# CASH FLOW OPTIMIZATION BASED ON AN INTEGRATED ASSET MANAGEMENT

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## *ABSTRACT*

*Capital expenditure programs to ensure or to improve the quality of the existing utility infrastructures are often very expensive and lead to a low (and unsecure) rate of return on assets. What are the key-levers for a secure return on assets? How can the risks to achieve the objectives of the investment program be minimized? As an indication for a stable and secure return on assets, the related Cash Flow development of the investment program was chosen. To solve the given task, the existing cause-effect-relations of the applied asset simulation tool had to be adapted by additional influences on the asset base and additional financial and regulatory restrictions (like the revenue cap or revenue/expenditure stream) were considered. Based on this the existing asset simulation-tool had to be enabled to execute additional calculations of all relevant values (like costs and revenue cap) to evaluate the related Cash Flow of the investment program. Based on these adjustments, scenarios to optimize and to secure the return on assets were calculated.*

## INTRODUCTION AND OBJECTIVES

ENERVIE provides energy services for electricity, gas and water in North Rhine-Westphalia, Germany. ENERVIE´s subsidiary, EnervieAssetNetWork, is grid operator for electricity, gas and water distribution grids in Hagen, Lüdenscheid and the surrounding cities. To develop sustainable and proven investments and maintenance strategies for its infrastructures, ENERVIE AssetNetWork is, already for many years, applying a strategic asset simulation tool [1;2;3;4;5]. The asset simulation tool is fully integrated in the asset management processes and the IT landscape. It covers the technical asset part in focus, but also the financial- and regulatory influences (see Fig. 1).

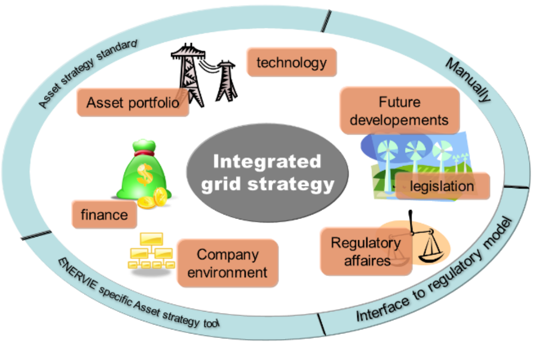


*Figure 1: Relevant influences are part of the simulation model*

Asset Simulation is the central planning tool of ENERVIE AssetNetWork and is fully integrated with the other parts of the business (see Fig. 2). The integrated simulation model covers 41 asset groups for the sectors electricity, gas, water and all relevant performance indicators for each asset role (allocation of financial resources and commissioning of measures for Asset Management; setting of strategic targets, financing decisions and balancing company interests for Asset Owner; operational planning of measures and state evaluation for Asset Service).

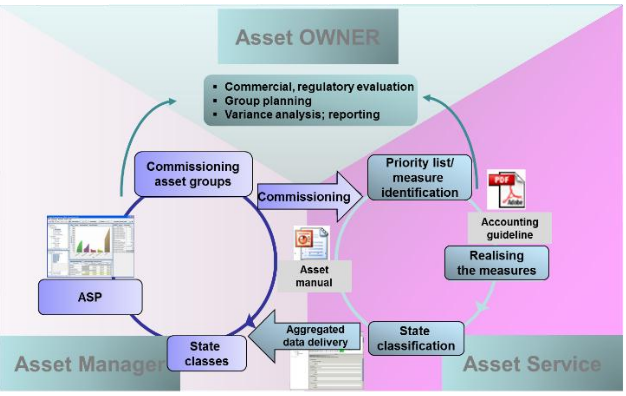


*Figure 2: Overview of strategic planning and operational implementation at EnervieAssetNetWork*

EnervieAssetNetWork had to manage a major capital expenditure program (~600 Mio. € over 20 years) to ensure that agreed quality targets for the existing electricity, gas and water infrastructure are achieved. Compared with unregulated markets, the return on investments was quite small and due to political circumstances (-> uncertainty how the energy transition is handled / changing objectives of next regulation periods) uncertain, too. Against this background, several questions had to be answered:

- What are the key-levers for a secure return on assets?
- What is the impact of the different sectors electricity, gas and water?
- Does the current schedule of the capital expenditure program lead to the best return on assets? Is there potential for better timing?

