricity (and geothermal heat) are ignored (see paragraph 7.1).

Conclusion: The deficits in production of electrical energy resulting from the transition described have to be taken into account on the upper layer of the "energy system Switzerland" (see fig. 10. 11. 22, 23).

7.5 Basic data and consumption

Basic assumptions

As stated earlier, energy consumption is assumed to remain constant for all scenarios, meaning that there would occur no growth of population, industry production or wealth. On the contrary, for the scenario "2035 wishful", a massive reduction in consumption of automotive transportation is assumed.

Sufficiency

"A sustainable and ecological society must walk on two legs: intelligent rationalisation of means (higher efficiency) and wise limitation of objectives. In other words: the "revolution in efficiency" stays blind if it is not accompanied by a "revolution of sufficiency." (Wolfgang Sachs, 1993)

"Sufficiency is far more delicate to discuss than efficiency." (Joachim Lohse, former managing director of the Öko-Institut)

Rebound effect

"The rebound effect (also known as take-back" or boomerang effect) "is the reduction in expected gains from new technologies that increase the efficiency of resource use, because of behavioural or other systemic responses. These responses usually tend to offset the beneficial effects of the new technology or other measures taken." (from [8])

The theory can be applied to the use of any natural resource or other input, such as labour, while literature initially focused on the effect of technological improvements on energy consumption.

The rebound effect is generally expressed as a ratio of the lost benefit compared to the expected environmental benefit when holding consumption constant.

For instance, if a 5 % improvement in vehicle fuel efficiency results in only a 2% drop in fuel use, there is a 60 % rebound effect, since (5 - 2) ⁄ 5 = 60 %. The "missing" 3 % might have been consumed by driving faster or further than before or by driving heavier cars with more and more energy consuming subsystems installed.

With the saved 2 %, the consumer may then buy and consume other things for his or her delight. If the gain in efficiency leads to higher consumption, this is called backfire-effect (rebound of > 100 %).

Conclusion: To prepare for future challenges it might be reasonable to consider scenarios with rising energy output consumption in addition to the ones with constant consumption already described – independently of reductions of energy input and energy output losses and waste.

The calculation would show an additional need for electrical energy – additional to the need for more electrical energy due to the transition from fossil fuels to electrical and geothermal energy.

7. Conclusion and findings

The "energy system Switzerland" can be depicted as energy flow diagrams with consistent and complete depiction of three major layers of the system (production – distribution – consumption) for four scenarios over time (see fig. 10/23 and fig. 11/21 (table)).

Calculations and system description are on a very rough level with the goal of depicting the right scale of effects and relations rather than precise description of subsystems or elements.

Energy output consumption is assumed as

- Constant for the reference (2010) and the two realistic scenarios (2035 and 2100);
- Reduced by more than 50 % for consumption of automotive transportation for the scenario "2035 wishful".

In any case, there are significant deficits in production of electrical energy of 8.7 - 30.6 TWh/a, while nuclear power plants feed 27.5 TWh/a to the grid in 2010. For comparison, this is 40 times the capacity of the planned but currently obstructed height increase to the Grimsel dam by 23 m, or 275 times the capacity of the never realized Greina plant (as planned from the 1940s to the 1980s).

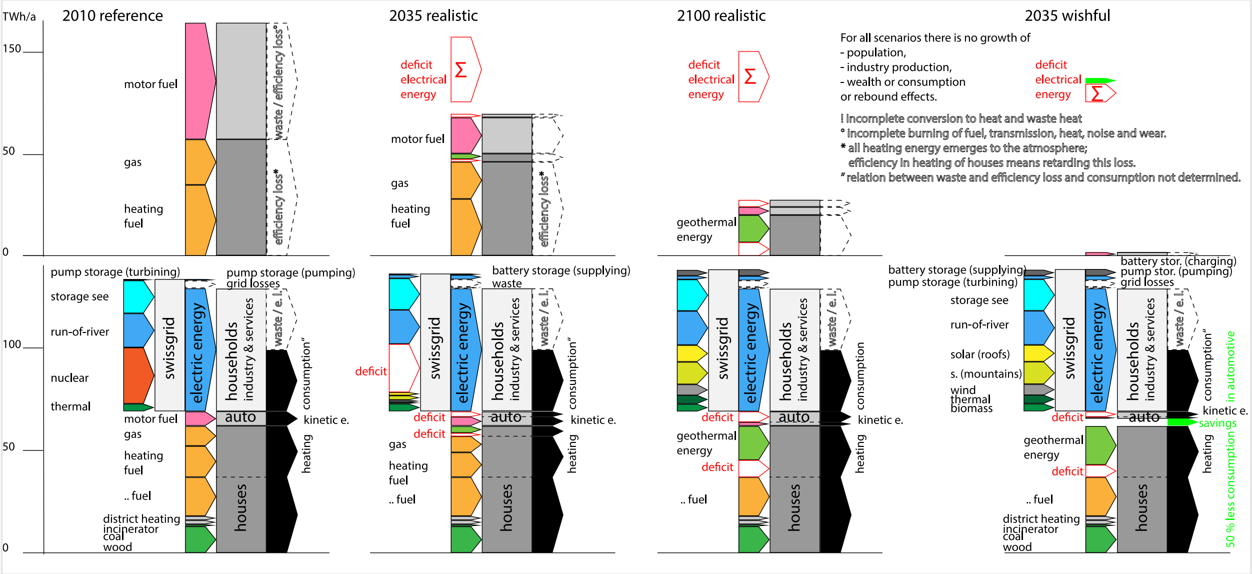
The deficit is highest in 2035, because progress of installation of renewables for production of electrical energy (after shutting down nuclear power plants) will most probably be slower than the increase in electrical energy consumption due to transition from fossil fuels to electrical and geothermal energy.

The transition to renewables will reduce the waste and efficiency losses of primary energy from fossil fuels and uranium* dramatically. *uranium isn't "wasted" but only partially burned.

Further discussions could get more precise about each layer of the systems, and add, for example:

- scenarios with a rising energy output consumption due to growth of population, industry production and wealth;
- discussion of grey energy including import of energy due to exploration and refinery, i.a.
- depiction of electrical energy imports to cover possible deficits and discussion of the share of production available.

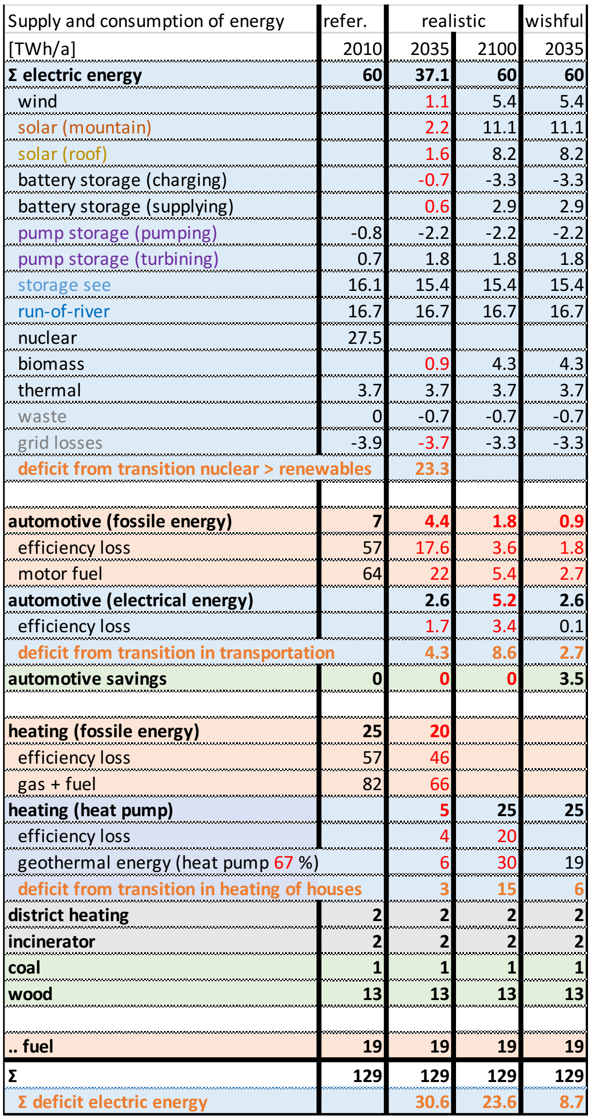
More detailed scenarios taking into account change over time seem to be of secondary importance at this stage of the investigation.



For all scenarios there is no growth of
- population,
- industry production,
- wealth or consumption
or rebound effects.

! incomplete conversion to heat and waste heat
° incomplete burning of fuel, transmission, heat, noise and wear.
* all heating energy emerges to the atmosphere;
efficiency in heating of houses means retarding this loss.
" relation between waste and efficiency loss and consumption not determined.

Fig. 10: Balance of energy for an average year: four scenarios. (see fig. 23)



Supply and consumption of energy	refer.	realistic		wishful
[TWh/a]	2010	2035	2100	2035
Σ electric energy	**60**	**37.1**	**60**	**60**
wind		1.1	5.4	5.4
solar (mountain)		2.2	11.1	11.1
solar (roof)		1.6	8.2	8.2
battery storage (charging)		-0.7	-3.3	-3.3
battery storage (supplying)		0.6	2.9	2.9
pump storage (pumping)	-0.8	-2.2	-2.2	-2.2
pump storage (turbining)	0.7	1.8	1.8	1.8
storage see	16.1	15.4	15.4	15.4
run-of-river	16.7	16.7	16.7	16.7
nuclear	27.5			
biomass		0.9	4.3	4.3
thermal	3.7	3.7	3.7	3.7
waste	0	-0.7	-0.7	-0.7
grid losses	-3.9	-3.7	-3.3	-3.3
deficit from transition nuclear > renewables		**23.3**		
automotive (fossile energy)	**7**	**4.4**	**1.8**	**0.9**
efficiency loss	57	17.6	3.6	1.8
motor fuel	64	22	5.4	2.7
automotive (electrical energy)		**2.6**	**5.2**	**2.6**
efficiency loss		1.7	3.4	0.1
deficit from transition in transportation		**4.3**	**8.6**	**2.7**
automotive savings	**0**	**0**	**0**	**3.5**
heating (fossile energy)	**25**	**20**		
efficiency loss	57	46		
gas + fuel	82	66		
heating (heat pump)		**5**	**25**	**25**
efficiency loss		4	20	
geothermal energy (heat pump 67 %)		6	30	19
deficit from transition in heating of houses		**3**	**15**	**6**
district heating	**2**	**2**	**2**	**2**
incinerator	**2**	**2**	**2**	**2**
coal	**1**	**1**	**1**	**1**
wood	**13**	**13**	**13**	**13**
.. fuel	**19**	**19**	**19**	**19**
Σ	**129**	**129**	**129**	**129**
Σ deficit electric energy		**30.6**	**23.6**	**8.7**

Fig. 11: Balance of energy for an average year:
four scenarios (table). (see fig. 21)

8. References

[1] The original quote by Winston Churchill is: “If you don’t *say* what you mean, you can never mean what you say. And a gentleman should always *mean* what he says.”

[2] Inversini, Martin (2012):
Triple critism of argumentation.

