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Holistic Evaluation of Operational Concepts for a Production Network Under Varied Market Conditions

Master's Thesis

to achieve the university degree of
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Graz University of Technology
Institute of Chemical Engineering and Environmental Technology

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Chemical Engineering and Environmental Technology

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by

Sascha Kleiber, BSc

Task description:

Evaluation of two alternative operation modes (summer and winter) of a refinery with a model based on historical measurement data in Wolfram Mathematica® and development of optimization case studies for highly interconnected production plant networks.

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Kurzfassung

Der Fokus dieser Arbeit liegt auf der Erweiterung der Optimierapplikation “OptiApp”, die ursprünglich von Pöllabauer [8] entwickelt wurde. Basierend auf historischen Messdaten wird ein vereinfachtes Model entwickelt, das verschiedene Fahrweisen hochgradig vernetzter Produktionsanlagen simulieren und optimieren kann. Als Beispiel eines komplexen Industrieanlagenverbunds wird in dieser Arbeit die OMV Raffinerie in Schwechat, Österreich, verwendet. Die Messdaten der Raffinerie werden zunächst in Wolfram Mathematica® importiert, bevor sie für verschiedene Zielsetzungen und Nebenbedingungen gefiltert werden. Basierend auf den gefilterten Messdaten wird ein Gleichungssystem erstellt, das lineare Abhängigkeiten der Ausgangs- von den Eingangsmassenströmen darstellt.

Mit dem linearen Gleichungssystem und dem Optimiermodell von Mayer [6], das auf dem Mixed Integer Linear Programming Ansatz beruht, können nun verschiedene Fahrweisen der Raffinerie simuliert werden. Dabei können individuelle Zielfunktionen und Nebenbedingungen formuliert, existierende Produktionsanlagen explizit an- oder ausgeschaltet, virtuelle neue hinzugefügt, Ströme umgeleitet oder mit neuen linearen Funktionen versehen werden. Als beispielhafte Erweiterungen werden in dieser Arbeit eine Erdgas-zu-Olefinen und eine Wasserelektrolyse Anlage untersucht und in den Anlagenverbund implementiert.

Abstract

The focus of this work is the extension of the optimization application “OptiApp”, originally designed by Pöllabauer [8]. Based on historical measurement data, a simplified model is developed, which is able to simulate and optimize different operation modes of a highly interconnected production network, using the example of OMV Refinery in Schwechat, Austria. The measurement data of the refinery are imported into Wolfram Mathematica® and filtered for different objective functions and constraints. Based on these filtered data, a set of linear equations is computed, which describes the dependencies of output and input streams of every production plant inside the refinery.

With this set of linear equations and the optimizing model, which was developed by Mayer [6] and is based on the Mixed Integer Linear Programming approach, different case studies can be simulated. Thereby, individual objective functions and constraints can be formulated, existing production plants explicitly switched on or off, virtual new ones added, streams re-routed, or supplied with new linear equations. As exemplary extensions, a gas-to-olefins and a power-to-hydrogen plant are investigated and implemented into the network.

Contents

1 Introduction and Objective

The oil occurrence on earth is limited. Although this fact is common knowledge, humankind is still very dependent on refined oil products. As it becomes more and more difficult to find new oil reservoirs and make them accessible, it is necessary to improve knowledge and handling of the refineries to be able to satisfy the to some extend increasing market demands for these products. In order to increase the efficiency of a whole refinery, optimal operating conditions for different case studies have to be found.

Soaring digitalization of economy and society is the moving spirit for the fourth industrial revolution. To the greatest possible extend self-organized production and intelligent linked logistics are the major trends in Industry 4.0. Total comprehension of the plant network and a digital interconnected system are requirements for a more efficient and flexible production, saving energy and resources, and increasing the economic feasibility.

In view of Industry 4.0 the aim of this work is to expand the optimization application "OptiApp" designed by Poellabauer [8]. Therefore, a simplified model is developed, based on historical measurement data, for intelligent optimization of highly cross-linked production networks using the example of a refinery. With the results of this thesis it is possible to prognosticate different operation modes and various case studies for estimated future market demands of refined products.

A refinery is a highly cross-linked network of plants, where the crude oil is processed into diesel, gasoline, kerosene, heating oil, heavy fuel oil, and many more. The required energy is provided by combined heat and power stations. Changing the operating conditions at a single plant may have a big, often not foreseeable, influence to this highly interconnected system of production units. Therefore, operating conditions for most units inside the refinery are arising from experience and given circumstances, such as amount of feed, feed composition, availability of steam and electricity, and the product demand.

Instead of optimizing the refinery in one step, which is nearly impossible due to the complexity of the network and hence accruing difficulty, the refinery is divided into several subsystems. Based on historical measurement data, linear behaviour is assumed and a linear function is fitted for each product, heating steam and electricity stream of every single plant inside the refinery with respect to its feed. The set of linear equations can be solved for different objective functions and constraints.

1.1 Description of the Production Network

This chapter gives a short overview of the OMV refinery in Schwechat, Austria, which is taken as an example of a highly cross-linked production network. In figure 1-1 its flow chart is shown.

The crude oil enters the crude-oil-distillation plant, where it is fractionated into different petroleum compounds. Excluding the top-gas and the residue, all separated fractions pass through desulfurization steps. The gasoline fraction is refined in an isomerising and platforming plant before it is blended into the final products. The diesel and heating oil fractions have to be blended as well before they reach their final product quality. On the contrary, kerosene can already be sold after the desulfurization step.

The top-gas of the crude-oil-distillation and several gases from other refinery plants are fed into the gas-separation plant, which produces heating gas, ethane, propane and butane. The heating gas is fed into power stations, where it is burned to produce steam and electric power. Besides covering all the heating and electricity demands inside the refinery, electricity and district heat for Vienna are exported as well.

Ethane, propane and butane are fed to the ethylene plant together with parts of the gasoline fraction from the crude-oil-distillation plant. The ethylene plant mainly produces hydrogen, ethylene and propylene as final products. Beside these bulk products, some blending components are manufactured as side products in this plant.

The residue of the atmospheric crude-oil-distillation is split up by vacuum distillation. Bitumen is the main product of this vacuum distillation. The residue of the vacuum distillation and several side products of different refining steps are fed into the thermal or catalytic-cracking plant, where long carbon chains are broken up into shorter ones. These cracked compounds can be fed to the ethylene and butadiene plant.

Natural gas is converted into hydrogen, which is used in several refining steps, and can also be sold separately. Sulphur-containing refining gases are cleaned in the amine washing plant. While the cleaned gases can be fed to the gas-separation plant, the extracted hydrogen sulphide is processed further to gain pure sulphur, which can also be sold.

OMV's refinery in Schwechat is a rather flexible one as it can be operated under various conditions. Different crude oils and mixtures can be processed without any constructional work and the refinery can be run in different operation modes. In

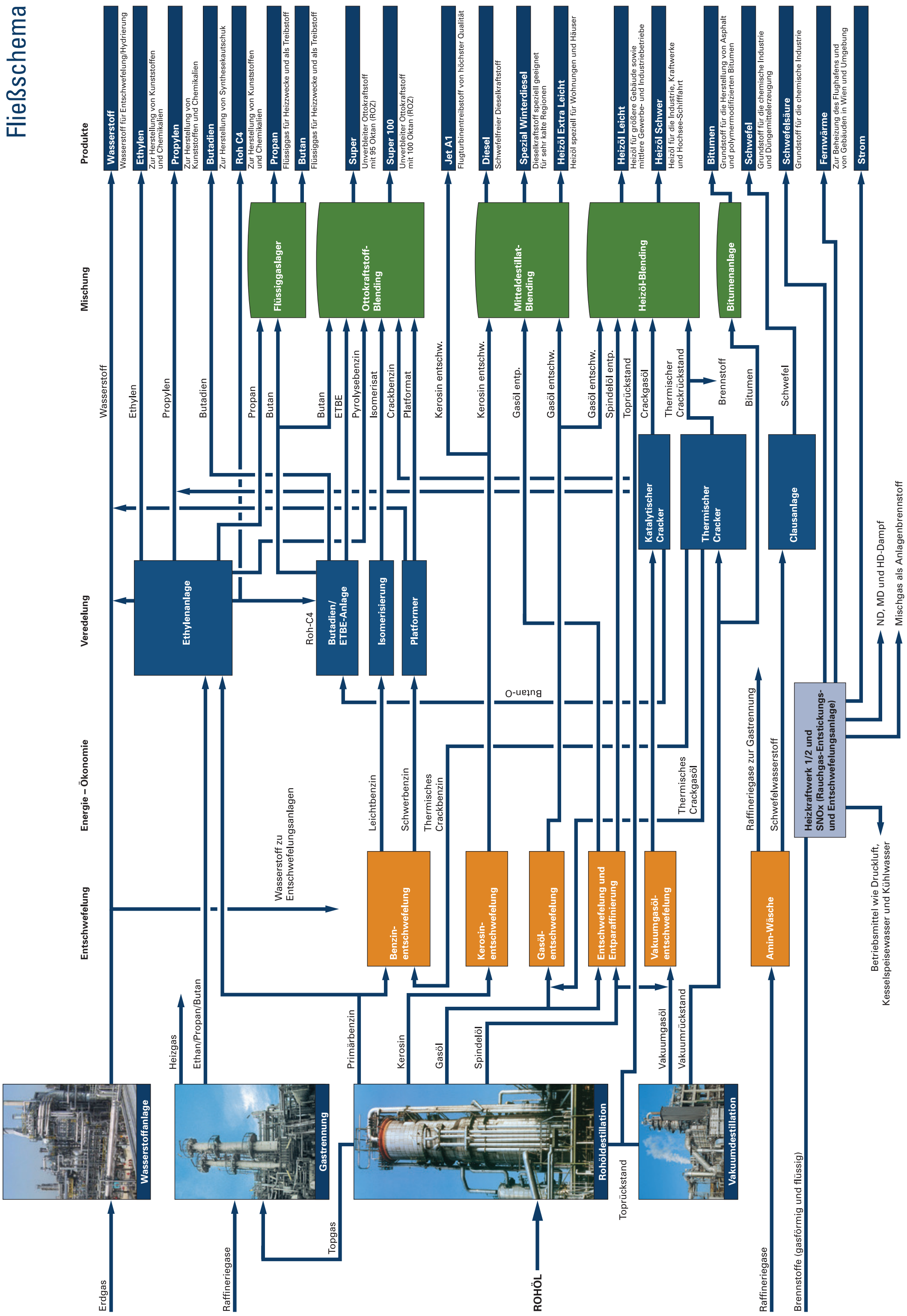

Figure 1-1: Flow chart of the OMV refinery in Schwechat, Austria [7]

general, the operation modes distinguish between summer and winter mode. They differ mainly in product quantities and required amount of energy. While in summer more bitumen is produced, in winter the production is shifted towards more heating oil. Due to general thermal conditions in winter more heating power is demanded. Those periods are not fixed to particular dates and have a rather flexible transition. In the OptiApp summer periods date from 21st of June until 22nd of September and winter mode starts at 21st of December and ends at 20th of March. Those default settings can be changed individually if necessary. Dividing the real measured data into these two classes offers the possibility to find optimal operation modes for both periods.

It is assumed that crude oil mixtures with different compositions only influence the quantitative amounts of the intermediate products but not the operation mode of the crude-oil-distillation plant. All following production plants have to run with the provided amount of feed from the previous ones and are not influenced in their yield or operation mode anyway. With more detailed data, i.e. hour-averaged or minute values, further differentiation seems plausible, but as long as only daily-averaged data is provided, no additional benefit can be found.

1.2 OptiApp Modeling

The optimization application OptiApp designed by Poellabauer [8] is a simplified model to deal with complex and highly interconnected systems, and to calculate and evaluate operation modes considering different objective functions and constraints. It is based on a top-down-approach, where everything is seen from coarse to precise. The refinery as top level is seen as a system containing subsystems. Each subsystem represents a plant inside the refinery. The third plane corresponds to the elementary systems, in this case the individual parts of each plant. This approach is shown in figure 1-2 by Klatt and Marquardt [5], and can be applied for any kind of complex production network. All measured data are provided by the real time data base Aspen Infoplus.21® and saved as Microsoft Excel® data sheets. For modeling and optimizing Wolfram Mathematica® is used.

The primary objective is the optimization of the refinery in its entirety. On the top level, the whole refinery is seen as one deterministic black box, where input streams enter and output streams leave the system boundaries. Intermediate steps are not considered. The output can be seen as a function of the input of the system. In this case, the input would be the crude oil and the final products, i.e. gasoline, diesel, and heating oil would leave the system as outputs. Due to its complexity this system is divided into subsystems.