## APPROACH

As an indication for a stable and secure return on assets, the related Cash Flow development of the investment program was chosen. To answer the questions the existing

cause-effect-relations of the applied asset simulation tool had to be extended by additional influences on the asset base and additional financial and regulatory restrictions (like the revenue cap or revenue/expenditure stream).
Furthermore it was necessary to combine the existing dynamic asset simulation approach with an „asset optimization approach". The chosen "asset optimization approach" works based on evolutionary algorithms and helps to find robust asset strategies for possible investment and maintenance measures taking into account all given restrictions [6;7;8;9;10].

## BUILDING THE OPTIMIZATION MODEL

### Model and data setup

The geographically separated areas and concessions of ENERVIE AssetNetWork are represented in the segment tree of the existing asset simulation model. To answer the given questions this level of detail is not required. Based on the existing asset Simulation model, ENERVIE AssetNetWork developed a "simplified" asset simulation model to execute the necessary calculations:

- The segment tree of the model is simplified by rearranging all the detailed information to the relevant groups "ENERVIE-owned" and "leased" (-grid parts).
- The segment tree was grouped from 264 individual asset types into 66 asset types. This reduction also reduces the system elements of the model by 70%, which improved the runtime of the following simulation considerably.

The aggregated asset simulation model provides the necessary level of detail to answer the questions. All asset segments in the new "simulation model" are governed by mapping tables and contain all relevant simulation data (stocks, costs, measure quantities…). The simplified model covers all relevant details and reproduces the results of the detailed model on the specified levels of the segment tree. The model provides all the complex dependencies between the grid components and target values which are worked out in the "cause and effect"- relations.
In addition the "simplified" asset simulation model was extended with the functionality "solution finder" which is used to find "best" solutions for the questions to be answered.

### Simulation of the revenue cap for sectors

The revenue cap for the electricity and gas distribution grid was simulated according to the existing regulatory requirements. In Germany the water distribution grid is not regulated like electricity and gas distribution, so a fictive revenue cap similar to gas was assumed and used in the asset model to cover the potential impact and to have comparable results.

### Design of the cash flow optimization scenario

The optimization scenario to find best solutions consists of the objective and restrictions as well as general settings.

The objective and restrictions are target values from the simulation model. As objective, one target value has to be selected and decided if the objective should be maximized or minimized within the simulation period. In general restrictions are limitations which are set by asset service (like the amount of possible measures), by finance (like the given budget) or regulation (like the revenue cap). The number of restrictions is not limited and restrictions are also target values from the asset simulation model and they have to be defined for the optimization scenario as upper or lower boundary with numerical values. The complexity of the scenario depends on one hand on the complexity of the underlying simulation model with the defined asset types and dependencies of the target values. On the other hand, the complexity of the scenario is related to the number of restrictions and how close the restrictions are defined. The restrictions mount the frame for the solution and the first goal is to find a valid solution which means a solution which is inside the frame of the restrictions and fulfills all defined restrictions for each year of the simulation period. The second step, after getting a valid solution, is to optimize the objective. It is obvious that well defined restrictions are necessary to obtain valid and sustainable solutions.

To find a solution for a stable and secure return on assets the optimization scenario to find a best solution for the given question was designed with all relevant restrictions and boundaries. The chosen scenario is described as "increase cash flow of related investment program with current investment budget and grid quality". These business questions were translated into the language of the developed asset simulation model (see Fig. 3).