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[6] Wiegand, Jürgen (2005):
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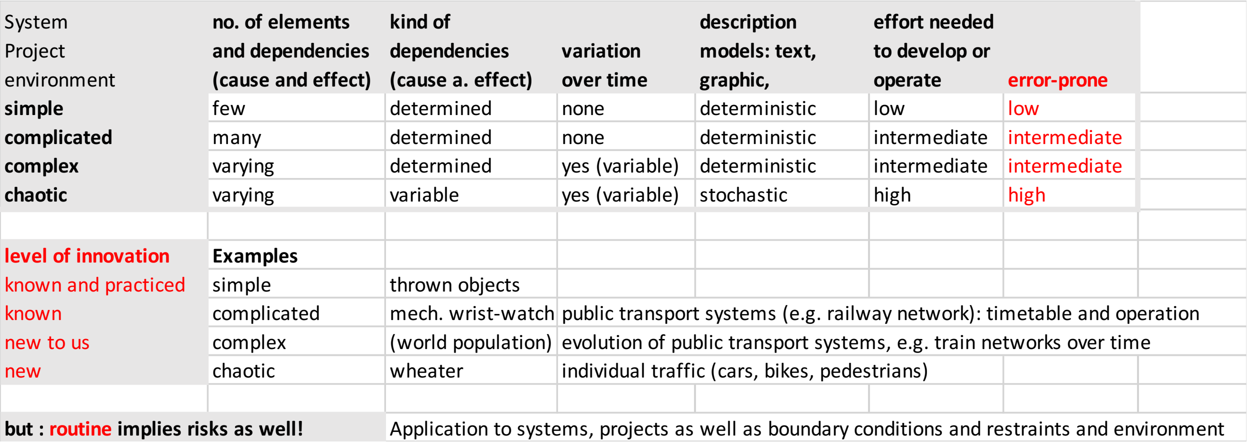
[8] https://en.wikipedia.org/wiki/Rebound_effect_(conservation)

9. Levels of Complexity in Systems Engineering



System Project environment	**no. of elements and dependencies (cause and effect)**	**kind of dependencies (cause a. effect)**	**variation over time**	**description models: text, graphic,**	**effort needed to develop or operate**	**error-prone**
simple	few	determined	none	deterministic	low	low
complicated	many	determined	none	deterministic	intermediate	intermediate
complex	varying	determined	yes (variable)	deterministic	intermediate	intermediate
chaotic	varying	variable	yes (variable)	stochastic	high	high
level of innovation	**Examples**					
known and practiced	simple	thrown objects				
known	complicated	mech. wrist-watch	public transport systems (e.g. railway network): timetable and operation			
new to us	complex	(world population)	evolution of public transport systems, e.g. train networks over time			
new	chaotic	wheater	individual traffic (cars, bikes, pedestrians)			
but : routine implies risks as well!		Application to systems, projects as well as boundary conditions and restraints and environment				

*Fig. 12: Levels of complexity in systems engineering.
Aspects relevant for risk mitigation in projects are shown in red.*

10. Energy revolution Switzerland from [7]

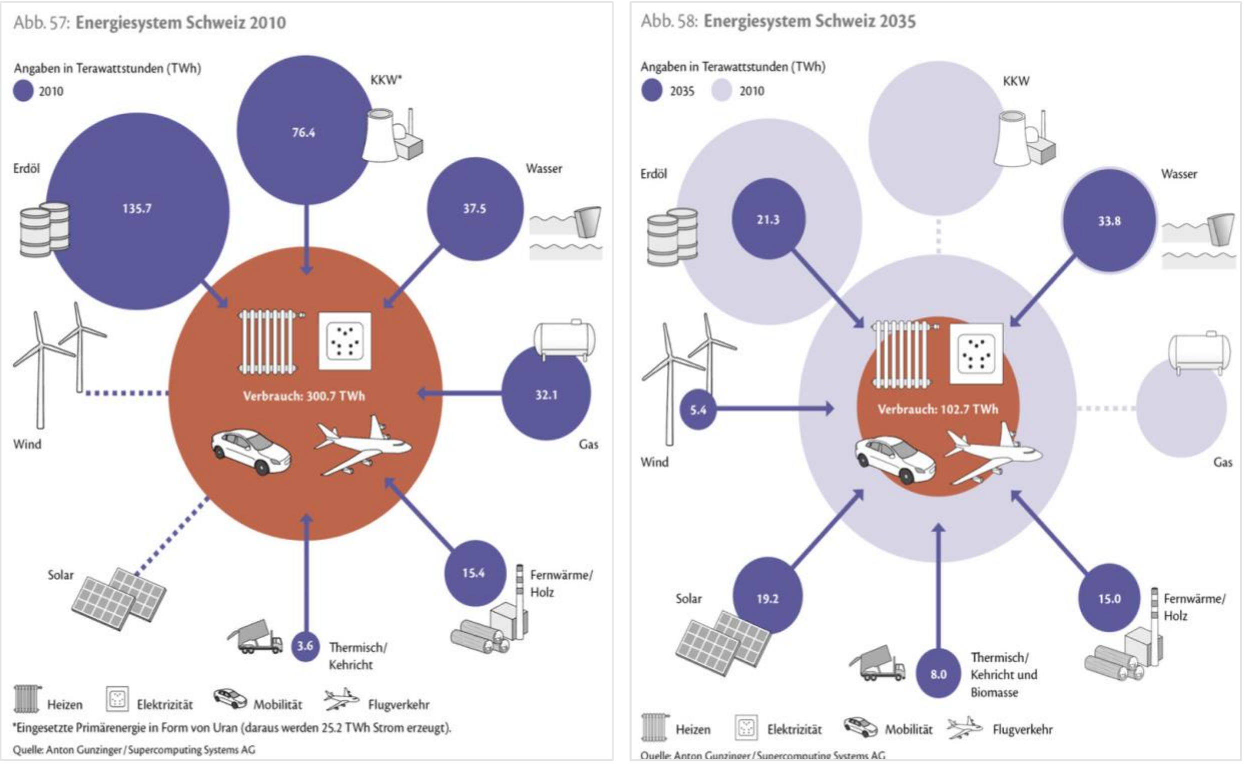


Fig. 13: Supply and consumption of energy for one year: initial state (left) and wishful thinking (right).

Scenario: Carrying on like before | Replacing nuclear by solar energy.. | .. plus wind | .. plus biomass | .. plus local battery storage

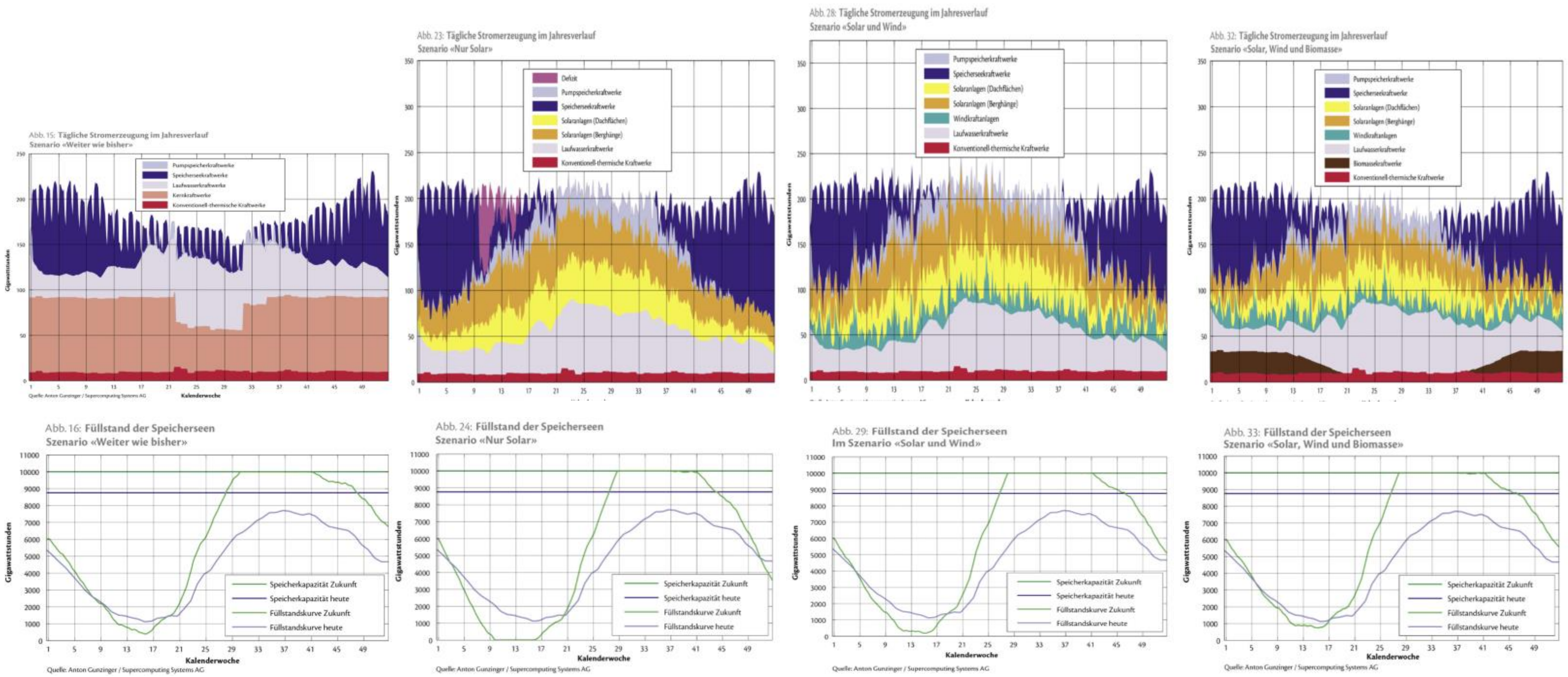
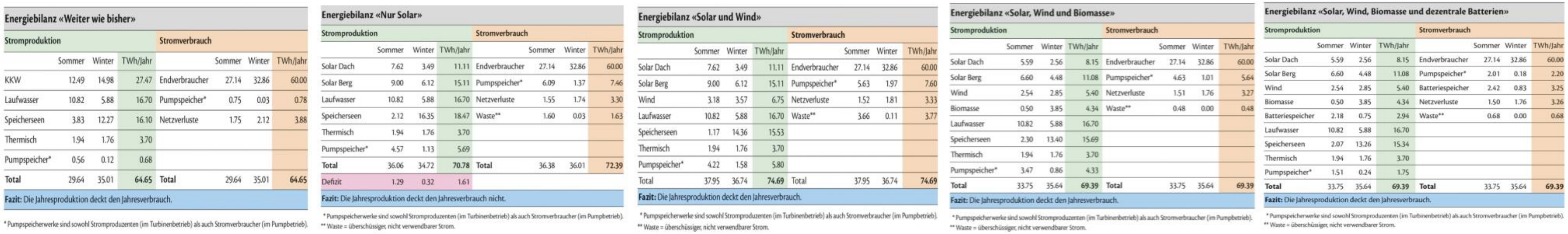


Fig. 14: Supply of energy over an average year (above) and filling level of reservoir lakes over an average year (below).



Energiebilanz «Weiter wie bisher»

Stromproduktion	Sommer	Winter	TWh/Jahr	Stromverbrauch	Sommer	Winter	TWh/Jahr
KKW	12.49	14.98	27.47	Endverbraucher	27.14	32.86	60.00
Laufwasser	10.82	5.88	16.70	Pumpspeicher*	0.75	0.03	0.78
Speicherseen	3.83	12.27	16.10	Netzverluste	1.75	2.12	3.88
Thermisch	1.94	1.76	3.70				
Pumpspeicher*	0.56	0.12	0.68				
Total	29.64	35.01	**64.65**	**Total**	29.64	35.01	**64.65**

Fazit: Die Jahresproduktion deckt den Jahresverbrauch.