On the subsystem level all plants of the refinery are depicted with intermediate products, interconnecting streams and recycles. Here, every single plant is seen as deterministic black box and has its own system boundaries, where mass and energy balances are fulfilled. Due to this fact, every subsystem can be taken under consideration individually. All products and the energy demand of a single plant depend on the input. As simplification this dependency is considered as a linear function. This is in fact the easiest function and can not depict real physical and chemical processes in detail, but its accuracy fulfills the requirements of the optimization model's task.

The elementary system level indicates individual parts of each plant. Analysing the processes on the elementary system level would provide more detailed information and depict each plant even better. According to the top-down-approach and the

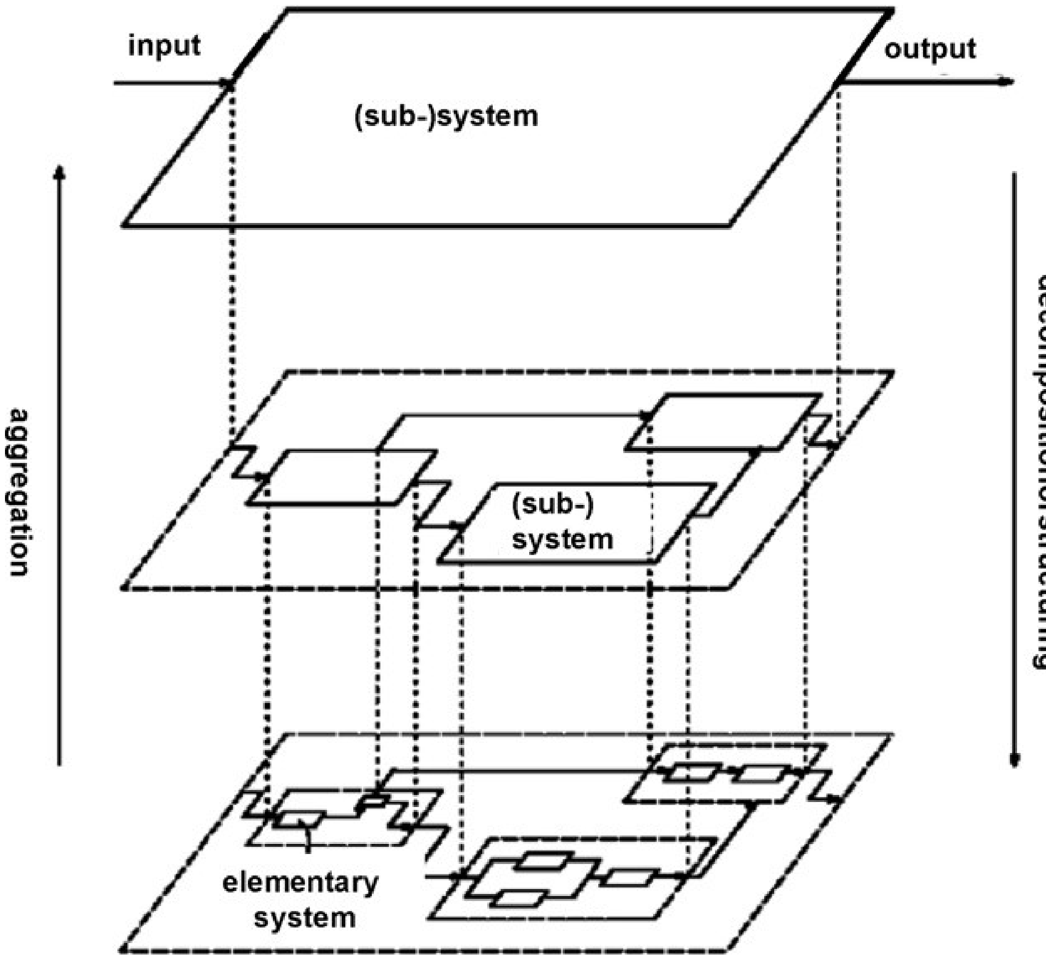

Figure 1-2: Top-down-approach of a system with subsystems and elementary systems [5]

aim of this thesis to evaluate optimized operation modes for the entire refinery, the elementary system level is not taken into consideration in this thesis. Any further optimization of single plants can be implemented into the OptiApp easily and would extend its functionality.

As a first approach, each plant is taken under consideration on its own. Based on historical measurement data, each output stream is modeled as a linear function in form of

$$Output = m \cdot Input + b \ , \tag{1-1}$$

where m indicates the slope and b the axis intercept. In order to fulfill the mass balance

$$\sum_{i=1}^{n} Output = \sum_{j=1}^{n} Input \tag{1-2}$$

has to be valid. The combination of all functions of all plants into one set of linear equations provides the possibility to optimize the whole refinery under different objective functions and constraints. Optimizing each subsystem individually would implicate the risk that an optimal operation mode for one plant effects another one in a way that prohibits the following one from reaching its own optimal operation mode. Further details are described in chapter 3.3 and 4.

2 Expansion of the Production Network

It often occurs that new plants are built and implemented into a production network, old ones get shut down or intermediate products have to be rerouted. These maintenance and infrastructural actions have to be executed to keep the production network up to date, which is important to be competitive and to meet market demands. Since this work exemplarily deals with a refinery, two suitable plants are investigated to extend the existing network thereby showing the flexible application of the OptiApp.

In search of suitable products, their commercial production justifies building new plants and implementing them into the refinery, ethylene, propylene and hydrogen turned out to be appropriate. Demands for olefins, also known as alkenes, and hydrogen increased in the last years rapidly and are expected to grow further. Therefore, a gas-to-olefins plant (GTO), which converts natural gas into light olefins, and a power-to-hydrogen plant (P2H2), which electrolyses water to generate hydrogen and oxygen, are investigated for the expansion of the refinery.

2.1 Theoretical Background of Water Electrolysis

As hydrogen does not occur in natural reservoirs it has to be generated and is a so-called secondary energy carrier. The hydrogen economy is a fast growing system, because it is seen as a sustainable fuel. Used for powering cars, stationary power generation, and as a medium for energy storage, hydrogen can serve many purposes [13]. Steam reforming of hydrocarbons is the leading technology for its production. Natural gas reacts with steam to hydrogen and carbon monoxide. Since this process is already implemented in the refinery and a different feedstock should be used, the electrolysis of water is another key technology for hydrogen production. Also described as power-to-hydrogen process, electric energy is used for converting water into hydrogen and oxygen.

$$H_2O(l) \longrightarrow H_2(g) + \frac{1}{2}O_2(g) \qquad \Delta H^\circ = 286\,\frac{kJ}{mol} \tag{2-1}$$

The high enthalpy of formation of water with 286 kJ/mol shows the high energy demand of this process [4]. For commercial usage the excessive electrical power demand has to be covered and therefore an interconnection to an electricity producing process would be highly reasonable.

2.2 Theoretical Background of Gas-to-Olefins

Olefins are unsaturated, cyclic or acyclic hydrocarbons. They are key components in chemical industry for syntheses of other organic and polymer molecules. Ethylene and propylene are the most important olefins. According to [2], their worldwide annual production is $1.5 \cdot 10^8$ t and $8 \cdot 10^7$ t, respectively, and demands are still increasing. Today most olefins are produced from side products of crude oil fractions by steam creaking, which is the current leading technology. It is estimated that steam cracking will proceed as leading process for olefin production in the near future [2]. But the increasing gap between market demands on ethylene and propylene and the production volumes necessitate additional process technologies.

Researchers have spent many years developing new mechanisms and found several promising approaches [2]. Most of them focus on converting methane directly to olefins and other valuable chemicals, but also light alkanes can be used as feed compounds. Methane is the main component of natural gas, ethane and propane are side products of different refining processes. Large natural gas reservoirs and fracking provide an abundance of cheap methane, ethane and propane.

2.3 Gas-to-Olefins Mechanisms

Figure 2-1 shows the most developed mechanisms to produce olefins from natural gas or light alkanes. In this chapter, these mechanisms are discussed in view of their advantages and drawbacks. Additionally, a rather new technology, generating olefins from natural gas by oxychlorination, is compared to the established ones. After evaluating the different production ways, one mechanism is chosen for the implementation into the refinery.

2.3.1 Steam Cracking (SC)

Steam cracking is the current leading technology and is well established all over the world. Most steam crackers' feedstock reaches from light alkanes up to naphthas or fuel oil. Technological advancements and refinements in fracking, mostly in the United States of America, have caused a significant price drop for ethane. Due to the low price and the high selectivity from ethane towards ethylene, it has become the favourable feedstock [2]. On the other hand, the steam cracking process itself limits the ratio from ethylene to propylene. Since demands on propylene are increasing even more than on ethylene, on-purpose production of propylene becomes necessary.

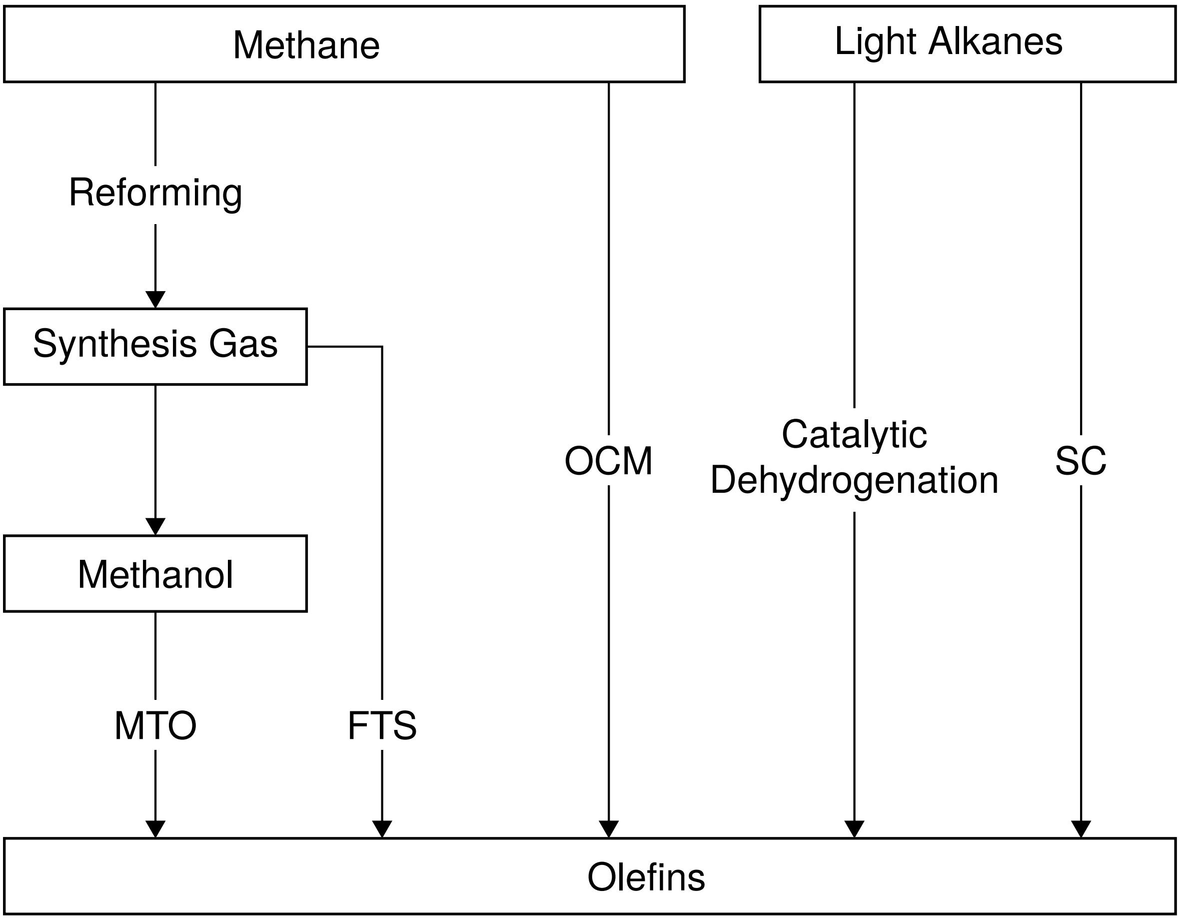

Figure 2-1: Different production mechanisms for olefines from natural gas and light alkanes [2]

2.3.2 Catalytic Dehydrogenation

Catalytic dehydrogenation plants provide the opportunity of selective production of single olefins. The selectivity is much higher than in steam crackers [9]. This offers the possibility of an on-purpose production of propylene. An abundance of cheap propane is the main reason for a dozen of new propane-dehydrogenation plants under construction worldwide. However, this process also has its drawbacks. The conversion is equilibrium limited. It also is an endothermic reaction, which means that low pressure and high temperature would favour the equilibrium to the product side. But high temperature decreases selectivity and therefore supports side reactions such as coke deposition. These side reactions necessitate a regeneration step, which is up until now not fully reversible and affects the activity of the catalyst. Current technology and catalysts available enable a commercialized process, which can run for several years continuously but cannot fulfill the increasing market demands on its own [2].