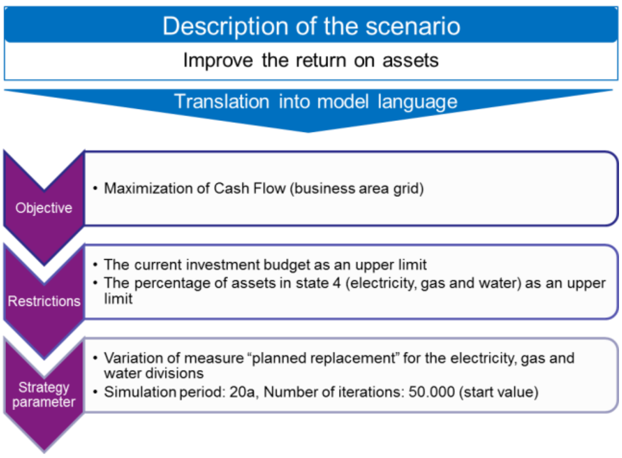


*Figure 3: Translation of business questions into model language*

The objective of the scenario is to maximize the cash flow of the related investment program. It is defined on the top level of the segment tree (on the business area grid) to provide the best solution for the highest level of the infrastructure with no "in between targets" for the electricity-, gas- or water grid.
As boundary conditions for the scenario, restrictions are defined from two categories. The first category is budget and the second is the condition of the grids. An upper limit is defined in the investment budget on the network level and as maximum budget the current CAPEX time series for the next 20 years is used. These restrictions ensure that the solution finder will provide solutions which are in the given budget frame. The definition of the restrictions on network level enables the solution finder to shift CAPEX among electricity-, gas- and water grids, but the sum of CAPEX on network level will not exceed the limit. The second restriction is defined as an upper limit for the assets in "condition 4". Assets in "condition 4" represent assets which exceeded their technical life time and are therefore a risk indicator for the infrastructure. The restrictions on this target value ensure that the risk of the grids is in a sustainable and manageable frame. The restrictions on "condition 4" are defined on a more detailed level as the budget restriction. They are specified on the level of relevant asset groups within the electricity-, gas- and water grid.

The last step in designing the scenario is agreeing on the general settings. First of all, measures which can act on the grids and work against the aging of the grid are agreed. For all asset types of the grids the measure "planned replacement" is allowed to achieve the objective. The solution finder will attempt to vary the amount of "planned replacement" for each asset type to find a better cash flow, but the solution finder is bounded by the budget and by "condition 4" restrictions. The simulation period is set to 20 years, which means the solution finder will provide the "best" solution exactly for this time horizon. In the first run the solution finder has evaluated 50.000 iterations in order to find one best solution.

## SOLUTION AND RESULTS

### Adapted restrictions lead to feasible solutions

The solution finder scenario is implemented in the ASP model and started for the first run. It turned out that it was not possible to find valid solutions with the initial restrictions and the general settings. The first insight is that the number of iterations of 50.000 is far too low for the complexity of the scenario. In the final solution the number of iterations is increased to 300.000 which is corresponding with an increase of run time for the solution finder.
The second insight is that the initial restrictions on budget and "condition 4" are too constrictive. After further tests and discussions, both categories of restrictions are extended in a sufficient frame to provide still acceptable solutions, but increase the frame in which the solution finder can search for best solutions (see Fig. 4).
The settings for the scenario were adapted with the agreed results and the new run provided valid solutions which show an optimized investment program with improved key-figures.

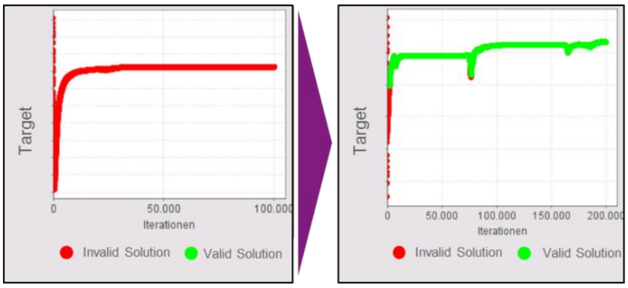


*Figure 4: Solutions before (left) and after (right) adaptions of restrictions*

### The related cash flow of the investment program can be improved

With respect to the given restrictions, the result shows an increase of the related cash flow of the planned investment program by around 2% compared to the current situation (see Fig. 5). The shape of the cash flow curve of the current and the optimized strategy is similar. The increase of the cash flow in the optimized strategy is a cumulated increase for the observed period of 20 years and is not linear along the simulation period and shows in the early years a lower cash flow which is compensated by increasing cash flow in later years. In summary: in early years more money has to be spend to achieve a higher related cash flow in total.