* Pumpspeicherwerke sind sowohl Stromproduzenten (im Turbinenbetrieb) als auch Stromverbraucher (im Pumpbetrieb).

Energiebilanz «Nur Solar»

Stromproduktion	Sommer	Winter	TWh/Jahr	Stromverbrauch	Sommer	Winter	TWh/Jahr
Solar Dach	7.62	3.49	11.11	Endverbraucher	27.14	32.86	60.00
Solar Berg	9.00	6.12	15.11	Pumpspeicher*	6.09	1.37	7.46
Laufwasser	10.82	5.88	16.70	Netzverluste	1.55	1.74	3.30
Speicherseen	2.12	16.35	18.47	Waste**	1.60	0.03	1.63
Thermisch	1.94	1.76	3.70				
Pumpspeicher*	4.57	1.13	5.69				
Total	36.06	34.72	**70.78**	**Total**	36.38	36.01	**72.39**
Defizit	1.29	0.32	1.61				

Fazit: Die Jahresproduktion deckt den Jahresverbrauch nicht.

* Pumpspeicherwerke sind sowohl Stromproduzenten (im Turbinenbetrieb) als auch Stromverbraucher (im Pumpbetrieb).
** Waste = überschüssiger, nicht verwendbarer Strom.

Energiebilanz «Solar und Wind»

Stromproduktion	Sommer	Winter	TWh/Jahr	Stromverbrauch	Sommer	Winter	TWh/Jahr
Solar Dach	7.62	3.49	11.11	Endverbraucher	27.14	32.86	60.00
Solar Berg	9.00	6.12	15.11	Pumpspeicher*	5.63	1.97	7.60
Wind	3.18	3.57	6.75	Netzverluste	1.52	1.81	3.33
Laufwasser	10.82	5.88	16.70	Waste**	3.66	0.11	3.77
Speicherseen	1.17	14.36	15.53				
Thermisch	1.94	1.76	3.70				
Pumpspeicher*	4.22	1.58	5.80				
Total	37.95	36.74	**74.69**	Total	37.95	36.74	**74.69**

Fazit: Die Jahresproduktion deckt den Jahresverbrauch.

* Pumpspeicherwerke sind sowohl Stromproduzenten (im Turbinenbetrieb) als auch Stromverbraucher (im Pumpbetrieb).
** Waste = überschüssiger, nicht verwendbarer Strom.

Energiebilanz «Solar, Wind und Biomasse»

Stromproduktion	Sommer	Winter	TWh/Jahr	Stromverbrauch	Sommer	Winter	TWh/Jahr
Solar Dach	5.59	2.56	8.15	Endverbraucher	27.14	32.86	60.00
Solar Berg	6.60	4.48	11.08	Pumpspeicher*	4.63	1.01	5.64
Wind	2.54	2.85	5.40	Netzverluste	1.51	1.76	3.27
Biomasse	0.50	3.85	4.34	Waste**	0.48	0.00	0.48
Laufwasser	10.82	5.88	16.70				
Speicherseen	2.30	13.40	15.69				
Thermisch	1.94	1.76	3.70				
Pumpspeicher*	3.47	0.86	4.33				
Total	33.75	35.64	**69.39**	**Total**	33.75	35.64	**69.39**

Fazit: Die Jahresproduktion deckt den Jahresverbrauch.

* Pumpspeicherwerke sind sowohl Stromproduzenten (im Turbinenbetrieb) als auch Stromverbraucher (im Pumpbetrieb).
** Waste = überschüssiger, nicht verwendbarer Strom.

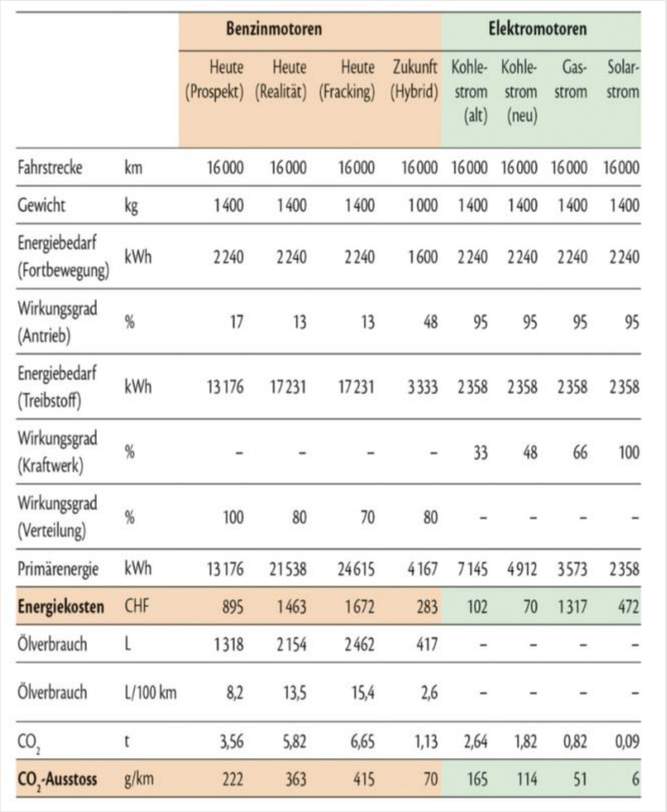
Energiebilanz «Solar, Wind, Biomasse und dezentrale Batterien»

Stromproduktion	Sommer	Winter	TWh/Jahr	Stromverbrauch	Sommer	Winter	TWh/Jahr
Solar Dach	5.59	2.56	8.15	Endverbraucher	27.14	32.86	60.00
Solar Berg	6.60	4.48	11.08	Pumpspeicher*	2.01	0.18	2.20
Wind	2.54	2.85	5.40	Batteriespeicher	2.42	0.83	3.25
Biomasse	0.50	3.85	4.34	Netzverluste	1.50	1.76	3.26
Batteriespeicher	2.18	0.75	2.94	Waste**	0.68	0.00	0.68
Laufwasser	10.82	5.88	16.70				
Speicherseen	2.07	13.26	15.34				
Thermisch	1.94	1.76	3.70				
Pumpspeicher*	1.51	0.24	1.75				
Total	33.75	35.64	**69.39**	**Total**	33.75	35.64	**69.39**

Fazit: Die Jahresproduktion deckt den Jahresverbrauch.

* Pumpspeicherwerke sind sowohl Stromproduzenten (im Turbinenbetrieb) als auch Stromverbraucher (im Pumpbetrieb).
** Waste = überschüssiger, nicht verwendbarer Strom.

Fig. 15: Balance of electrical energy for an average year.



		Benzinmotoren				Elektromotoren			
		Heute (Prospekt)	Heute (Realität)	Heute (Fracking)	Zukunft (Hybrid)	Kohle-strom (alt)	Kohle-strom (neu)	Gas-strom	Solar-strom
Fahrstrecke	km	16000	16000	16000	16000	16000	16000	16000	16000
Gewicht	kg	1400	1400	1400	1000	1400	1400	1400	1400
Energiebedarf (Fortbewegung)	kWh	2240	2240	2240	1600	2240	2240	2240	2240
Wirkungsgrad (Antrieb)	%	17	13	13	48	95	95	95	95
Energiebedarf (Treibstoff)	kWh	13176	17231	17231	3333	2358	2358	2358	2358
Wirkungsgrad (Kraftwerk)	%	-	-	-	-	33	48	66	100
Wirkungsgrad (Verteilung)	%	100	80	70	80	-	-	-	-
Primärenergie	kWh	13176	21538	24615	4167	7145	4912	3573	2358
Energiekosten	CHF	895	1463	1672	283	102	70	1317	472
Ölverbrauch	L	1318	2154	2462	417	-	-	-	-
Ölverbrauch	L/100 km	8,2	13,5	15,4	2,6	-	-	-	-
CO_2	t	3,56	5,82	6,65	1,13	2,64	1,82	0,82	0,09
CO_2-Ausstoss	g/km	222	363	415	70	165	114	51	6

Fig. 16: Key figures for automotive drive.

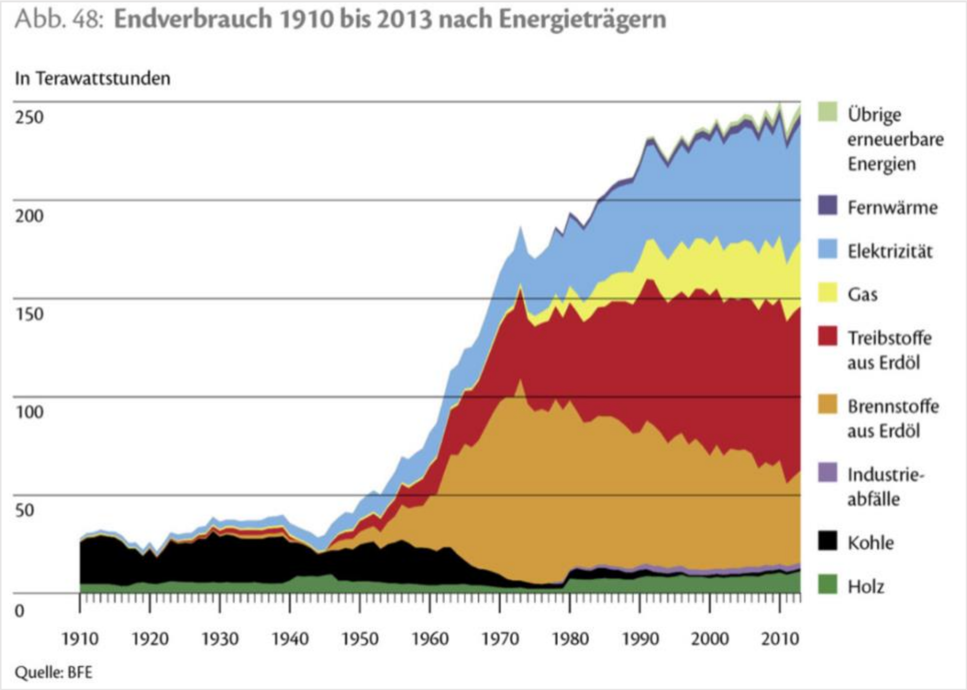


Abb. 48: **Endverbrauch 1910 bis 2013 nach Energieträgern**

Quelle: BFE

Fig. 17: Energy output consumption.

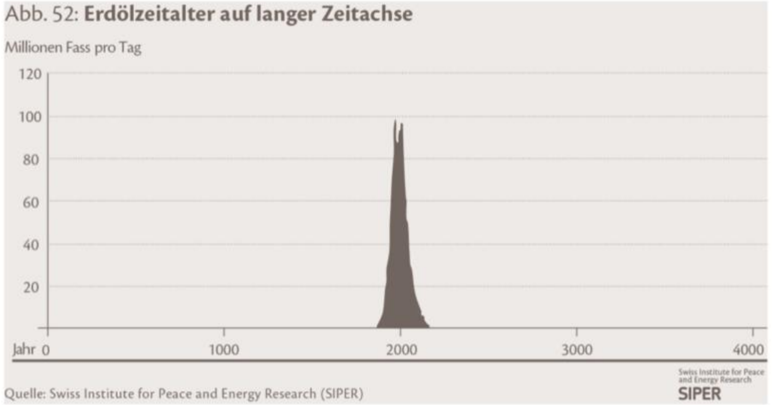


Abb. 52: **Erdölzeitalter auf langer Zeitachse**

Quelle: Swiss Institute for Peace and Energy Research (SIPER)

Fig. 18: Fossil fuel age over the long term.