2.3.3 Oxidative Coupling of Methane (OCM)

Oxidative coupling of methane is one of the most promising direct routes to convert methane to ethylene [11]. The process is able to handle ethane, propane, nitrogen and carbon dioxide as co-feeds up to a certain limit, as long as methane is the major component [10]. According to equation 2-2 and 2-3, methane is oxidized in a first step to ethane, which in a second step is further oxidized to ethylene. Unconverted ethane can be recycled. The combined yield of ethylene and ethane is limited to 25 % according to [1]. To achieve a high C_2-hydrocarbon selectivity it is necessary to keep the oxygen to methane ratio low. Too much oxygen would result in total oxidization as shown in equation 2-4 due to the higher activity of ethane and ethylene compared to methane. The low oxygen to methane ratio results in a low methane conversion and a low ethylene concentration in the product, which requires expensive separation. Furthermore, the high process temperature of 800 °C makes a thermal and hydrothermal resistant catalyst indispensible. This temperature and the exothermic reactions cause a major problem in the reactor design. According to Siluria Technologies [10], a demonstration plant is running since 2015 and has completed over 20 different operation modes successfully. However, this process is not commercialized so far.

$$2CH_4 + \frac{1}{2}O_2 \longrightarrow C_2H_6 + H_2O \qquad \Delta H^\circ = -174.2\,\frac{kJ}{mol} \tag{2-2}$$

$$C_2H_6 + \frac{1}{2}O_2 \longrightarrow C_2H_4 + H_2O \qquad \Delta H^\circ = -103.9\,\frac{kJ}{mol} \tag{2-3}$$

$$C_xH_y + zO_2 \longrightarrow xCO_2 + zH_2O \qquad \Delta H^\circ \ll 0\,\frac{kJ}{mol} \tag{2-4}$$

2.3.4 Fischer-Tropsch Synthesis (FTS)

Fischer-Tropsch synthesis is an indirect route to convert methane to light olefins. It requires the intermediate step of reforming synthesis gas, a valuable mixture of hydrogen and carbon monoxide. Under the right process conditions, catalytic conversion of the synthesis gas yields light olefins. At different reaction temperatures side products such as high molecular linear waxes, alcohols, ketones, and aldehydes are favoured. The selectivity is rather low and the highly exothermic reaction makes reactor design very difficult. A sulphur resistant catalyst needs to be found for improving this process, since sulphur poisoning is a big issue. Despite the drawbacks of this process, Fischer-Tropsch Synthesis is industrially operated in a few countries [2].

2.3.5 Methanol to Olefins (MTO)

Methanol to olefins is another indirect route for converting methane to light olefines. Reforming synthesis gas and converting it to methanol are the necessary intermediate steps for this process. Recently researchers have developed a process with a selectivity between 75 % and 80 % for conversions over a zeolite with active acid sides [2]. The flexibility of the ethylene to propylene ratio, which can be varied from 0.5 to 1.5, is a big advantage of this process and offers the possibility to react to the olefin market demands. However, disadvantages of this process still overcome these developments. Rapid deactivation of the catalyst and side reactions leading to coke deposition are the main challenges of this technology.

2.3.6 Oxychlorination

Using oxychlorination reactions for converting natural gas into olefins is an innovative technology and was introduced by Zichitella [14]. The process offers a selective production of ethylene and propylene by converting mixtures of methane, ethane and propane over an europium oxychloride (EuOCl) catalyst. Yields of 90 % for ethylene and 40 % for propylene can be achieved, respectively. These are higher than those of any other existing process technology. Even though the catalyst was supported on suitable carriers, evaluated in extrudate form and preserved performance for over 150 hours under realistic process conditions, the oxychlorination process still has to be scaled up and tested for commercial use. A promising fact is that the oxidative chlorination reaction is already used commercially in the halogenated hydrocarbon production [11].

2.4 Selection of an Appropriate GTO Mechanism

Summarizing the information about the different GTO mechanisms, it can be said that for every process some issues still have to be solved, before they can be considered as industrial alternative to steam cracking. Catalytic dehydrogenation is well established and a favourable route for on-purpose production of propylene. However, the poor energy efficiency and major issues with catalyst deactivation hamper this process from commercialized bulk production. FTS and MTO are also proven processes, but require high capital investment costs and depend on synthesis gas, whose production is inherently inefficient. Additionally, FTS is not selective enough and produces a lot of side products. Oxychlorination is an innovative technology, which advantages are high yields and a selective production of ethylene and propylene. Usage of rare earth elements as basis material for the catalyst and the lack of a demonstration plant or commercially production experience are the major drawbacks. With further research this process may become a promising industrial alternative.

OCM is the most promising direct route to convert natural gas into light olefins. The two major issues of this process, catalyst development and novel reactor design, seem to have been solved, as Siluria Technologies is operating a demonstration plant since 2015 [10]. This plant has successfully run over 20 operation modes. The demonstration plant in La Porte, Texas, should be the last step to prove economical usage of plants with production volumes of $2.5 \cdot 10^5$ t up to more than 10^6 t of ethylene per year.

The direct route from natural gas to light olefin production uses a catalyst, which offers the possibility to operate at lower temperature than all the other processes and practical pressures of 5 to 10 bar. Thus it was decided to use an OCM process as a possible new production plant for the refinery. In combination with a P2H2 plant, which uses the generated electrical power of the OCM plant to produce hydrogen, a feasible way of implementing those two new plants into the highly cross-linked production network of the refinery must be found.

2.5 Implementing OCM and P2H2 Plants into the Refinery

Since Siluria Technologies is still investigating and developing final settings for their OCM process, detailed information about process parameters, exact conversions and yields, heat and electricity demands, and the overall operating costs are classified and not for public usage. This implementation of an OCM and P2H2 plant is a virtual case to show the extensive possibilities of the OptiApp. The new plants are added to the simulation application as subsystems, according to figure 1-2. In order to include the OCM and P2H2 processes into the OptiApp a mass and energy balance has to be calculated.

The mass and energy balances for the OCM plant are based on the work of Fini [3], where the planing, construction and operating of an OCM plant is described in detail. The senior design report was published at the University of Pennsylvenia in April 2014. Even though this is just a plan of a hypothetical plant, which should be implemented to the production network, it is well informing about all the necessary

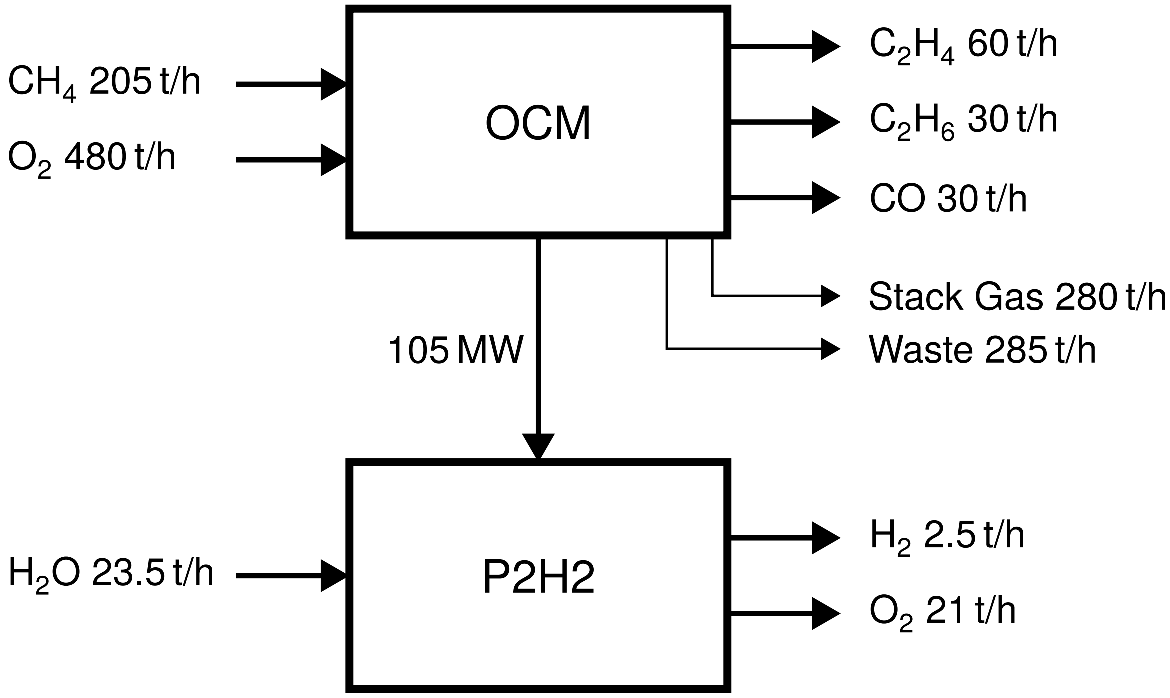

Figure 2-2: Flow chart of the OCM and P2H2 plants

facts. Additionally, it should be stated that the planned location for the OCM plant of Fini is just a few kilometres away from Siluria Technologies' demonstration plant. Although the production volumes differ significantly, the regional closeness as well as the almost simultaneous publication of the senior design report and starting up the demonstration plant raise the question about a connection between them.

The interconnection of the OCM and P2H2 plant is depicted in figure 2-2. As mentioned before, the mass and energy balances around the OCM plant are based on [3]. Beside the major product ethylene, carbon monoxide with a purity of 99.9 mass–% is produced and can be sold immediately. The generated ethane can be fed to the existing ethylene plant of the refinery, as the OCM plant can only handle a certain amount of recycled ethane. Unconverted methane is burned in order to produce electricity. After covering all process needs, the excess of electrical power is used in the P2H2 plant for the electrolysis of water. While the produced hydrogen can also be sold instantly, the manufactured oxygen can be rerouted to the OCM plant.

3 Application of the OptiApp for Selecting and Processing Measured Data

The optimization application OptiApp was originally designed by Poellabauer to develop a meaningful model for different operation modes of production networks based on a small amount of representative historical measurement data [8]. Hence, the selection of data used for the model is of significant importance and has to be done very carefully. For developing a static model of a refinery the selected data have to originate from a continuous operation mode. Ideally, all plants inside the refinery operate in a constant mode and process the intermediate products of the previous plants immediately without storing them temporarily in tanks. A scenario like this is very seldom in highly cross-linked production networks like a refinery. Besides, even with representative data this model still cannot describe dynamic influences, i.e. changing operation mode of one plant and the effect on the following one.

Extending the basic population and including daily-averaged data from several years instead of just a few representative values, single plants and the whole network can be depicted much better. Changing operation mode in one plant results usually in runaway values in the following one or temporary storage of their intermediate products in tanks. Due to the multiplicity of data it is now possible to filter for particular criteria, i.e. minimum or maximum of feed or product amounts, certain time intervals or runaway values, which exceed a specific daily deviation limit. With the filtered data regression lines can be computed and joined into a model. This extended model still cannot describe dynamic effects directly, but it represents the corresponding operation modes much better because it relies on much more data.

Generally, it needs to be differentiated between the data management at the refinery and the data processing with the OptiApp. Like every other highly cross-linked production network, the refinery in Schwechat is operated and controlled by a Process Control System (PCS). The PCS consists of production unit connected components and user connected components. Production unit connected components are sensors and actuators. They provide the measured data and execute the automatic control engineering. User connected components are operating software and control stations, where measured data is displayed and actuators can be regulated. The PCS is a highly secured software and only authorised employees can access it. For users, who have to work with the measured data, the PCS is linked to a real time data base. Using an Microsoft Excel® Add-In the data is saved in various data sheets.

Along the production plants there are many measuring stations for temperature, pressure, volumetric, and mass flow. These data are saved in different files as information about product compositions. The charging levels of tanks for different crude oil mixtures or intermediate products are saved separately. The administration and reckoning of the energy network inside the refinery is documented again in a different form. Additionally over the years the formatting of some of these Microsoft Excel® sheets and the naming of a couple of measuring stations has varied.

3.1 Data Import

This variety of different documented data illustrates the difficulty for the OptiApp to import this information into Wolfram Mathematica® for further processing. The different types of refinery data are imported individually, but are combined into one dataset. In fact, the OptiApp generates three datasets, in order to save computing capacity in further processing steps. Without going into coding detail, it was decided to simplify this context for better comprehension and easier graphical illustrations. The above mentioned three datasets are combined in this thesis into one big dataset.

This dataset is two dimensional, with “Time” as one dimension. The second one is called “Tags”, which represents the in some extend multidimensional data of the different data types. For correct evaluation of the plants and later on optimization of the whole refinery, it is of major importance to unite all types of data for an intersecting time period into one dataset.