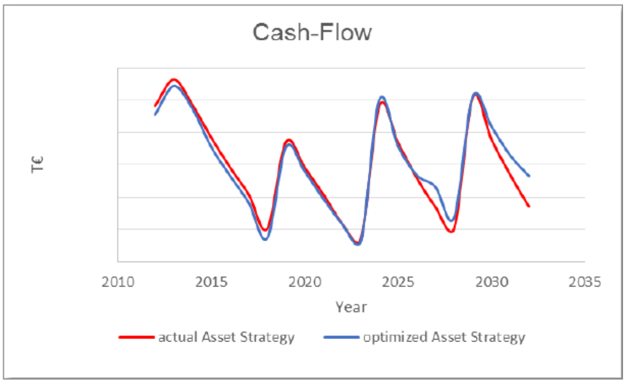


*Figure 5: Comparison of the cash flow development for the planned investment program of the observed period of 20 years*

The contribution of the infrastructures electricity grid, gas grid and water grid to the related cash flow of the investment program differs too. The gas grid and water grid show a cumulated decreasing cash flow on one hand, while the electricity grid shows a cumulated increased cash flow on the other hand.

Further analysis of the results reveals the imputed depreciation as a key-lever for a secure return on assets (see Fig. 6).

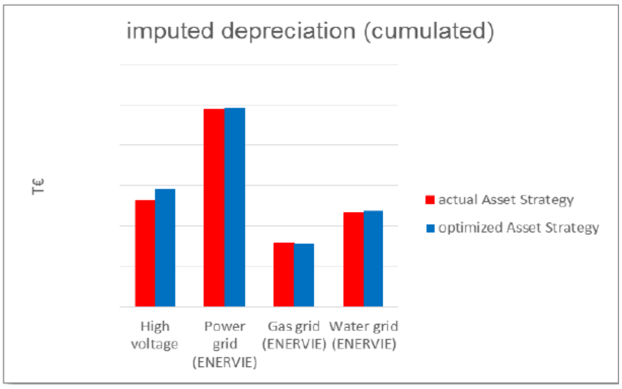


*Figure 6: Increase of imputed depreciation related to different grids of the infrastructure*

A comparison of the grid infrastructures shows that the high voltage part of the electricity grid has the highest impact on the imputed depreciation. Moving one step deeper into the structure of the high voltage grid, the high voltage cables are identified as the key lever for the imputed depreciation and show the biggest increase (see Fig. 7).

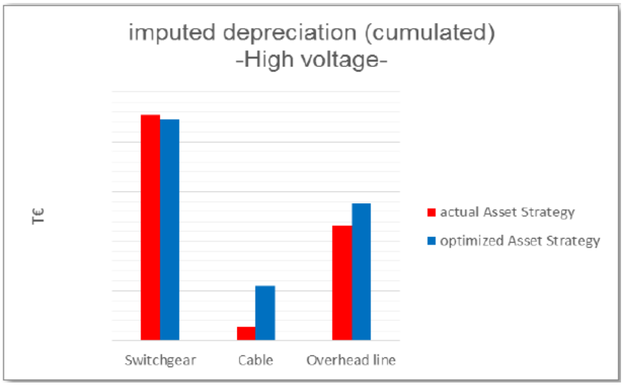


*Figure 7: Impact of imputed depreciation of high voltage assets*

The highest benefit for the objective "improve return on assets" results from the beneficial combination of investments (replacement costs) and depreciation period of high voltage cables in the electricity grid. The cash flow improvement of the related investment program can be achieved by shifting investments within the segment tree among the different infrastructures to high voltage cables as the "best" way to maximize the objective of the scenario. All restrictions are fulfilled and the optimized investment program has an acceptable "condition 4" risk within the given investment and quality boundaries.

## CONCLUSION AND OUTLOOK

In conclusion, EnervieAssetNetWork successfully developed an approach (by applying an asset simulation tool with a simplified asset tree and additional functionality) for its major capital expenditure program to ensure that both agreed quality targets and a secured rate of return on assets for the existing electricity, gas and water infrastructure are achieved. All considered questions are answered and the main key-levers to secure a return on assets are identified. The impact of the different sectors electricity, gas and water are known. The current schedule of planned capital expenditure program can be secured by shifting investments in two different ways: firstly among infrastructure to asset types with higher impact on the return on assets and secondly on the timeline to early years.

Further calculations with more detailed restrictions and adapted assumptions (e.g. revenue cap for water grid and separation ENERVIE-owned and leased areas) have to be executed to achieve a better understanding of the sensitivity of the results.

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