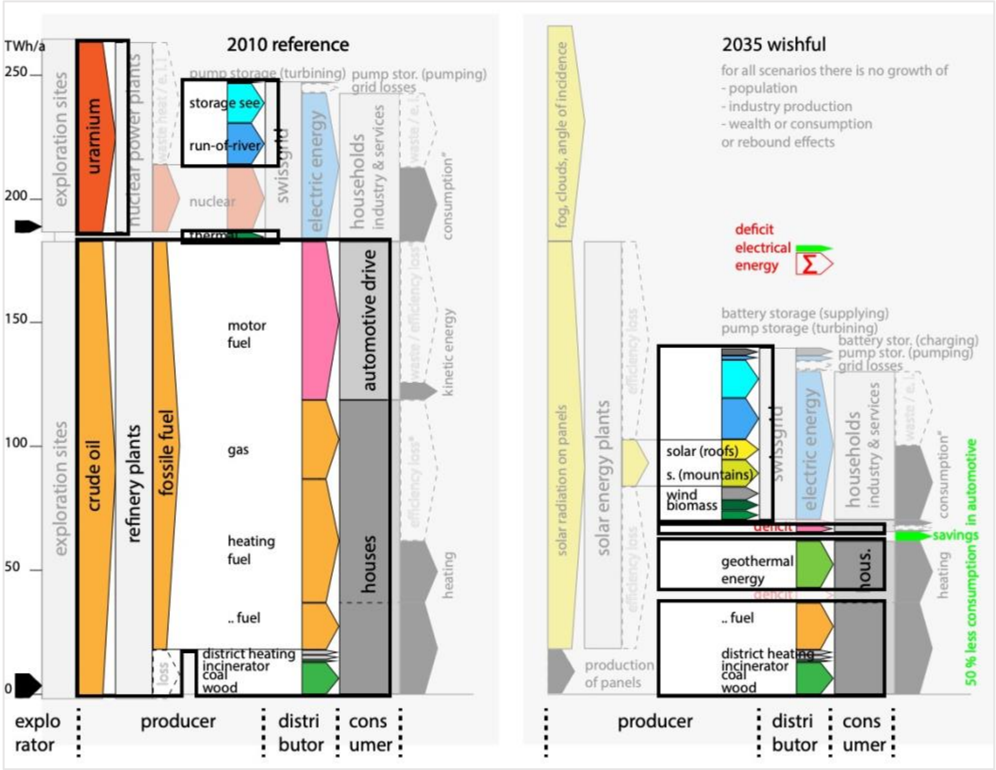


Fig. 19: Balance of energy for an average year: Scenarios according to [7], depiction from case study.

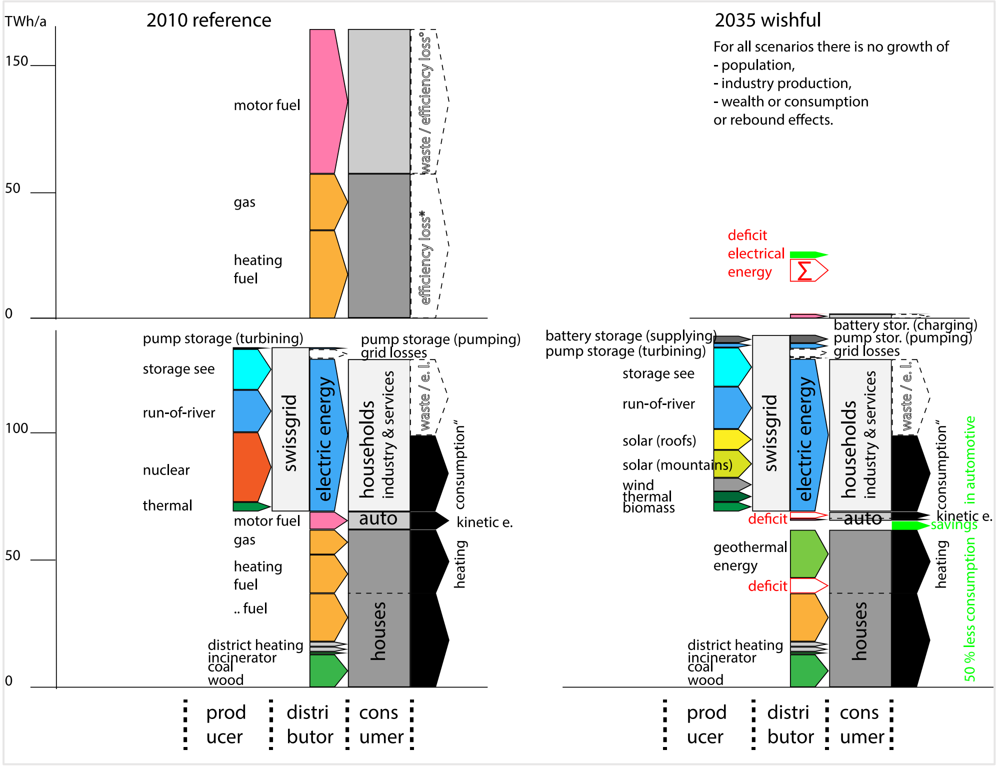


Fig. 20: Balance of energy for an average year: Scenarios according to [7], depiction from case study.

11. Energy revolution Switzerland: Case study

Fig. 21: Balance of energy for an average year: Scenarios according to [7] and case study (on the next page).

	2010	Wishful thinking for 2035			
		~~nuc..~~ Solar ..	.. + wind	.. + biomass	.. + local battery store
Supply and consumption of energy [TWh/a]					
Σ electric energy	**60**	**58.4**	**60**	**60**	**60**
wind			6.8	5.4	5.4
solar (mountain)		15.1	15.1	11.1	11.1
solar (roof)		11.1	11.1	8.2	8.2
battery storage (charging)					-3.3
battery storage (supplying)					2.9
pump storage (pumping)	-0.8	-7.5	-7.6	-5.6	-2.2
pump storage (turbining)	0.7	5.7	5.8	4.3	1.8
storage see	16.1	18.5	15.5	15.7	15.4
Grimselwerke	2.2	2.2	2.2	2.2	2.2
Grimsel, rise of dam by 23 m		0.7			
Creuson-Dixence	1.8	1.8	1.8	1.8	1.8
~~Greina~~	~~0.1~~				
..and many more	12.1	12.1	12.1	12.1	12.1
additional plants		1.7			
run-of-river	16.7	16.7	16.7	16.7	16.7
nuclear	27.5				
Leibstadt	9.2				
Gösgen	7.8				
Beznau I+II	5.8				
Mühleberg	2.8				
biomass				4.3	4.3
thermal	3.7	3.7	3.7	3.7	3.7
waste	0	-1.6	-3.8	-0.5	-0.7
grid losses	-3.9	-3.3	-3.3	-3.3	-3.3
deficit from transition nuclear > renewables		**1.6**			
automotive (fossile energy)	**7**	**0.9**	**0.9**	**0.9**	**0.9**
efficiency loss (90 / 60 %)	-57	-1.8	-1.8	-1.8	-1.8
motor fuel	64	2.7	2.7	2.7	2.7
automotive (electrical energy)		**2.6**	**2.6**	**2.6**	**2.6**
efficiency loss: weight (-)					
efficiency loss: (5 %)		-0.1	-0.1	-0.1	-0.1
deficit from transition in transportation		**2.7**	**2.7**	**2.7**	**2.7**
automotive savings		**3.5**	**3.5**	**3.5**	**3.5**
heating (fossile energy)	**25**				
efficiency loss	-57				
gas	32				
fuel	50				
heating (heat pump)		**25**	**25**	**25**	**25**
efficiency loss		0	0	0	0
geothermal energy (heat pump 75 %)		19	19	19	19
deficit from transition in heating of houses		**6**	**6**	**6**	**6**
district heating	**2**	**2**	**2**	**2**	**2**
incinerator	**2**	**2**	**2**	**2**	**2**
coal	**1**	**1**	**1**	**1**	**1**
wood	**13**	**13**	**13**	**13**	**13**
.. fuel	**19**	**19**	**19**	**19**	**19**
Σ	**129**	**129**	**129**	**129**	**129**
Σ deficit electric energy		**10.3**	**8.7**	**8.7**	**8.7**
Leibstadt		9.2	9.2	9.2	9.2
Gösgen					
Beznau I+II					
Mühleberg		2.8			
Σ incl. nuclear power	**129**	**129**	**129**	**129**	**129**
Σ deficit electric energy					

	2010	More realistic approach until 2035			
		~~nuc..~~ Solar ..	.. + wind	.. + biomass	.. + local battery store
Supply and consumption of energy [TWh/a]					
Σ electric energy	**60**	**35.1**	**33.1**	**36.4**	**36.7**
wind			1.3	1.1	1.1
solar (mountain)		3	3	2.2	2.2
solar (roof)		2.2	2.2	1.6	1.6
battery storage (charging)					-0.7
battery storage (supplying)					0.6
pump storage (pumping)	-0.8	-7.5	-7.6	-5.6	-2.2
pump storage (turbining)	0.7	5.7	5.8	4.3	1.8
storage see	16.1	16.6	15.5	15.7	15.4
Grimselwerke	2.2	2.2	2.2	2.2	2.2
~~Grimsel, rise of dam by 23 m~~		~~0.7~~			
Creuson-Dixence	1.8	1.8	1.8	1.8	1.8
~~Greina~~	~~0.1~~				
..and many more	12.1	12.1	12.1	12.1	12.1
additional plants		0.5			
run-of-river	16.7	16.7	16.7	16.7	16.7
nuclear	27.5				
Leibstadt	9.2				
Gösgen	7.8				
Beznau I+II	5.8				
Mühleberg	2.8				
biomass				0.9	0.9
thermal	3.7	3.7	3.7	3.7	3.7
waste	0	-1.6	-3.8	-0.5	-0.7
grid losses	-3.9	-3.7	-3.7	-3.7	-3.7
deficit from transition nuclear > renewables		**24.9**	**26.9**	**23.6**	**23.3**
automotive (fossile energy)	**7**	**4.4**	**4.4**	**4.4**	**4.4**
efficiency loss (90 / 60 %)	-57	-17.6	-17.6	-17.6	-17.6
motor fuel	64	22	22	22	22
automotive (electrical energy)		**2.6**	**2.6**	**2.6**	**2.6**
efficiency loss: weight (20 %)		-0.85	-0.85	-0.85	-0.85
efficiency loss: accumulation a.o. (20 %)		-0.85	-0.85	-0.85	-0.85
deficit from transition in transportation		**4.3**	**4.3**	**4.3**	**4.3**
automotive savings		**0**	**0**	**0**	**0**
heating (fossile energy)	**25**	**20**	**20**	**20**	**20**
efficiency loss	-57	-46	-46	-46	-46
gas	32	26	26	26	26
fuel	50	40	40	40	40
heating (heat pump)		**5**	**5**	**5**	**5**
efficiency loss		-4	-4	-4	-4
geothermal energy (heat pump 67 %)		6	6	6	6
deficit from transition in heating of houses		**3**	**3**	**3**	**3**
district heating	**2**	**2**	**2**	**2**	**2**
incinerator	**2**	**2**	**2**	**2**	**2**
coal	**1**	**1**	**1**	**1**	**1**
wood	**13**	**13**	**13**	**13**	**13**
.. fuel	**19**	**19**	**19**	**19**	**19**
Σ	**129**	**129**	**129**	**129**	**129**
Σ deficit electric energy		**32.2**	**34.2**	**30.9**	**30.6**
Leibstadt	9.2	9.2	9.2	9.2	9.2
Gösgen	7.8	7.8	7.8	7.8	7.8
Beznau I+II	5.8	5.8	5.8	5.8	5.8
Mühleberg	2.8	2.8	2.8	2.8	2.8
Σ incl. nuclear power	**129**	**129**	**129**	**129**	**129**
Σ deficit electric energy		**4.7**	**6.7**	**3.4**	**3.1**