The import function of the OptiApp offers two possibilities. First, a new dataset can be generated. This option is used, if no dataset is present or a totally new one should be created. The second possibility for importing data is to extend an existing dataset. This is a very valuable function, because it saves time and computing capacity. In this case it is feasible to add some more data to an existing dataset, rather than generating a new one.

3.1.1 Generate New Dataset

Every dataset has to consist of data corresponding to the production plants, compositions, tanks, and the utility network. In figure 3-1, a graphical illustration of generating a new dataset is depicted. The different coloured boxes represent the data of the various data types. The red dashed line shows the intersecting time period, in which all data types are available. The information inside this area is used in further pro-

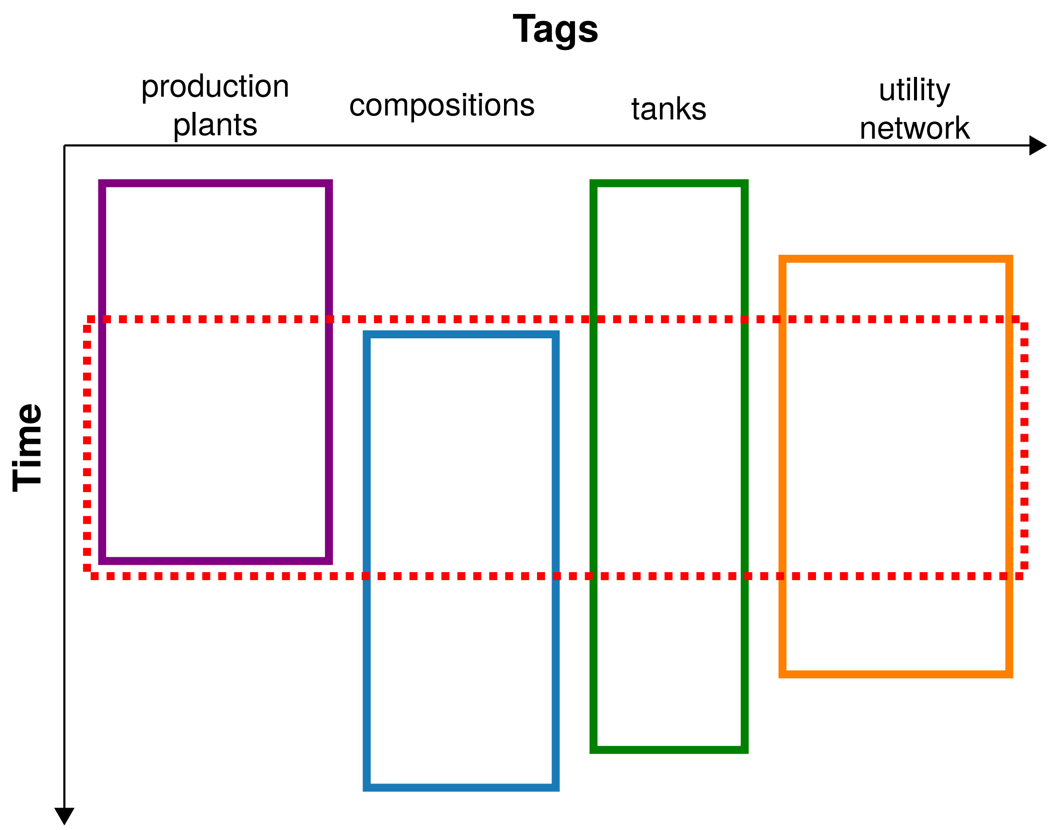

Figure 3-1: Graphical illustration for generating a new dataset

cessing steps. However, the new dataset also saves the information exceeding the limits of the intersecting time period. Even though this data cannot be used right now, it may be of interest for the case of extending this dataset and increasing the intersecting time period. The process of extending an existing dataset is described in chapter 3.1.2.

The graphical user interface (GUI) of the OptiApp offers the possibility to select files of Microsoft Excel® sheets in a browser window. The selected files are imported into Wolfram Mathematica® and the type of data is identified on basis of their formatting. Any four types of data have to be imported separately, but it is possible to process several files at once, as long as they are all of the same type. If more than one file is imported, they are sorted chronologically and edited for further processing. Since only a consecutive period can be depicted in a dataset, the next step is to check for any time gaps.

As any type of data has to be imported separately, the above described process has to be repeated until all types of refinery information are available in the OptiApp. After importing one type of data, the intersecting time with the already imported information is checked before combining the different data sheets into one dataset. In the case of

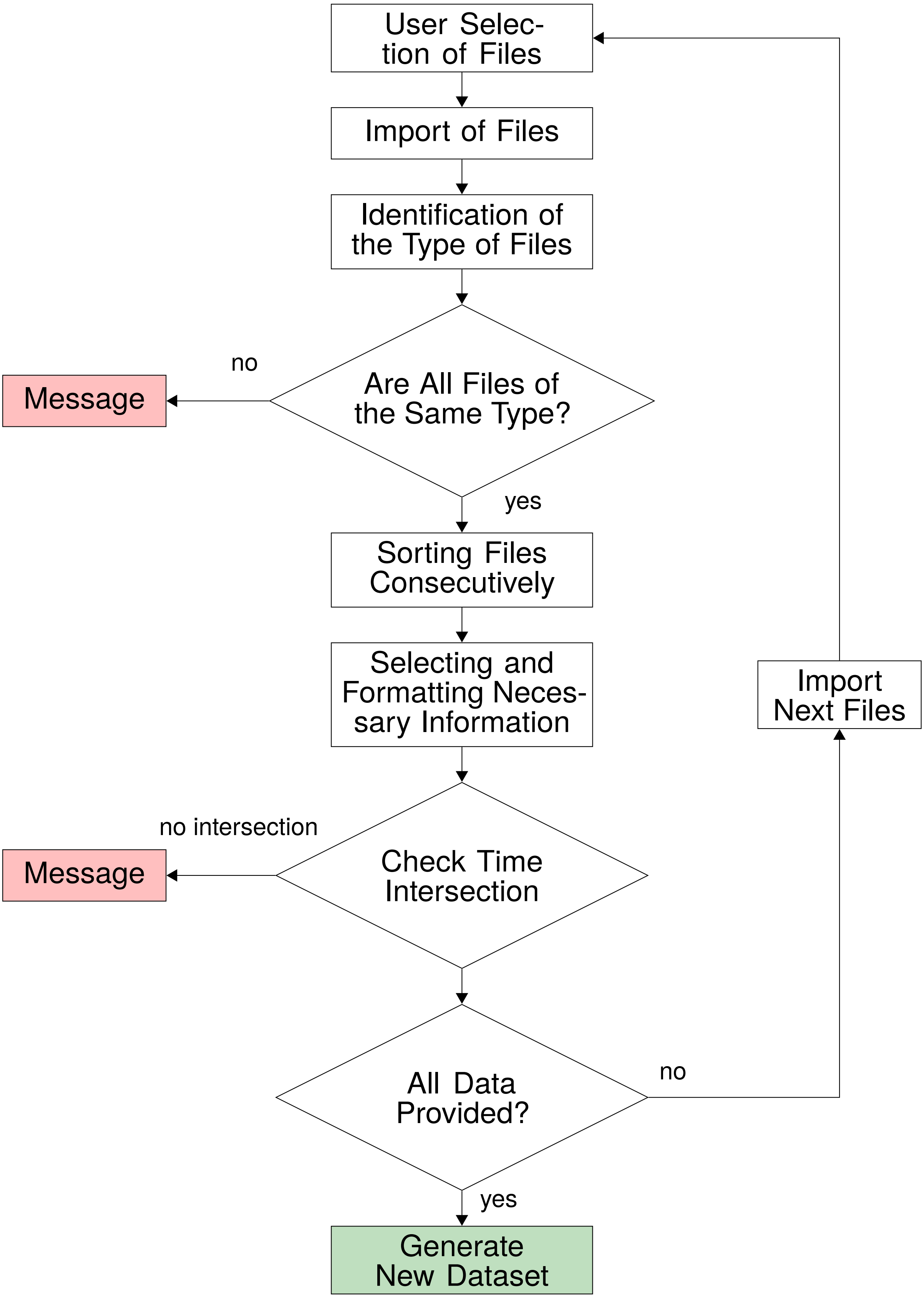

Figure 3-2: Sequence of generating a new dataset

no time intersection, the import is stopped and a failure message is displayed. As long as files of one type are missing, the system asks for more files and returns to the step where the next files have to be selected. After importing all data a new dataset is generated. In figure 3-2, the sequence of generating a new dataset is depicted.

3.1.2 Extend Existing Dataset

Generating a new dataset is only done in a few situations. Different operation modes of utilities, various mixtures of crude oil compositions and seasonal production are the major reasons for a new dataset. As soon as they are generated, it is recommended to extend these datasets instead of generating a complete new one, just to include some more data. The “Extend Existing Dataset” function offers this possibility. This saves computing capacity and time. As shown in figure 3-3, an existing dataset, represented by the black rectangle, can be extended either in the “Time” dimension (blue) or the “Tags” dimension (orange). The extended datasets are depicted by the dashed lines, respectively. Extending a dataset in both dimensions in one step is not possible.

Extending a dataset into the “Time” dimension requires two essential criteria. All tags, which are in the existing dataset, also have to be present in the extending data file. The second requirement is an intersecting time period. This is crucial because only consecutive data can be evaluated. For the extension of a dataset into the “Tags” dimension, the extending data has to cover the exact same time period as the existing dataset. Due to the fact that there is no consecutive order of the tags, there cannot be a gap in between two tags, as it is possible in the time dimension. Every single tag