	2010	More realistic approach until 2100			
		~~nuc..~~ Solar ..	.. + wind	.. + biomass	.. + local battery store
Supply and consumption of energy [TWh/a]					
Σ electric energy	**60**	**58.4**	**60**	**60**	**60**
wind			6.8	5.4	5.4
solar (mountain)		15.1	15.1	11.1	11.1
solar (roof)		11.1	11.1	8.2	8.2
battery storage (charging)					-3.3
battery storage (supplying)					2.9
pump storage (pumping)	-0.8	-7.5	-7.6	-5.6	-2.2
pump storage (turbining)	0.7	5.7	5.8	4.3	1.8
storage see	16.1	18.5	15.5	15.7	15.4
Grimselwerke	2.2	2.2	2.2	2.2	2.2
Grimsel, rise of dam by 23 m		0.7			
Creuson-Dixence	1.8	1.8	1.8	1.8	1.8
~~Greina~~	~~0.1~~				
..and many more	12.1	12.1	12.1	12.1	12.1
additional plants		1.7			
run-of-river	16.7	16.7	16.7	16.7	16.7
nuclear	27.5				
Leibstadt	9.2				
Gösgen	7.8				
Beznau I+II	5.8				
Mühleberg	2.8				
biomass				4.3	4.3
thermal	3.7	3.7	3.7	3.7	3.7
waste	0	-1.6	-3.8	-0.5	-0.7
grid losses	-3.9	-3.3	-3.3	-3.3	-3.3
deficit from transition nuclear > renewables		**1.6**			
automotive (fossile energy)	**7**	**1.8**	**1.8**	**1.8**	**1.8**
efficiency loss (90 / 60 %)	-57	-3.6	-3.6	-3.6	-3.6
motor fuel	64	5.4	5.4	5.4	5.4
automotive (electrical energy)		**5.2**	**5.2**	**5.2**	**5.2**
efficiency loss: weight (20 %)		-1.7	-1.7	-1.7	-1.7
efficiency loss: accumulation a.o. (20 %)		-1.7	-1.7	-1.7	-1.7
deficit from transition in transportation		**8.6**	**8.6**	**8.6**	**8.6**
automotive savings		**0**	**0**	**0**	**0**
heating (fossile energy)	**25**				
efficiency loss	-57				
gas	32				
fuel	50				
heating (heat pump)		**25**	**25**	**25**	**25**
efficiency loss		-20	-20	-20	-20
geothermal energy (heat pump 67 %)		30	30	30	30
deficit from transition in heating of houses		**15**	**15**	**15**	**15**
district heating	**2**	**2**	**2**	**2**	**2**
incinerator	**2**	**2**	**2**	**2**	**2**
coal	**1**	**1**	**1**	**1**	**1**
wood	**13**	**13**	**13**	**13**	**13**
.. fuel	**19**	**19**	**19**	**19**	**19**
Σ	**129**	**129**	**129**	**129**	**129**
Σ deficit electric energy		**25.2**	**23.6**	**23.6**	**23.6**
Leibstadt	9.2	9.2	9.2	9.2	9.2
Gösgen	7.8	7.8	7.8	7.8	7.8
Beznau I+II	5.8	5.8	5.8	5.8	5.8
Mühleberg	2.8	2.8			
Σ incl. nuclear power	**129**	**129**	**129**	**129**	**129**
Σ deficit electric energy		**-2.3**	**-3.9**	**-3.9**	**-3.9**

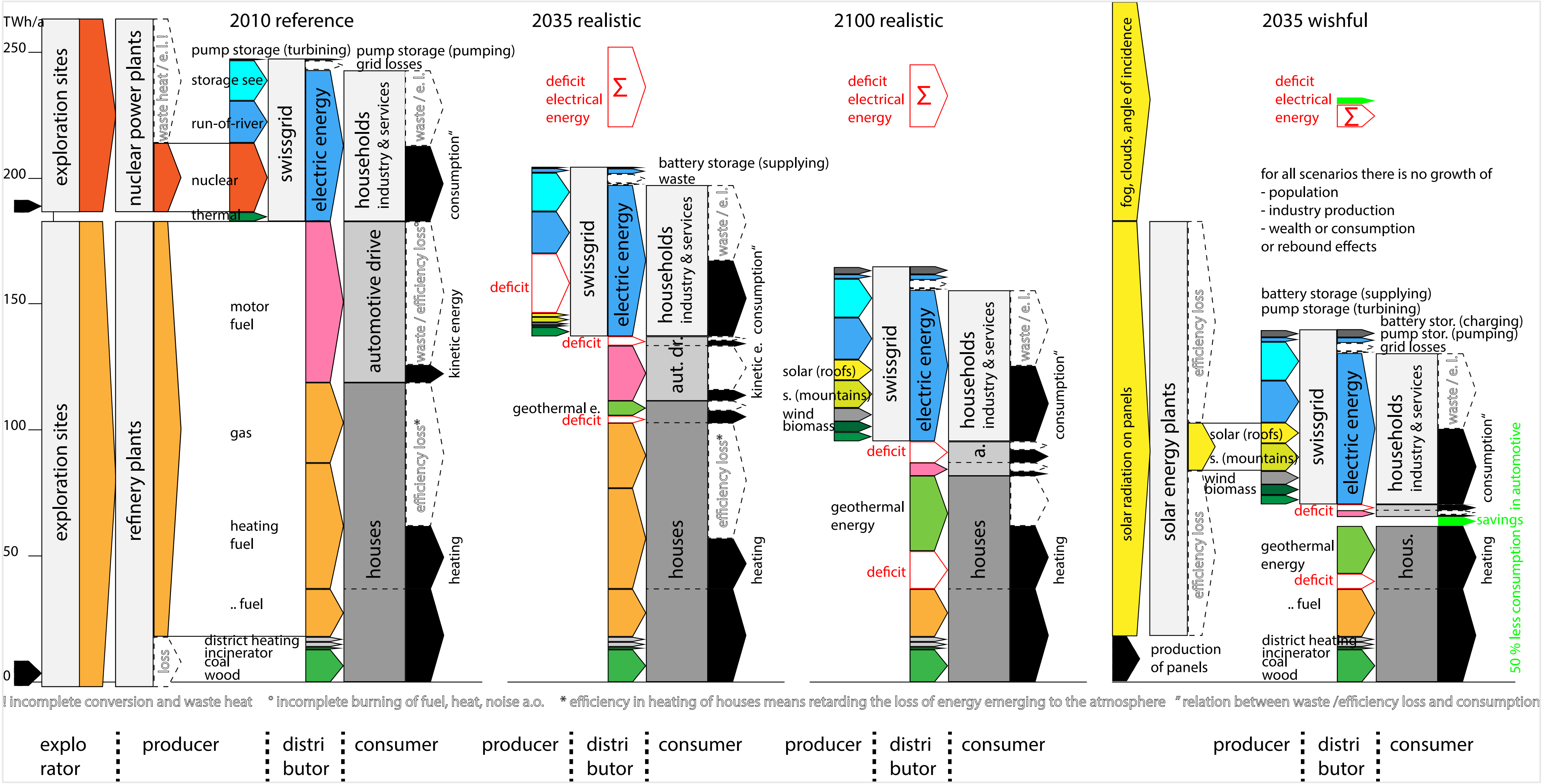


Fig. 22: Balance of energy for an average year: Scenarios according to [7] and case study.

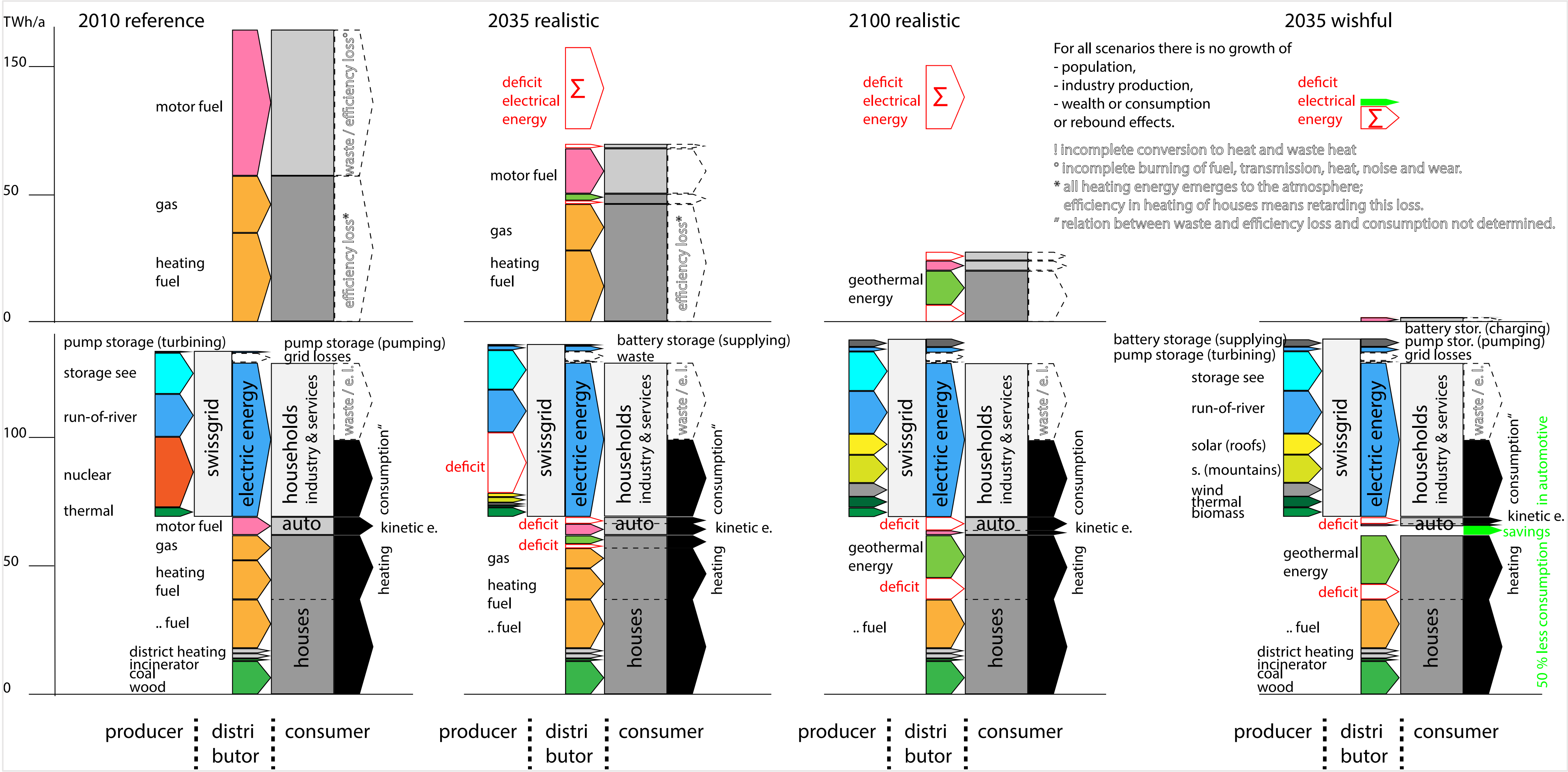


Fig. 23: Balance of energy for an average year: Scenarios according to [7] and case study.