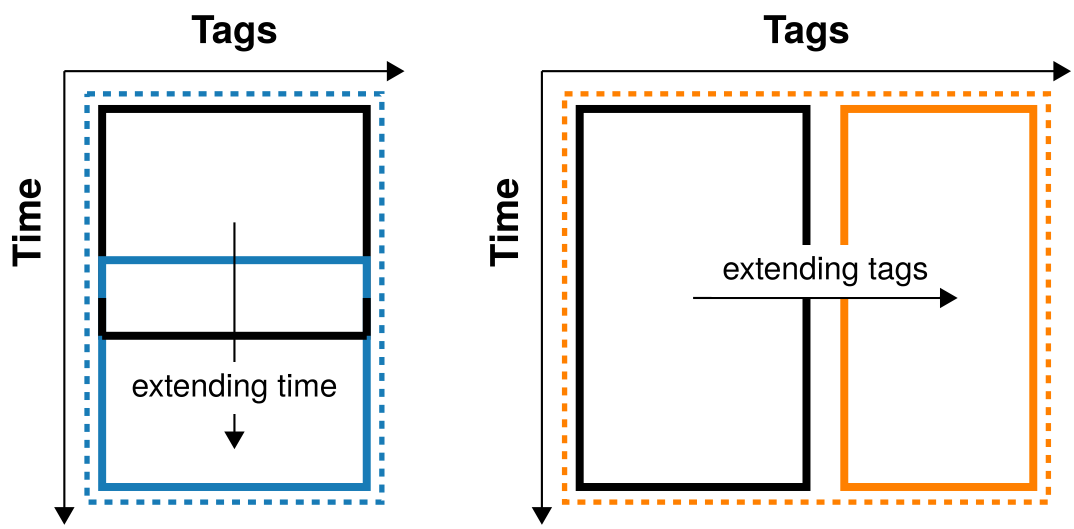

Figure 3-3: Graphical illustration for extending an existing dataset

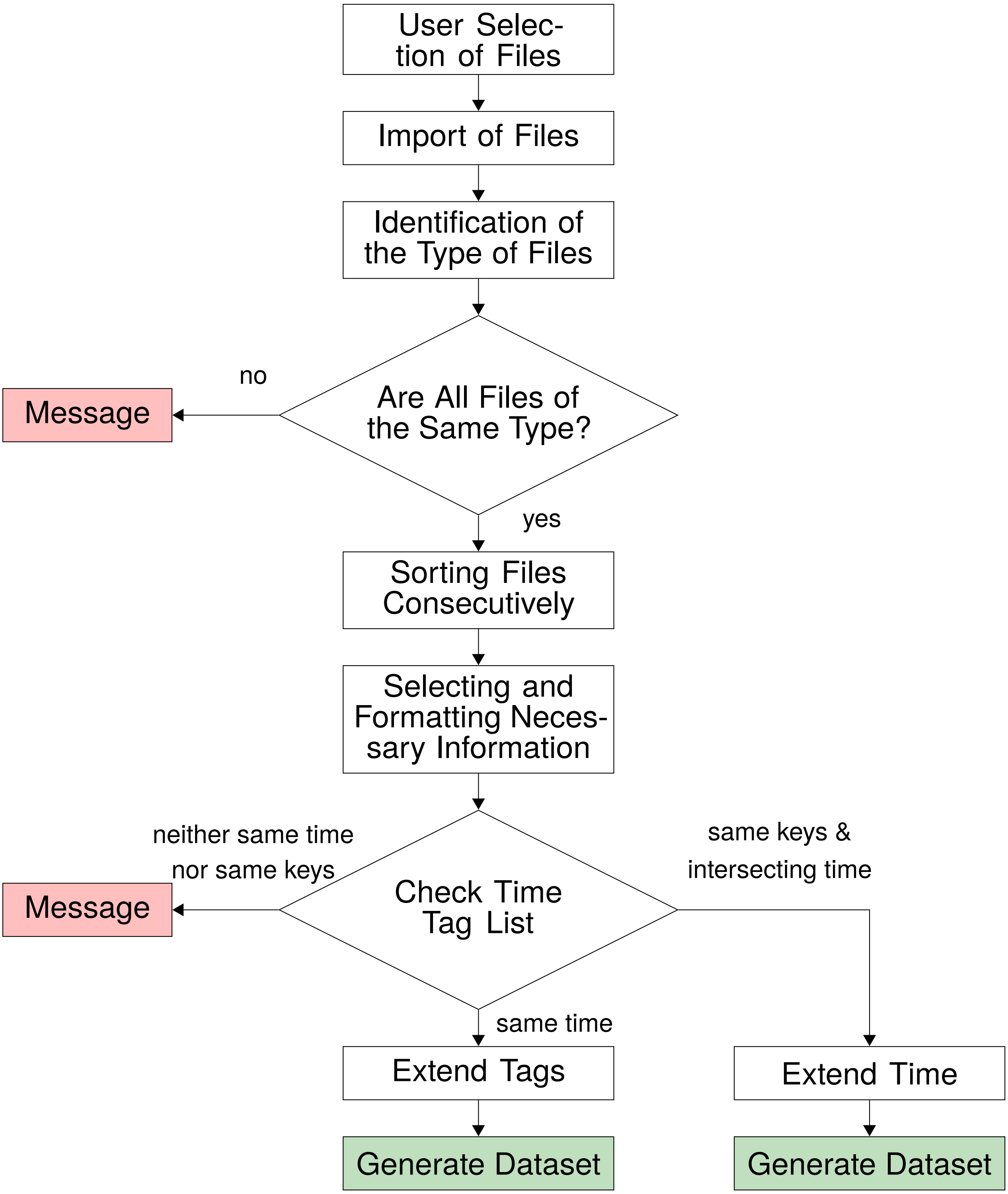

Figure 3-4: Sequence of extending an existing dataset

includes information, which are evaluable independently. Therefore, a tag intersection is not necessary. However, if some tags occur in both datasets, the existing and the extending one, a pop-up message informs about it and asks which data should be used for the new dataset. It is not possible to have two identical tags in one dataset.

The sequence of the “Extend Existing Dataset” function is very similar to the one of “Generate New Dataset”. After selecting the extending files, they are imported, identified, sorted and formatted as described in chapter 3.1.1. As explained above, the extending data either has to include the same tags and an intersection in time or cover the exact same time period. If it does not fulfill the requirements for either of these two cases, a failure message is displayed and the import is stopped. Therefore, it might be necessary to prepare the extending data in a previous step analog to the “Generate New Dataset” function. The sequence of the “Extend Existing Dataset” function is depicted in figure 3-4.

3.2 Data Filter

In the primary version of the OptiApp, the models were based on a small amount of representative and well selected historical measurement data. Generally, the current version is based on a multiplicity of data from several years. In this time period, a lot of different crude oil mixtures were processed and the plants inside the refinery operated in several modes. A simulative model is just as meaningful as the selected data it is based on. Due to that fact it is of significant importance to choose the right data filter settings.

For evaluating the data, the product and utility streams are plotted over the corresponding feed stream of each plant. During the further process, regression lines are computed, which represent a trend of the filtered data. These regression lines are linear functions in the form of equation (1-1). The linear functions show the correlations between the input and output streams of every plant inside the refinery. Electricity is depicted in MW, the feed, product, and heating steam streams in t/h.

During the further process, the set of linear functions are used as input for the Mixed Integer Linear Pogramming (MILP), designed by Mayer [6]. Any selected data, which does not originate from the operation mode the model is developed for, falsifies the results. For that reason various possibilities for filter settings are provided. Figure 3-5 depicts the input interface of the data filter settings. The individual settings are itemized and described below.

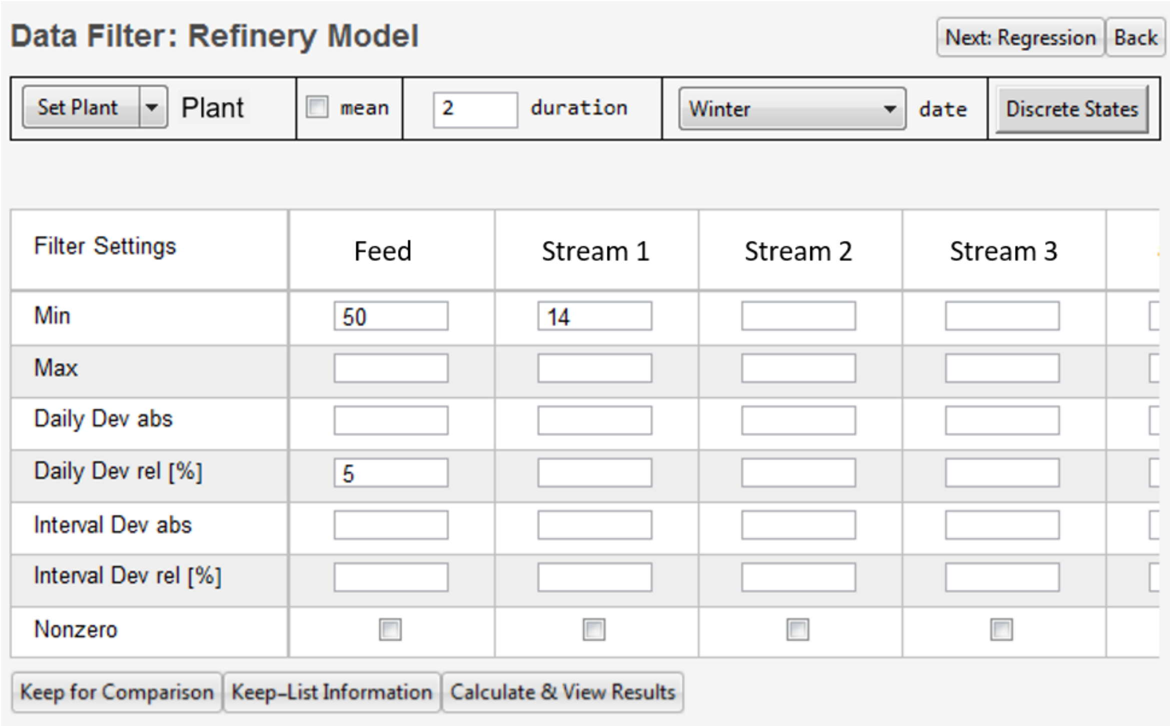

Figure 3-5: Graphical user interface of OptiApp's Data Filter settings

- **Set Plant:** A single plant can be selected by this drop-down list.
- **Mean:** An arithmetic mean is calculated for every duration of consecutive days, for which individual stream filter settings are valid.
- **Duration:** The inserted number represents the consecutive days of the duration, in which the individual stream settings have to be valid.
- **Seasonal Selection:** Predefined time intervals for summer and winter can be selected, as well as individual chosen start and end dates or no temporal restrictions.
- **Discrete States:** Different crude oil components and their ratio in considered mixtures can be selected with this button.
- **Stream Filter Settings:** For every stream crossing the balance area of the selected plant individual filter settings can be applied.
  - **Min:** The minimum mass flow rate of the stream restricts the lower limit for the area of validity in t/h.
  - **Max:** The maximum mass flow rate of the stream restricts the upper limit for the area of validity in t/h.

  - **Daily Dev abs:** The absolute daily deviation restricts the maximum amount of mass flow rate difference between consecutive days in t/h.
  - **Daily Dev rel:** The relative daily deviation restricts the maximum percentaged mass flow rate difference between consecutive days.
  - **Interval Dev abs:** The absolute interval deviation restricts the maximum amount of mass flow rate difference around an arithmetic mean in t/h.
  - **Interval Dev rel:** The relative interval deviation restricts the maximum percentaged mass flow rate difference around an arithmetic mean.
  - **Nonzero:** By checking this box, all data is excluded, where the stream mass flow rate equals zero.
- **Keep for Comparison:** This button saves a new case with all the data filter settings, which are currently inserted.
- **Keep-List Information:** This button shows a pop-up window, providing the number of plants, the number of saved cases and number of duplicate cases.
- **Calculate & View Results:** This button starts computing the data filter and illustrates the results in diagrams, where product and utility streams are plotted over the feed stream.

Developing the best suitable data filter settings is an iterative process. Figure 3-6 depicts all available data of an exemplary stream without any data filter. The filter process starts by selecting a plant from the drop-down list in the top left corner of the input interface, depicted in figure 3-5. For every plant individual settings have to be adjusted. While the number of days of consecutive duration, seasonal selection, and the discrete states are mandatory, the individual stream settings are optional. By checking the mean box, an arithmetic mean is calculated for every period of consecutive durations, for which the individual stream filter settings are valid. This offers the possibility to compare continuous operations varying in length, without weighting them by their length for the calculation of regression lines. The drawback of this setting is a multiple averaging, first for the interval then for the regression line.

After defining all data filter settings for one plant, the case has to be saved by clicking Keep for Comparison in the bottom left corner. It is possible to create several different cases for one plant. This procedure has to be repeated for all plants, where individual filter settings should be applied. For plants without a saved case all available data is plotted with default adjustments for mandatory settings. As

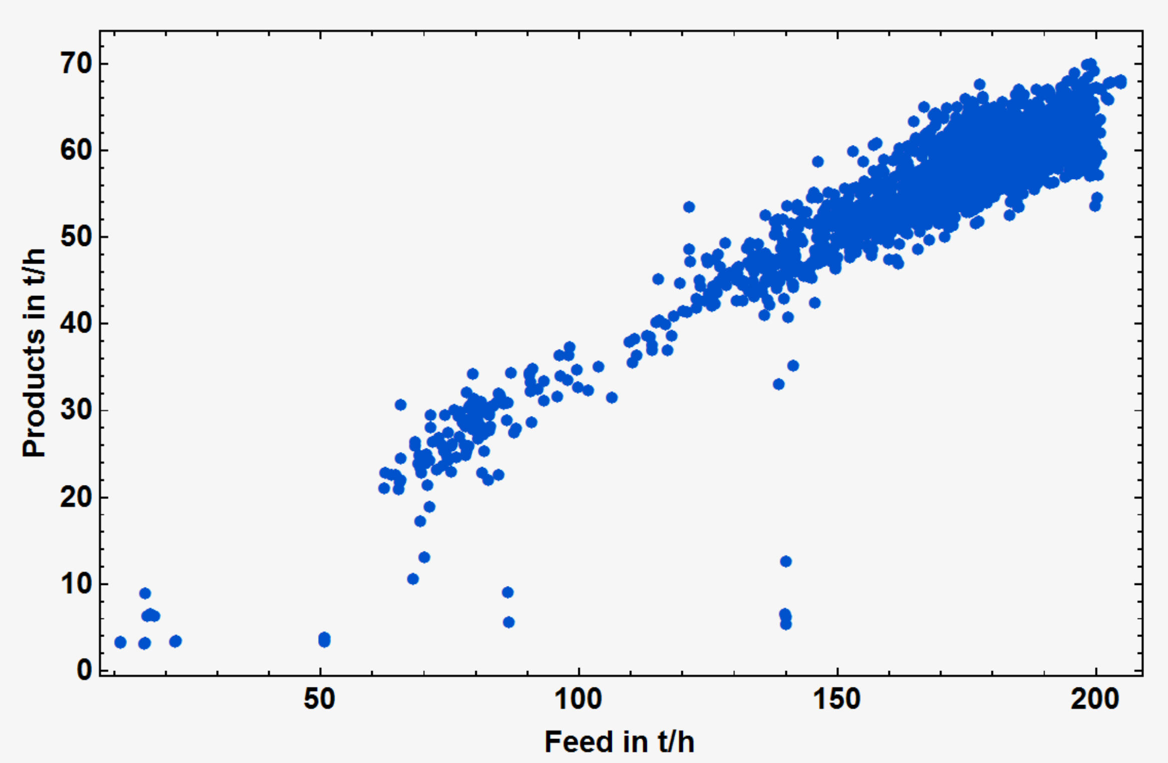

Figure 3-6: Exemplary stream without any data filter settings

soon as all cases are saved, the data for all defined criteria is filtered by clicking Calculate & View Results.