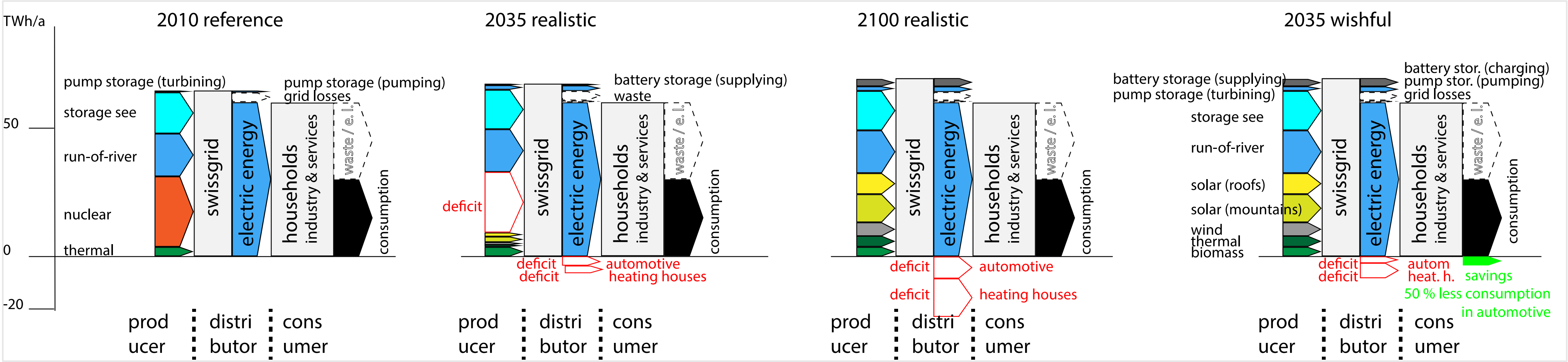
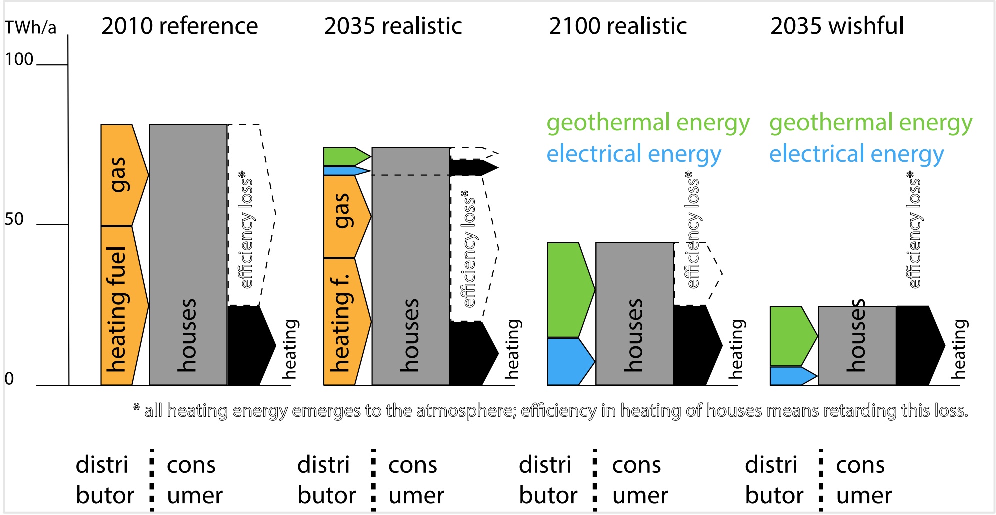
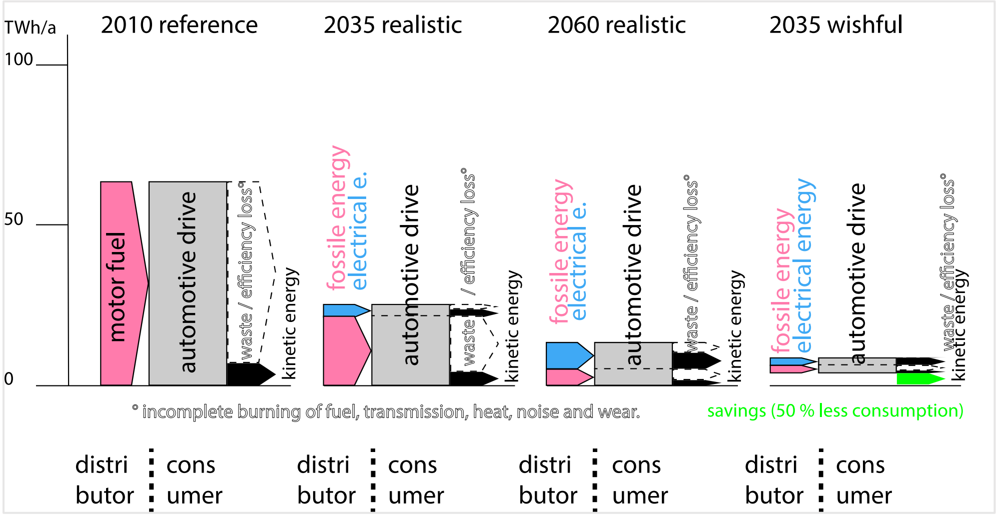


Fig. 24: Balance of energy for an average year: Scenarios according to [7] and case study.



* all heating energy emerges to the atmosphere; efficiency in heating of houses means retarding this loss.

Fig. 25: Scenarios for energy consumption of heating of houses.



° incomplete burning of fuel, transmission, heat, noise and wear.

Fig. 26: Scenarios for energy consumption of automotive.

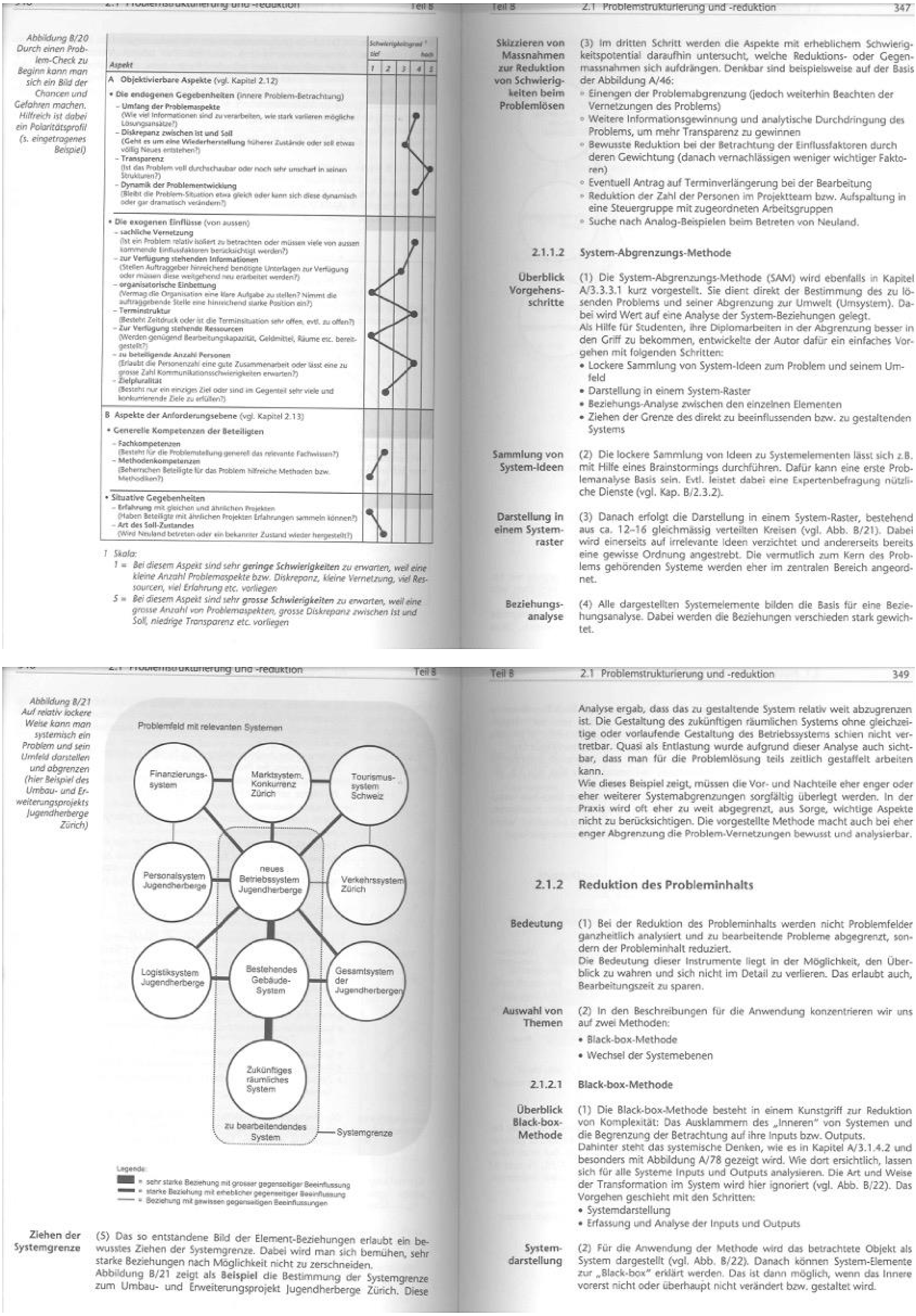


Abbildung B/20
Durch einen Problem-Check zu Beginn kann man sich ein Bild der Chancen und Gefahren machen. Hilfreich ist dabei ein Polaritätsprofil (s. eingetragenes Beispiel)

Aspekt — Schwierigkeitsgrad¹ tief … hoch: 1 2 3 4 5

A **Objektivierbare Aspekte** (vgl. Kapitel 2.12)

- **Die endogenen Gegebenheiten** (innere Problem-Betrachtung)
  - **Umfang der Problemaspekte** (Wie viel Informationen sind zu verarbeiten, wie stark variieren mögliche Lösungsansätze?)
  - **Diskrepanz zwischen Ist und Soll** (Geht es um eine Wiederherstellung früherer Zustände oder soll etwas völlig Neues entstehen?)
  - **Transparenz** (Ist das Problem voll durchschaubar oder noch sehr unscharf in seinen Strukturen?)
  - **Dynamik der Problementwicklung** (Bleibt die Problem-Situation etwa gleich oder kann sich diese dynamisch oder gar dramatisch verändern?)
- **Die exogenen Einflüsse** (von aussen)
  - **sachliche Vernetzung** (Ist ein Problem relativ isoliert zu betrachten oder müssen viele von aussen kommende Einflussfaktoren berücksichtigt werden?)
  - **zur Verfügung stehenden Informationen** (Stellen Auftraggeber hinreichend benötigte Unterlagen zur Verfügung oder müssen diese weitgehend neu erarbeitet werden?)
  - **organisatorische Einbettung** (Vermag die Organisation eine klare Aufgabe zu stellen? Nimmt die auftraggebende Stelle eine hinreichend starke Position ein?)
  - **Terminstruktur** (Besteht Zeitdruck oder ist die Terminsituation sehr offen, evtl. zu offen?)
  - **Zur Verfügung stehende Ressourcen** (Werden genügend Bearbeitungskapazität, Geldmittel, Räume etc. bereitgestellt?)
  - **zu beteiligende Anzahl Personen** (Erlaubt die Personenzahl eine gute Zusammenarbeit oder lässt eine zu grosse Zahl Kommunikationsschwierigkeiten erwarten?)
  - **Zielpluralität** (Besteht nur ein einziges Ziel oder sind im Gegenteil sehr viele und konkurrierende Ziele zu erfüllen?)