The graphical interface of the data filter shows the results as plots. Again it is necessary to select a plant and a stream first before any diagram is shown. The selected product or utility stream is plotted over the corresponding feed stream. In figure 3-7, the filtered data of the exemplary stream are depicted with the settings from figure 3-5. It is possible to select multiple streams of the same plant and show their results in one plot. To evaluate the settings of the different cases, it is also feasible to compare one or more streams of various cases. By clicking Filter Criteria a pop-up window with some hard facts for each case is shown. The actual number of considered data, the relative mass balance error as arithmetic mean, median, minimum and maximum value, the operating range, and minimum and maximum feed mass flow rate are listed. Besides the very subjective evaluation of the different cases by their graphical illustrations, these hard facts provide the possibility to evaluate the cases and find the best suitable one in a rather objective way.

As mentioned before, finding the best suitable settings requires experience and still is an iterative process. For the purpose of changing the adjustments, Edit Filter Settings returns to the input interface. Altered filter settings have to be saved as a new case

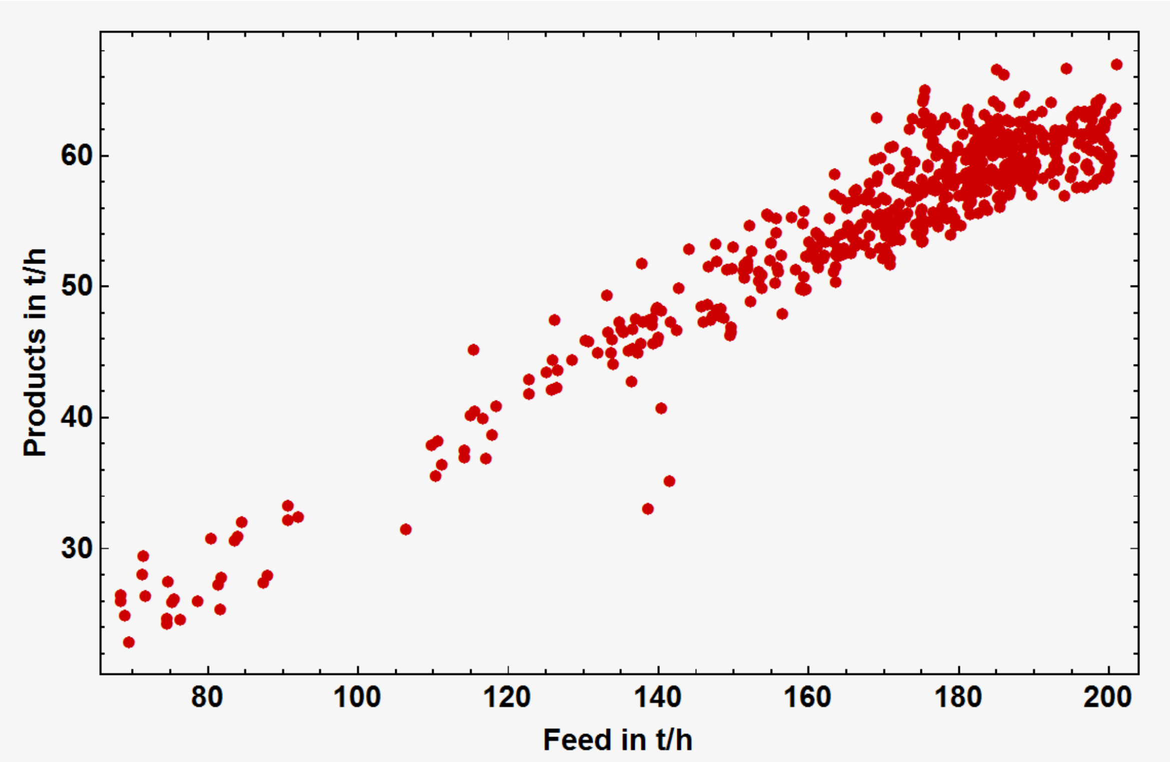

Figure 3-7: Exemplary stream with the data filter settings from figure 3-5

before results can be calculated and depicted in the graphical interface again. As for each case the data is saved, the file increases in memory size with every new case. For further processing it is necessary to reduce that memory size and only provide one case per plant. Save Favourite keeps the selected case and deletes all other ones of this plant. Every plant with individual filter settings requires this step of saving the favourite case. For all plants that lack saved favourite cases, the default settings with all unfiltered data are considered as favourite and saved for further processing. As soon as all plants are edited and favourite cases are saved, the data filter process is finished. The sequence of its procedure is depicted in figure 3-8. The next step is calculating regression lines for the filtered data and generating a set of linear equations. This is described in the following chapter.

3.3 Generating a Set of Linear Equations

After importing and filtering the data, regression lines for the product and utility streams can now be computed. Every regression line is represented in the form of equation (1-1) and shows the dependency between input and output of each plant as a linear function. The regression lines have to express the trends of the measured data as well as fulfill additional constraints. Additional constraints are the validation of the mass

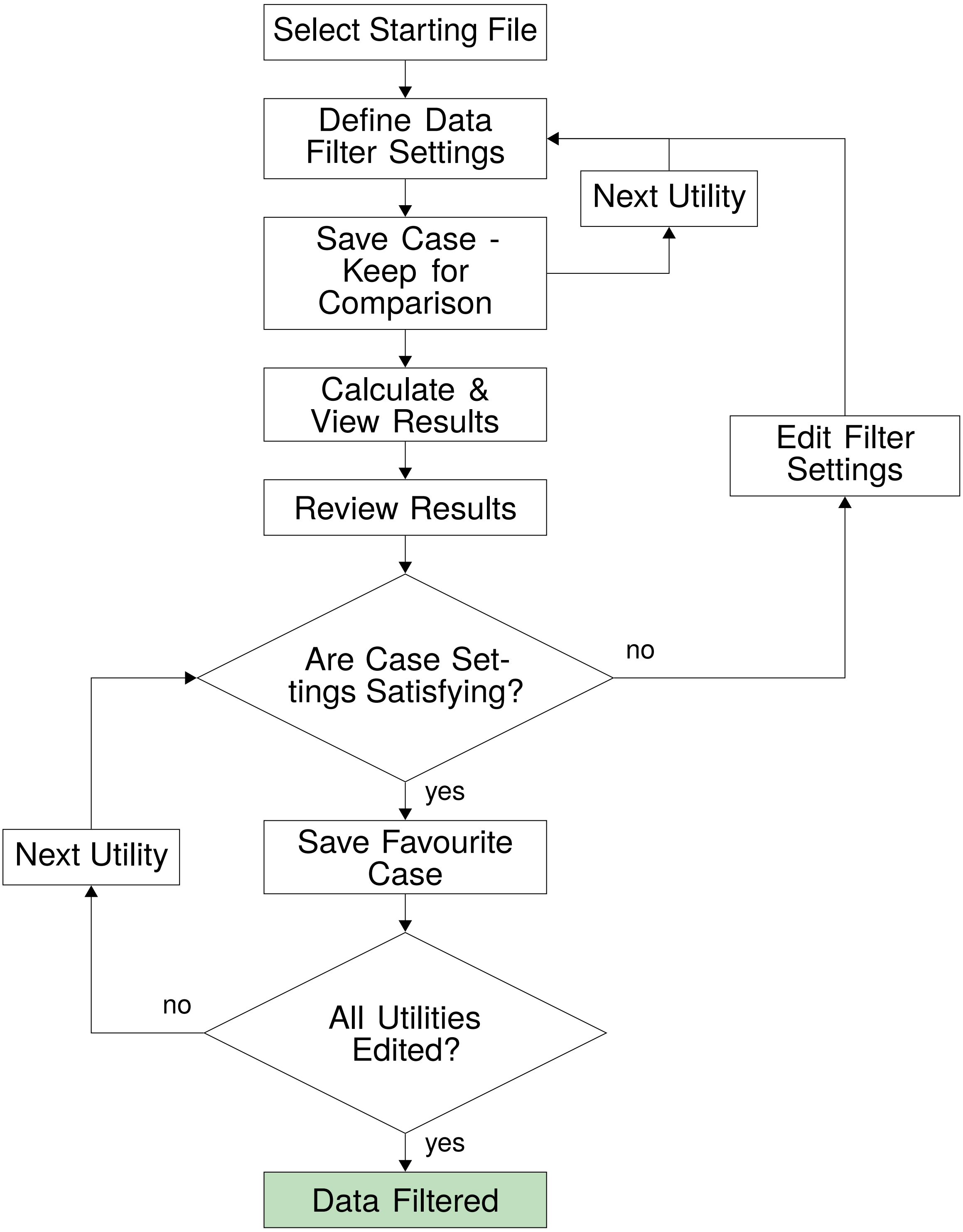

Figure 3-8: Sequence of the procedure of filtering data

balance around a single plant, splitter adjustments, which force the regression lines to intercept the ordinate at zero, or user defined settings for minimum and maximum values for the slope and axis intersection of each stream.

The combination of the gained equations of the regression lines into a set of linear equations is the last step of evaluation of the plants inside the refinery. With the set of linear equations, representing the behaviour of each plant in this operation mode, the refinery can be optimized for different constraints and objections by the usage of MILP. The functionality and application of MILP and the development of different case studies are described in chapter 4.

The regression process can be started directly out of the main menu of the OptiApp or as a consecutive function from the data filter interface by clicking Next: Regression, as seen in the top right corner of figure 3-5. In both cases the first step is to select a file, where the filtered data are saved. Subsequently, there is the decision to load existing regression settings or start with an empty list. For each operation mode investigated a set of linear equations is necessary. It is advised to start with an empty regression settings list for each new set of linear equations.

Analog to filtering the data, a plant has to be selected at the main regression interface and the settings have to be defined for every single one individually. An empty regression settings list is provided with default settings, which include the validation of the mass balance. This implicates that along every single point of the regression lines the sum of all output streams equals the sum of all feed streams according to equation (1-2). A regression line, which fulfills the mass balance may not represent the measured data as good as one without this additional constraint, but due to the major importance for the realistic approach of the model, this default setting may only be switched off for good reasons.

Mathematically speaking the mass balance around a plant is valid as long as the sum of all feed streams equals the sum of all product streams. This applies also in case that one or more streams have negative values. If data of one stream generates a regression line, which intersects the ordinate at a positive value, another stream has to intersect below zero, in order to achieve the mass balance constraint. This scenario is depicted in figure 3-9. Even though the mathematical constraints are fulfilled, this case is not possible in a real utility, as product mass flow rates can not be negative, which would be the case as soon as the regression line crosses the abscissa.

In the exemplary case of figure 3-9 the regression line of stream three crosses the abscissa at a feed mass flow rate of 250 t/h, depicted by the black vertical line. All

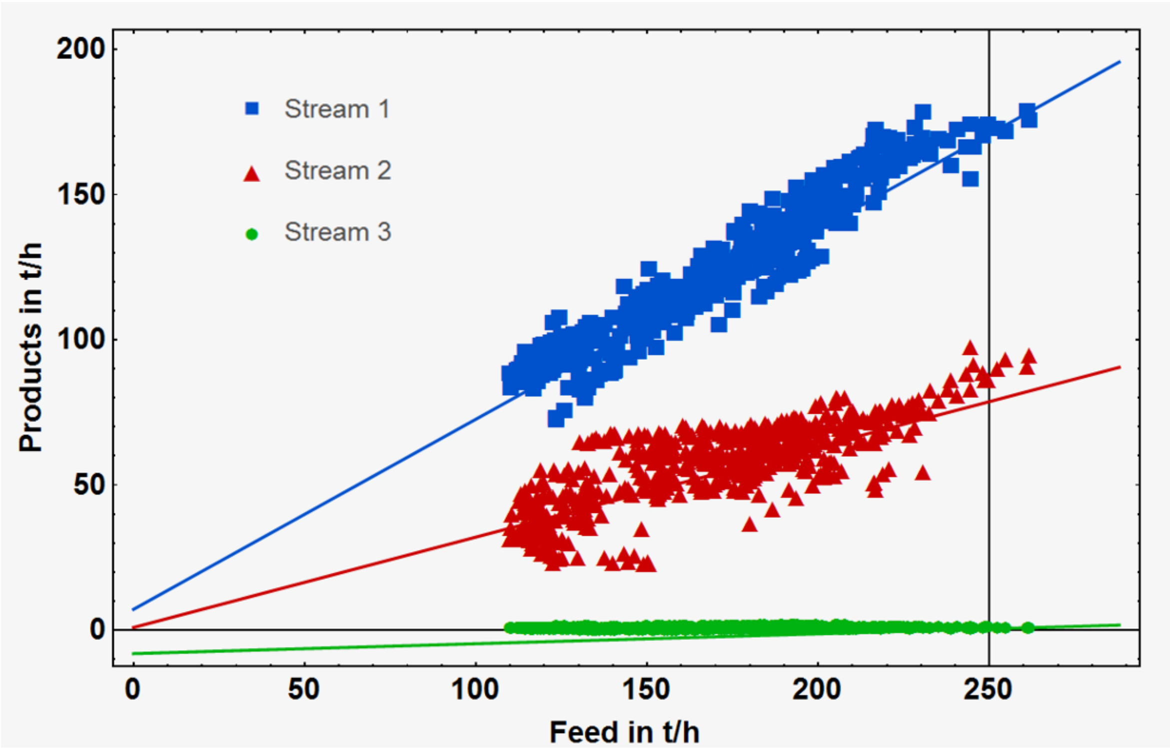

Figure 3-9: Exemplary case with three streams of one plant without any additional regression settings

feed mass flow rates below 250 t/h cannot be simulated any further with this set of equations. This would limit the area of validity of this model significantly and is no longer representative.

To avoid cases like this, it is possible to apply regression settings similarly to in the data filter. Figure 3-10 depicts the input interface. The individual plant and stream settings are itemized and described below.

- **Set Plant:** A single plant can be selected by this drop-down list.
- **Pr Mass Balance:** If this box is ticked, product mass balance has to be valid according to equation (1-2).
- **Pr Deviation:** The product deviation can be selected to be absolute or relative.
- **Ut Zero intercept:** If this box is ticked, all utility streams are intercepting the ordinate at zero.
- **Automatic:** Default settings are applied.
- **Splitter:** All product streams are intercepting the ordinate at zero.

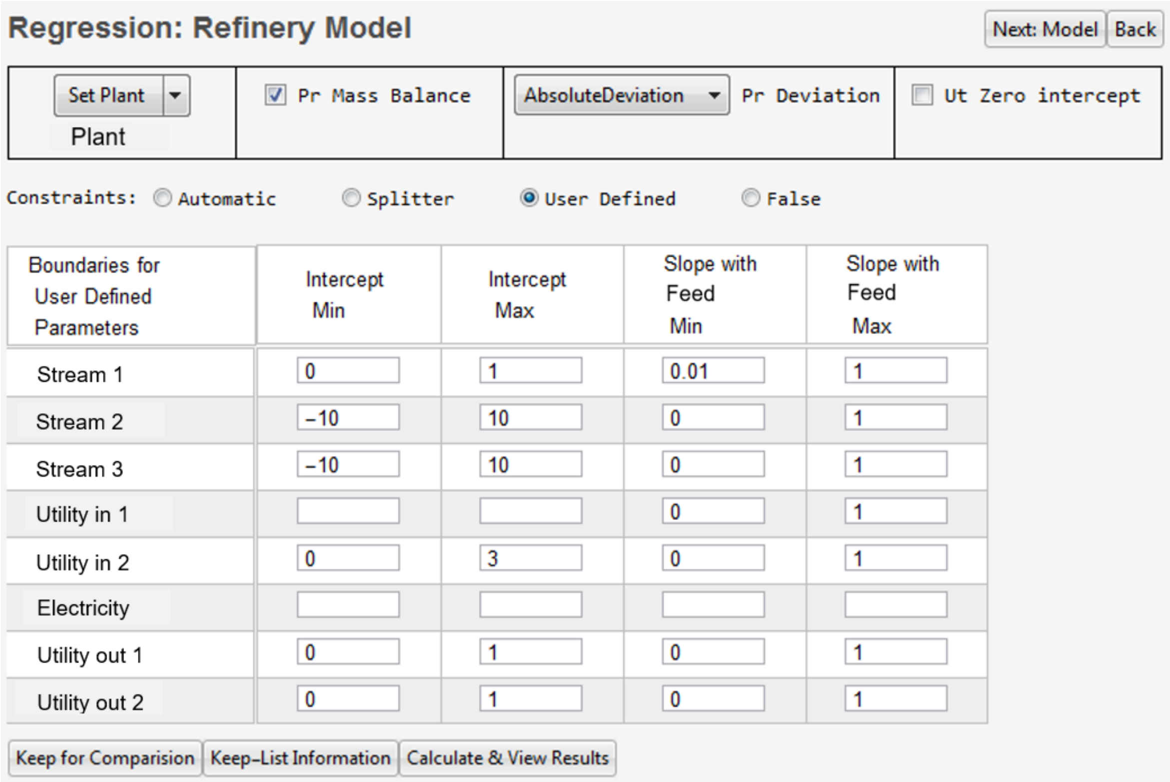

Figure 3-10: Input interface for the regression settings

- **User Defined:**
  - **Slope:** Setting minimum and maximum values for the slope of the regression lines.
  - **Ordinate Intersection:** Setting minimum and maximum values for the ordinate intersection of the regression lines.
- **False:** No further constraints applied. In order to fulfill the mass balance, it is allowed that the regression line does not meet the area of data, depicted in figure 3-11.

The regression settings contain default values, i.e. for every utility the product mass balance has to be valid. In order to generate a model with a realistic approach of the operation modes, this is indispensable and may only be changed for good reasons. The product deviation is set to absolute deviation by default. Due to this setting, absolute deviations between any data point and the corresponding value of the regression line is calculated and minimized, according to

$$\text{absolute Deviation} = y_{\text{Reg}} - y_{\text{Data}} \,. \tag{3-1}$$

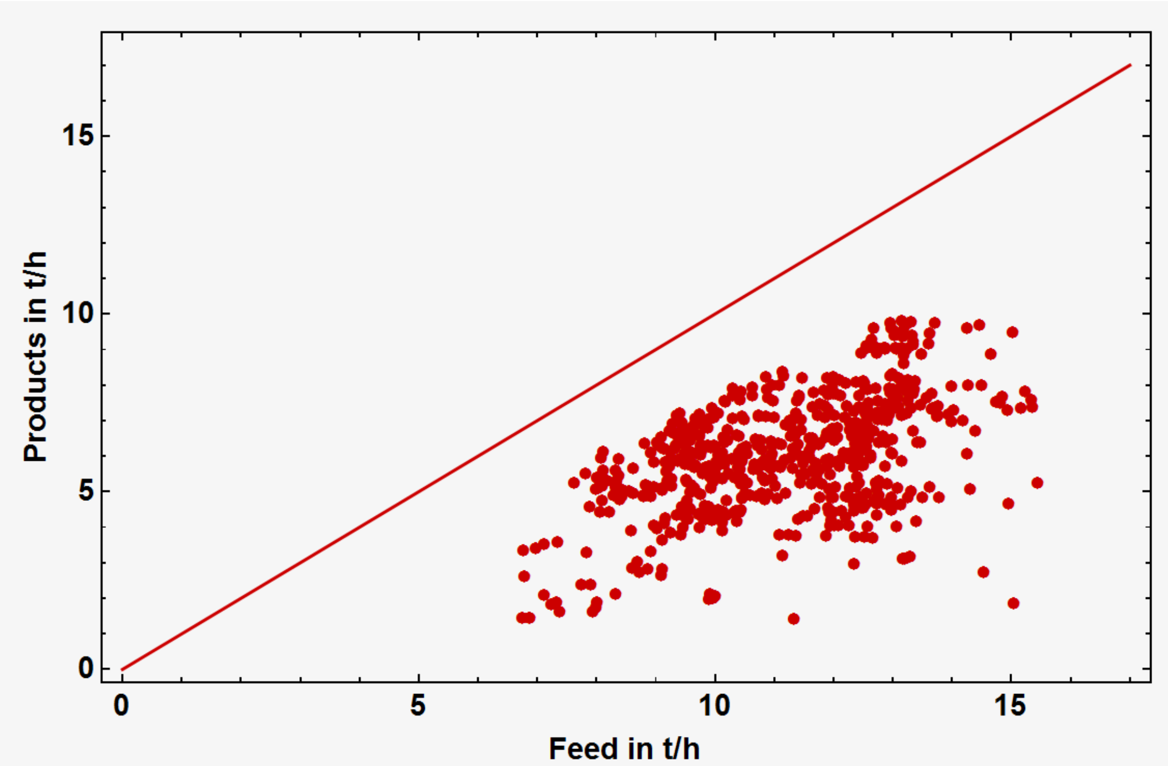

Figure 3-11: Exemplary stream, where the regression line does not meet the data area, in order to fulfill the mass balance

The relative deviation setting minimizes the relative deviations between any data point and the corresponding value of the regression line, according to

$$\text{relative Deviation} = \frac{y_{\text{Reg}} - y_{\text{Data}}}{y_{\text{Data}}}\,. \tag{3-2}$$

For this setting, it is necessary that no data of any stream has a value of zero. Those stream data points have to be filtered, as this would result in a division by zero. To avoid any failure messages at the beginning, the default setting is absolute product deviation. The constraint setting “Automatic” defines no further adjustments. All other adjustment possibilities are optional and have to be considered in any case individually.

By changing the settings to “Splitter” mode, all regression lines of the production streams are forced through origin. As long as every stream has a positive slope, the area of validity of this model is no longer limited. On the other hand, the drawback of this mode is that the regression lines may not represent the trend of the measured data accurately.

However, it is not always necessary that the area of validity ranges down to zero, as every plant has a minimum feed requirement. Below this mass flow the plant can

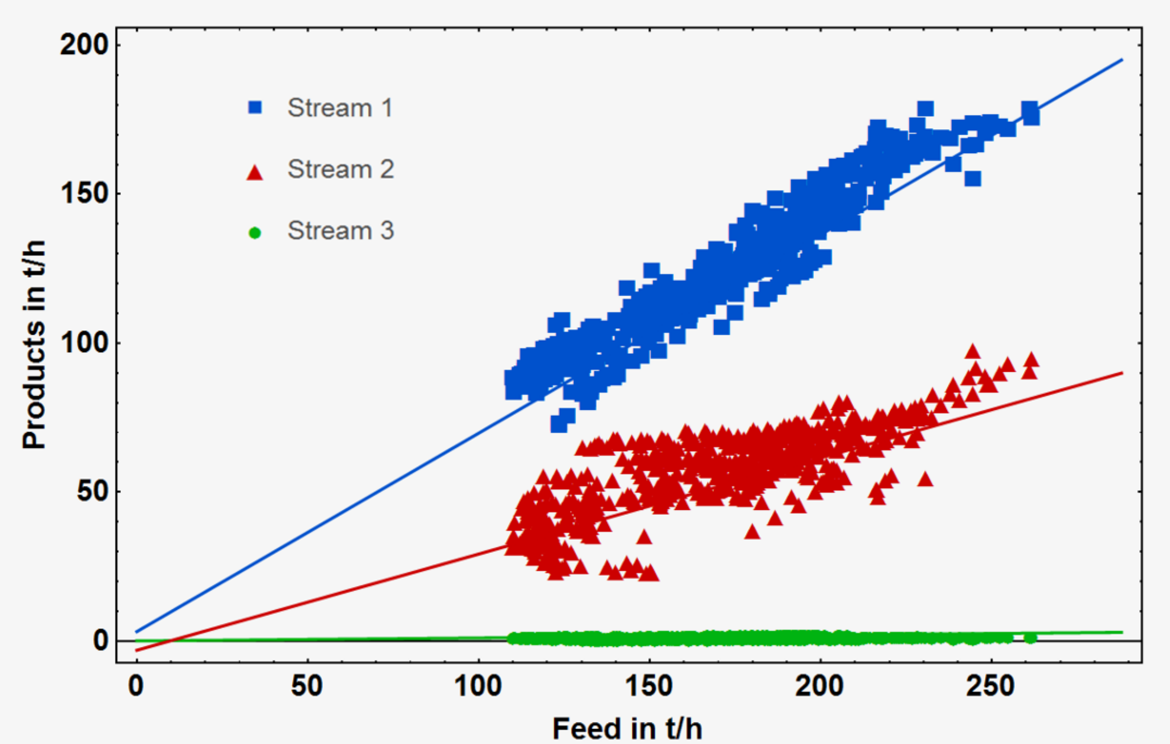

Figure 3-12: Exemplary case with three streams of one plant with user defined regression settings from figure 3-10

not be operated, and therefore, it is not necessary for the model to extrapolate an operation mode into this area. Generally, the priority for the regression lines is to represent the measured data as good as possible inside the operating range of the plant, depicted by the minimum and maximum feed mass flow. To fully represent this area it might be necessary for some streams to limit the slope or ordinate intersection in order to find a compromise. This is possible by changing into “User Defined” mode and defining these limits, as depicted in figure 3-10.