B **Aspekte der Anforderungsebene** (vgl. Kapitel 2.13)

- **Generelle Kompetenzen der Beteiligten**
  - **Fachkompetenzen** (Besteht für die Problemstellung generell das relevante Fachwissen?)
  - **Methodenkompetenzen** (Beherrschen Beteiligte für das Problem hilfreiche Methoden bzw. Methodiken?)
- **Situative Gegebenheiten**
  - **Erfahrung** mit gleichen und ähnlichen Projekten (Haben Beteiligte mit ähnlichen Projekten Erfahrungen sammeln können?)
  - **Art des Soll-Zustandes** (Wird Neuland betreten oder ein bekannter Zustand wieder hergestellt?)

1 *Skala:*
1 = *Bei diesem Aspekt sind sehr **geringe Schwierigkeiten** zu erwarten, weil eine kleine Anzahl Problemaspekte bzw. Diskrepanz, kleine Vernetzung, viel Ressourcen, viel Erfahrung etc. vorliegen*
5 = *Bei diesem Aspekt sind sehr **grosse Schwierigkeiten** zu erwarten, weil eine grosse Anzahl von Problemaspekten, grosse Diskrepanz zwischen Ist und Soll, niedrige Transparenz etc. vorliegen*

Skizzieren von Massnahmen zur Reduktion von Schwierigkeiten beim Problemlösen

(3) Im dritten Schritt werden die Aspekte mit erheblichem Schwierigkeitspotential daraufhin untersucht, welche Reduktions- oder Gegenmassnahmen sich aufdrängen. Denkbar sind beispielsweise auf der Basis der Abbildung A/46:

- Einengen der Problemabgrenzung (jedoch weiterhin Beachten der Vernetzungen des Problems)
- Weitere Informationsgewinnung und analytische Durchdringung des Problems, um mehr Transparenz zu gewinnen
- Bewusste Reduktion bei der Betrachtung der Einflussfaktoren durch deren Gewichtung (danach vernachlässigen weniger wichtiger Faktoren)
- Eventuell Antrag auf Terminverlängerung bei der Bearbeitung
- Reduktion der Zahl der Personen im Projektteam bzw. Aufspaltung in eine Steuergruppe mit zugeordneten Arbeitsgruppen
- Suche nach Analog-Beispielen beim Betreten von Neuland.

2.1.1.2 System-Abgrenzungs-Methode

Überblick Vorgehensschritte

(1) Die System-Abgrenzungs-Methode (SAM) wird ebenfalls in Kapitel A/3.3.3.1 kurz vorgestellt. Sie dient direkt der Bestimmung des zu lösenden Problems und seiner Abgrenzung zur Umwelt (Umsystem). Dabei wird Wert auf eine Analyse der System-Beziehungen gelegt.
Als Hilfe für Studenten, ihre Diplomarbeiten in der Abgrenzung besser in den Griff zu bekommen, entwickelte der Autor dafür ein einfaches Vorgehen mit folgenden Schritten:

- Lockere Sammlung von System-Ideen zum Problem und seinem Umfeld
- Darstellung in einem System-Raster
- Beziehungs-Analyse zwischen den einzelnen Elementen
- Ziehen der Grenze des direkt zu beeinflussenden bzw. zu gestaltenden Systems

Sammlung von System-Ideen

(2) Die lockere Sammlung von Ideen zu Systemelementen lässt sich z.B. mit Hilfe eines Brainstormings durchführen. Dafür kann eine erste Problemanalyse Basis sein. Evtl. leistet dabei eine Expertenbefragung nützliche Dienste (vgl. Kap. B/2.3.2).

Darstellung in einem System-raster

(3) Danach erfolgt die Darstellung in einem System-Raster, bestehend aus ca. 12–16 gleichmässig verteilten Kreisen (vgl. Abb. B/21). Dabei wird einerseits auf irrelevante Ideen verzichtet und andererseits bereits eine gewisse Ordnung angestrebt. Die vermutlich zum Kern des Problems gehörenden Systeme werden eher im zentralen Bereich angeordnet.

Beziehungs-analyse

(4) Alle dargestellten Systemelemente bilden die Basis für eine Beziehungsanalyse. Dabei werden die Beziehungen verschieden stark gewichtet.

Abbildung B/21
Auf relativ lockere Weise kann man systemisch ein Problem und sein Umfeld darstellen und abgrenzen (hier Beispiel des Umbau- und Erweiterungsprojekts Jugendherberge Zürich)

Ziehen der Systemgrenze

(5) Das so entstandene Bild der Element-Beziehungen erlaubt ein bewusstes Ziehen der Systemgrenze. Dabei wird man sich bemühen, sehr starke Beziehungen nach Möglichkeit nicht zu zerschneiden.
Abbildung B/21 zeigt als **Beispiel** die Bestimmung der Systemgrenze zum Umbau- und Erweiterungsprojekt Jugendherberge Zürich. Diese

Analyse ergab, dass das zu gestaltende System relativ weit abzugrenzen ist. Die Gestaltung des zukünftigen räumlichen Systems ohne gleichzeitige oder vorlaufende Gestaltung des Betriebssystems schien nicht vertretbar. Quasi als Entlastung wurde aufgrund dieser Analyse auch sichtbar, dass man für die Problemlösung teils zeitlich gestaffelt arbeiten kann.
Wie dieses Beispiel zeigt, müssen die Vor- und Nachteile eher enger oder eher weiterer Systemabgrenzungen sorgfältig überlegt werden. In der Praxis wird oft eher zu weit abgegrenzt, aus Sorge, wichtige Aspekte nicht zu berücksichtigen. Die vorgestellte Methode macht auch bei eher enger Abgrenzung die Problem-Vernetzungen bewusst und analysierbar.

2.1.2 Reduktion des Probleminhalts

Bedeutung

(1) Bei der Reduktion des Probleminhalts werden nicht Problemfelder ganzheitlich analysiert und zu bearbeitende Probleme abgegrenzt, sondern der Probleminhalt reduziert.
Die Bedeutung dieser Instrumente liegt in der Möglichkeit, den Überblick zu wahren und sich nicht im Detail zu verlieren. Das erlaubt auch, Bearbeitungszeit zu sparen.

Auswahl von Themen

(2) In den Beschreibungen für die Anwendung konzentrieren wir uns auf zwei Methoden:

- Black-box-Methode
- Wechsel der Systemebenen

2.1.2.1 Black-box-Methode

Überblick Black-box-Methode

(1) Die Black-box-Methode besteht in einem Kunstgriff zur Reduktion von Komplexität: Das Ausklammern des „Inneren" von Systemen und die Begrenzung der Betrachtung auf ihre Inputs bzw. Outputs.
Dahinter steht das systemische Denken, wie es in Kapitel A/3.1.4.2 und besonders mit Abbildung A/78 gezeigt wird. Wie dort ersichtlich, lassen sich für alle Systeme Inputs und Outputs analysieren. Die Art und Weise der Transformation im System wird hier ignoriert (vgl. Abb. B/22). Das Vorgehen geschieht mit den Schritten:

- Systemdarstellung
- Erfassung und Analyse der Inputs und Outputs

System-darstellung

(2) Für die Anwendung der Methode wird das betrachtete Objekt als System dargestellt (vgl. Abb. B/22). Danach können System-Elemente zur „Black-box" erklärt werden. Das ist dann möglich, wenn das Innere vorerst nicht oder überhaupt nicht verändert bzw. gestaltet wird.

Fig. 27: System demarcation method from [6].

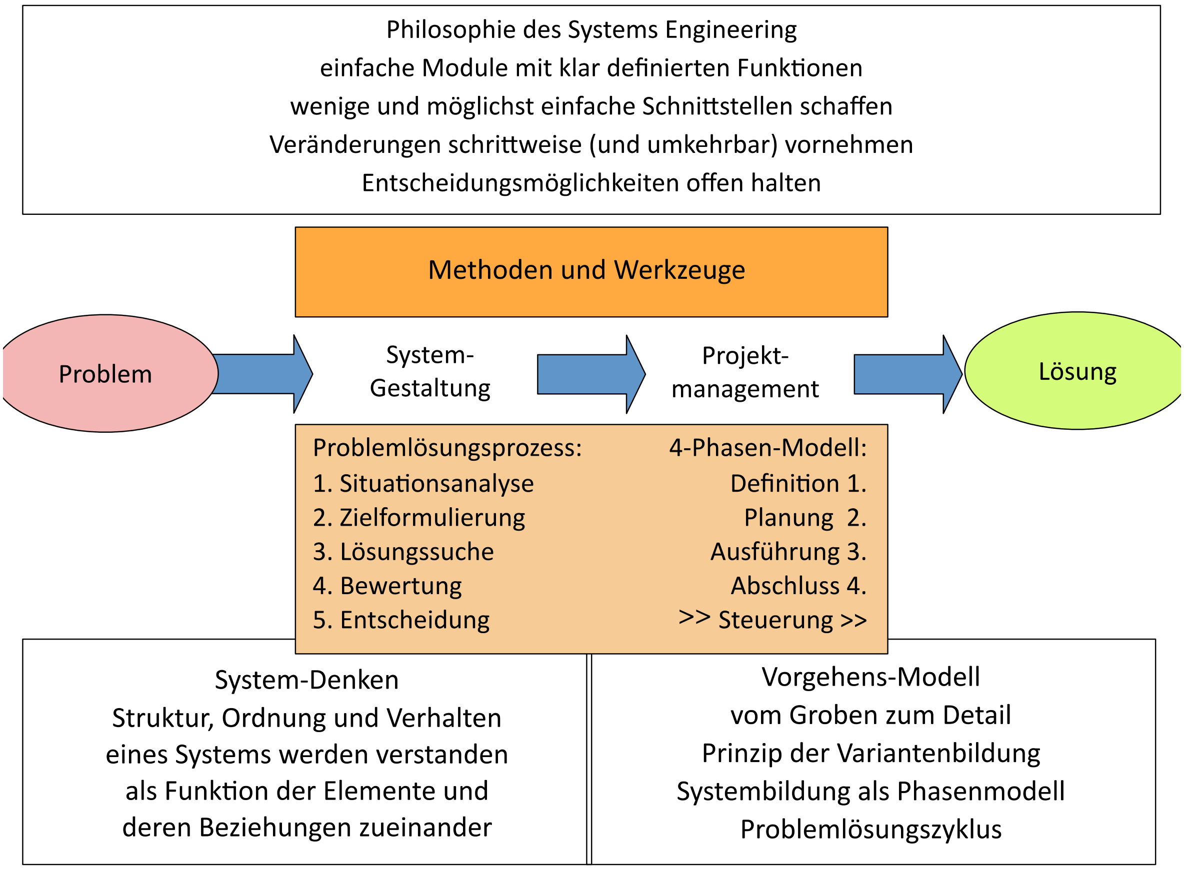


Fig. 28: Systems engineering overview (from [4]).

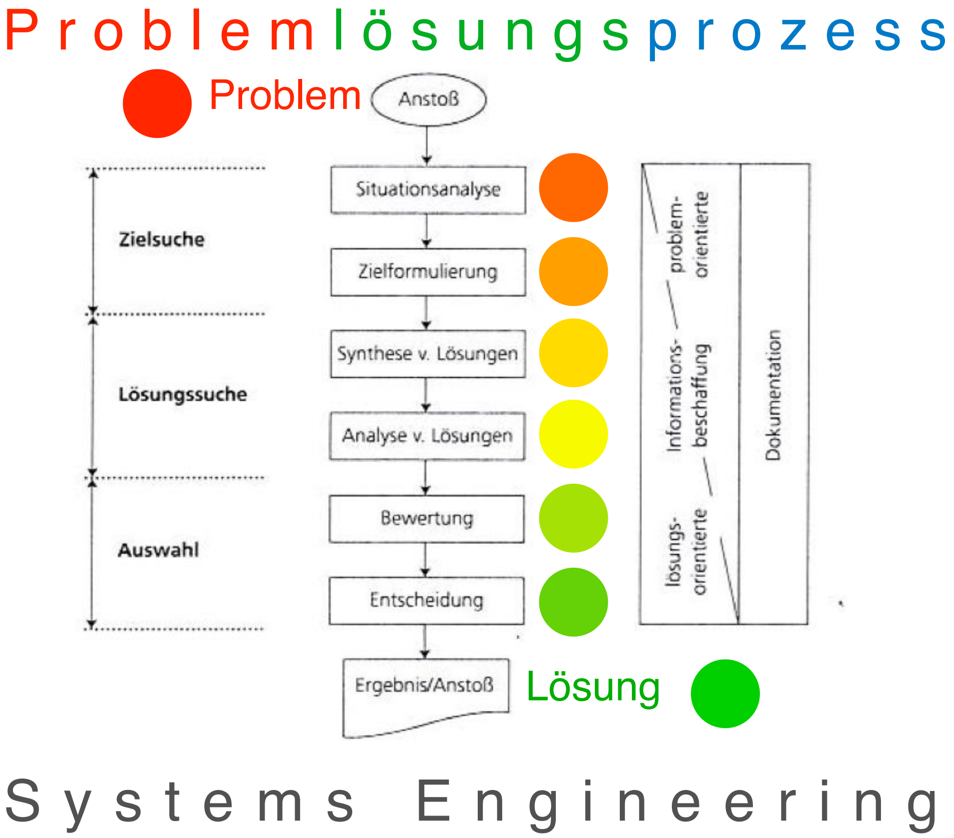


Fig. 29: Problem solving process (from [4]).

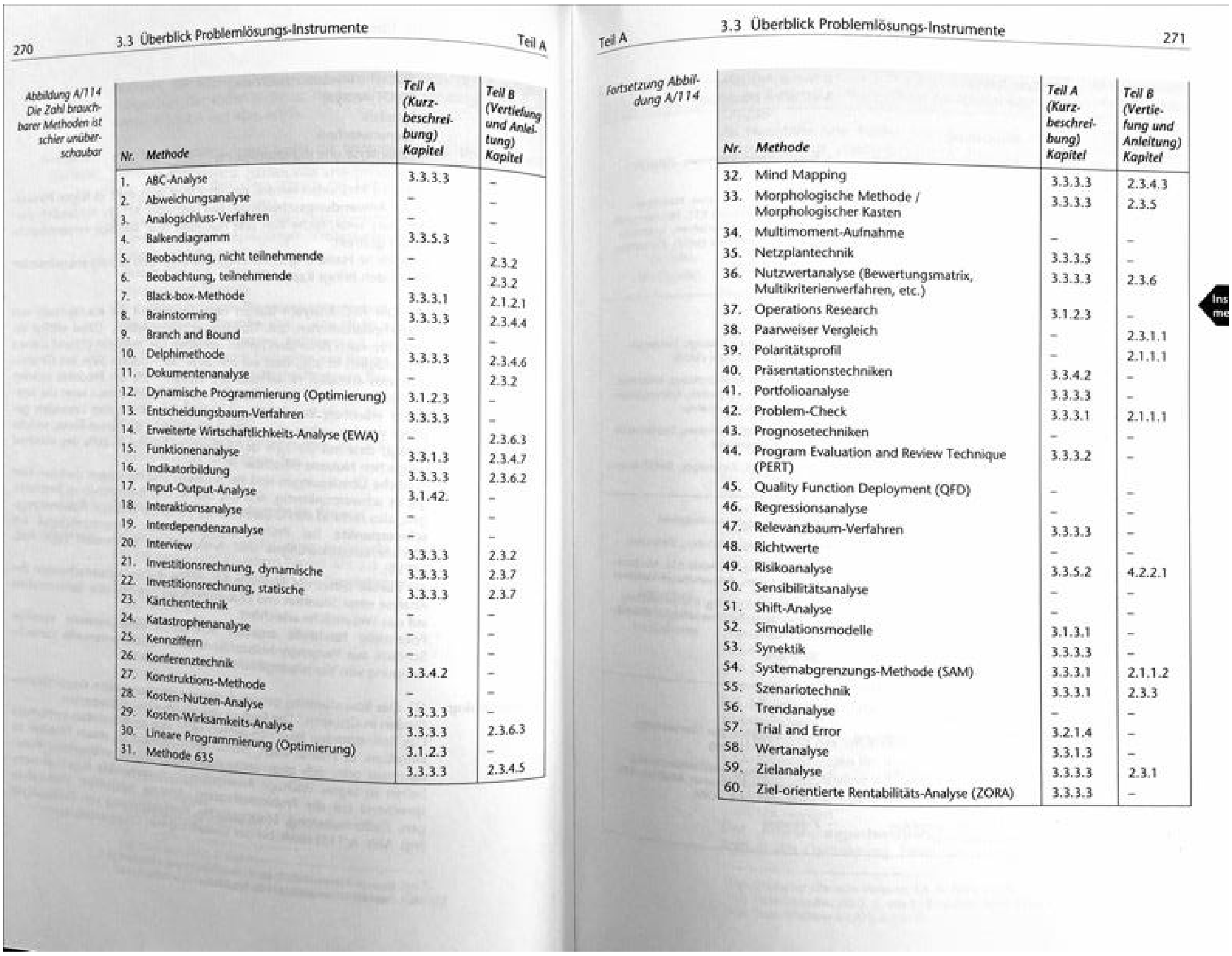


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Abbildung A/114 Die Zahl brauchbarer Methoden ist schier unüberschaubar

Nr.	Methode	Teil A (Kurzbeschreibung) Kapitel	Teil B (Vertiefung und Anleitung) Kapitel
1.	ABC-Analyse	3.3.3.3	–
2.	Abweichungsanalyse	–	–
3.	Analogschluss-Verfahren	–	–
4.	Balkendiagramm	3.3.5.3	–
5.	Beobachtung, nicht teilnehmende	–	2.3.2
6.	Beobachtung, teilnehmende	–	2.3.2
7.	Black-box-Methode	3.3.3.1	2.1.2.1
8.	Brainstorming	3.3.3.3	2.3.4.4
9.	Branch and Bound	–	–
10.	Delphimethode	3.3.3.3	2.3.4.6
11.	Dokumentenanalyse	–	2.3.2
12.	Dynamische Programmierung (Optimierung)	3.1.2.3	–
13.	Entscheidungsbaum-Verfahren	3.3.3.3	–
14.	Erweiterte Wirtschaftlichkeits-Analyse (EWA)	–	2.3.6.3
15.	Funktionenanalyse	3.3.1.3	2.3.4.7
16.	Indikatorbildung	3.3.3.3	2.3.6.2
17.	Input-Output-Analyse	3.1.42.	–
18.	Interaktionsanalyse	–	–
19.	Interdependenzanalyse	–	–
20.	Interview	3.3.3.3	2.3.2
21.	Investitionsrechnung, dynamische	3.3.3.3	2.3.7
22.	Investitionsrechnung, statische	3.3.3.3	2.3.7
23.	Kärtchentechnik	–	–
24.	Katastrophenanalyse	–	–
25.	Kennziffern	–	–
26.	Konferenztechnik	3.3.4.2	–
27.	Konstruktions-Methode	–	–
28.	Kosten-Nutzen-Analyse	3.3.3.3	–
29.	Kosten-Wirksamkeits-Analyse	3.3.3.3	2.3.6.3
30.	Lineare Programmierung (Optimierung)	3.1.2.3	–
31.	Methode 635	3.3.3.3	2.3.4.5
32.	Mind Mapping	3.3.3.3	2.3.4.3
33.	Morphologische Methode / Morphologischer Kasten	3.3.3.3	2.3.5
34.	Multimoment-Aufnahme	–	–
35.	Netzplantechnik	3.3.3.5	–
36.	Nutzwertanalyse (Bewertungsmatrix, Multikriterienverfahren, etc.)	3.3.3.3	2.3.6
37.	Operations Research	3.1.2.3	–
38.	Paarweiser Vergleich	–	2.3.1.1
39.	Polaritätsprofil	–	2.1.1.1
40.	Präsentationstechniken	3.3.4.2	–
41.	Portfolioanalyse	3.3.3.3	–
42.	Problem-Check	3.3.3.1	2.1.1.1
43.	Prognosetechniken	–	–
44.	Program Evaluation and Review Technique (PERT)	3.3.3.2	–
45.	Quality Function Deployment (QFD)	–	–
46.	Regressionsanalyse	–	–
47.	Relevanzbaum-Verfahren	3.3.3.3	–
48.	Richtwerte	–	–
49.	Risikoanalyse	3.3.5.2	4.2.2.1
50.	Sensibilitätsanalyse	–	–
51.	Shift-Analyse	–	–
52.	Simulationsmodelle	3.1.3.1	–
53.	Synektik	3.3.3.3	–
54.	Systemabgrenzungs-Methode (SAM)	3.3.3.1	2.1.1.2
55.	Szenariotechnik	3.3.3.1	2.3.3
56.	Trendanalyse	–	–
57.	Trial and Error	3.2.1.4	–
58.	Wertanalyse	3.3.1.3	–
59.	Zielanalyse	3.3.3.3	2.3.1
60.	Ziel-orientierte Rentabilitäts-Analyse (ZORA)	3.3.3.3	–

Teil A 3.3 Überblick Problemlösungs-Instrumente 271

Fortsetzung Abbildung A/114

Fig. 30: Methods for problem solving (from [6]).