As soon as all settings are done for one plant, the case has to be saved by clicking Keep for Comparison. Analog to the data filter, it is possible to save several cases for one plant. The progress of defining the regression settings has to be repeated for all plants, where the default settings should be varied. After saving the last case and clicking Calculate & View Results, the regression lines are computed and the results are depicted in diagrams.

By selecting a plant, it is possible to evaluate the regression line of each stream and case individually. Combinations of a few streams of one case, one stream in different cases, and even several streams in multiple cases are feasible. Comparing the sum of relative and absolute deviations of the regression lines in the different cases helps to find the best suitable case. This information is provided in a pop-up window after

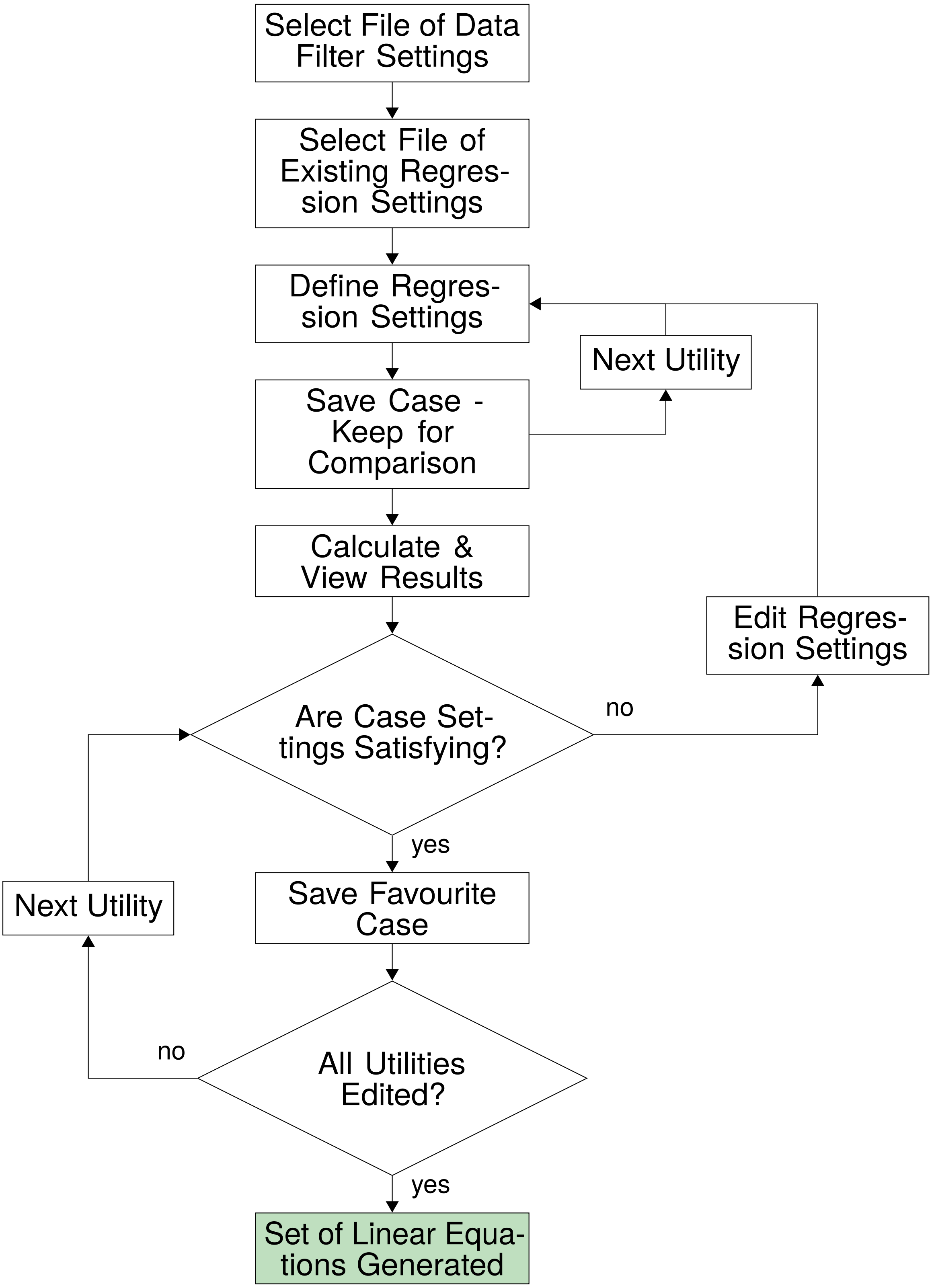

Figure 3-13: Sequence of generating a set of linear equations

clicking Regression Criteria. The best case can be saved with Save Favourite. Analog to the data filter, all other designed cases of this plant are then deleted by this function. The graphical illustration or the computed result can be saved by Save Plot and Save Result as .m-file. If any settings should be changed or extra ones should be added, Edit Regression Settings leads back to the input interface. Just like the data filter, finding the right regression settings is an iterative process. The sequence of generating a set of linear equations is depicted in figure 3-13.

4 Mixed Integer Linear Programming

For an intelligent optimization of highly cross-linked production networks as a refinery, the used method is of significant importance. Mayer compared different optimization methods in [6]. As all product and utility streams are described by linear equations, MILP is a sufficient optimizing method. The solver of the mathematical programming of MILP expects matrices and vectors as input, which are difficult to read. An input conversion algorithm was developed by Mayer, which offers two significant advantages. First, most parts of the optimizing model are generated automatically by preprocessed data of the OptiApp. Second, the input syntax for user-defined objective functions and constraints is simplified.

The input conversion algorithm expects three input arguments. First, a set of linear equations is required, generated as described in chapter 3.3. Second, a stream dataset is needed, which contains the information about origin and destination of any stream inside the refinery. The third argument includes all user-defined input with up to eight different kinds of information. It is advised to provide as much information as possible, even though it is not mandatory to provide all of them. The eight different types of information are itemized and described below.

- **Objective:** The objective is the linear target function for the optimization, consisting of parameters and stream names. The parameters represent the cost of the corresponding streams and have to be real numbers. Generally, a minimization is performed by the algorithm. Maximizing a stream is possible with a negative parameter.
- **New plant:** Defining a new plant is the next argument. It is possible to implement new plants, which are not mentioned in the stream dataset, to the existing production network. New plants also need new streams and new functions, which are the next two arguments. Without associated streams and functions, a new plant is not implemented into the production network, and therefore, is not considered during optimization.
- **New streams:** New streams have to be defined with the same structure as they appear in the stream dataset. However, a full definition is not necessary, but the origin, the destination, and the class of the stream have to be defined.
- **New functions:** It is mandatory to define new functions for new streams, but also possible to specify a new function for an existing stream. New functions have to be linear equations, where the dependencies of the output streams

from the input streams of a plant are depicted. It is crucial that new functions are assigned explicitly to a plant, otherwise they cannot be considered for the optimization.

- **New stream ranges:** For a meaningful model the stream ranges, between which the MILP's values can vary, need to be as tight as possible. The bounds can be of physical, practical or economical nature for the corresponding plant. The default stream ranges for every stream are defined by the minimum and maximum mass flow rate of this particular stream. Defining new stream ranges is possible by assigning a new lower and upper bound.

- **Re-routing streams:** While new streams can be designed with the argument of the same name, existing streams can be re-routed by changing the origin or destination. Therefore, it is necessary to define only the part that needs to be changed.

- **Fixed on/off:** Generally, the solver of the optimization can decide which plant and corresponding streams are switched on or off. With this argument it is possible to predefine this decision by turning certain plants on or off manually.

- **Additional constraints:** Additional constraints are the most flexible arguments. They can consist of equations and inequations. Even chains of equations in form of

  100 $\leq$ "Stream 1-1" $\leq$ 120

  or

  "Stream 2-4" + "Stream 3-1" == 1

  can be defined, as they are automatically split up into several individual ones.

More detailed information and an extensive collection of examples can be found in [6]. As mentioned before for the data filter and generation of the set of linear equations, the modeling requires experience with MILP, the optimization model, and the production network, which should be considered.

4.1 Case 0 - Recomputing a Historical Set of Data

Before the MILP can compute any optimized operation modes for the refinery, the generated set of linear equations and the MILP itself have to be verified to be able to calculate meaningful results. This is done by recomputing a historical set of data. While the mass flow rates of the feed streams for each plant are predefined by the data of a historical date, the mass flow rates of the product streams are calculated by the usage of the set of linear equations. If the results of the calculated streams are not significantly deviating from the historical data, the MILP and the sets of linear equations are said to be representative.

It is important to select an appropriate date for recomputing the historical measurement data. As the OptiApp is a static system, which can not depict and calculate dynamic changes, a day with constant production should be selected. Since only daily-averaged data is saved and outliers are neglected during the data filter process, a suitable day for recomputing is given, when one day's data for all plants are available. If there is no day, when data for all plants are available, the day with the most plants is chosen. For the validation of the MILP and the set of linear equations August 31st, 2016 for summer and February 16th, 2016 for winter are selected, respectively.

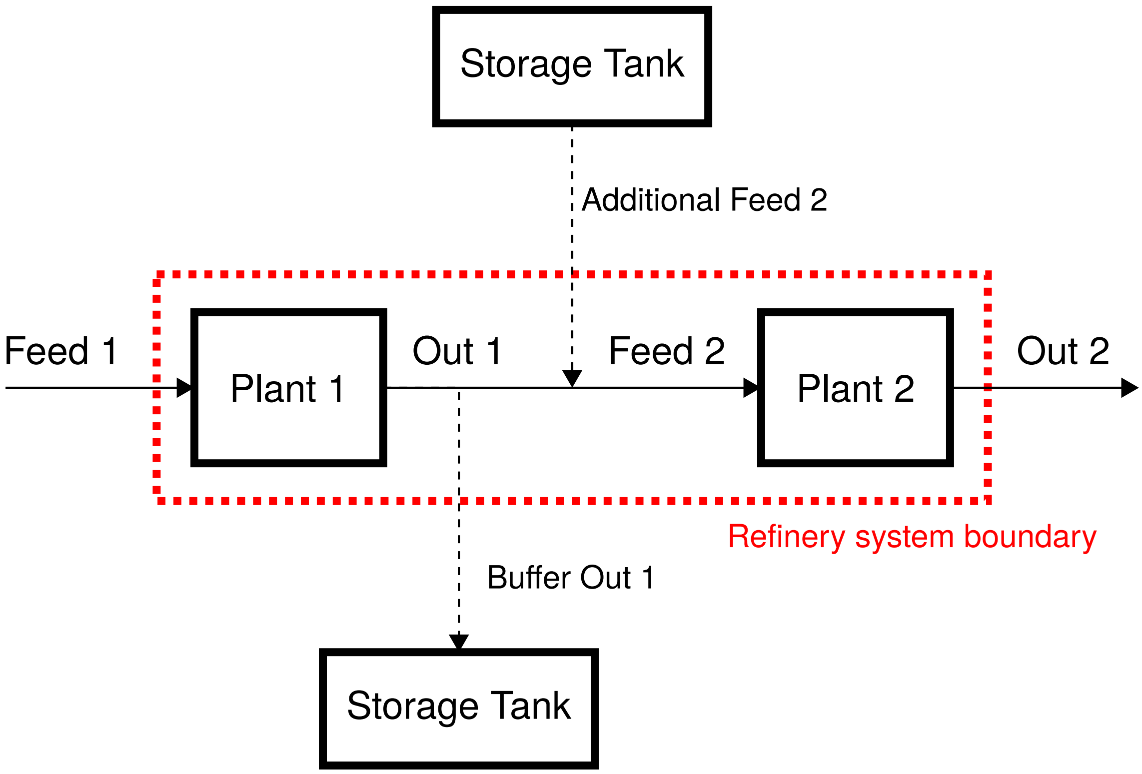

Figure 4-1: Graphical illustration for two interconnected plants with storage tanks

In the OptiApp intermediate products are expected to be processed by the next plant immediately. However, this is not always the case in a real refinery. A lot of tanks for the storage of intermediate products are used. In order to recompute the historical data, additional streams towards and from storage tanks have to be created. Figure 4-1 shows a schematic flow chart for two interconnected plants with the possibility of leading excess amounts of "Out 1" into a storage tank or providing extra input for plant 2 by "Additional Feed 2". To fulfill mass balance around every single plant and overall, for the optimization model all storage tanks are located outside of the refinery system boundary. As a further simplification, the storage tanks are not limited in size, so they can infinitely take up or provide intermediate products.

For every plant inside the refinery, an additional feed stream is generated, which provides extra input from a tank. This is necessary for all plants, which were partly fed from storage tanks at the selected days. For all output streams of every plant, additional buffer streams are generated, where excess amounts of intermediate products can be lead into storage tanks. These streams are necessary for all plants, which produced more intermediate products than the following plants processed at the selected dates.

There are streams, where the regression line does not meet the data area. Those

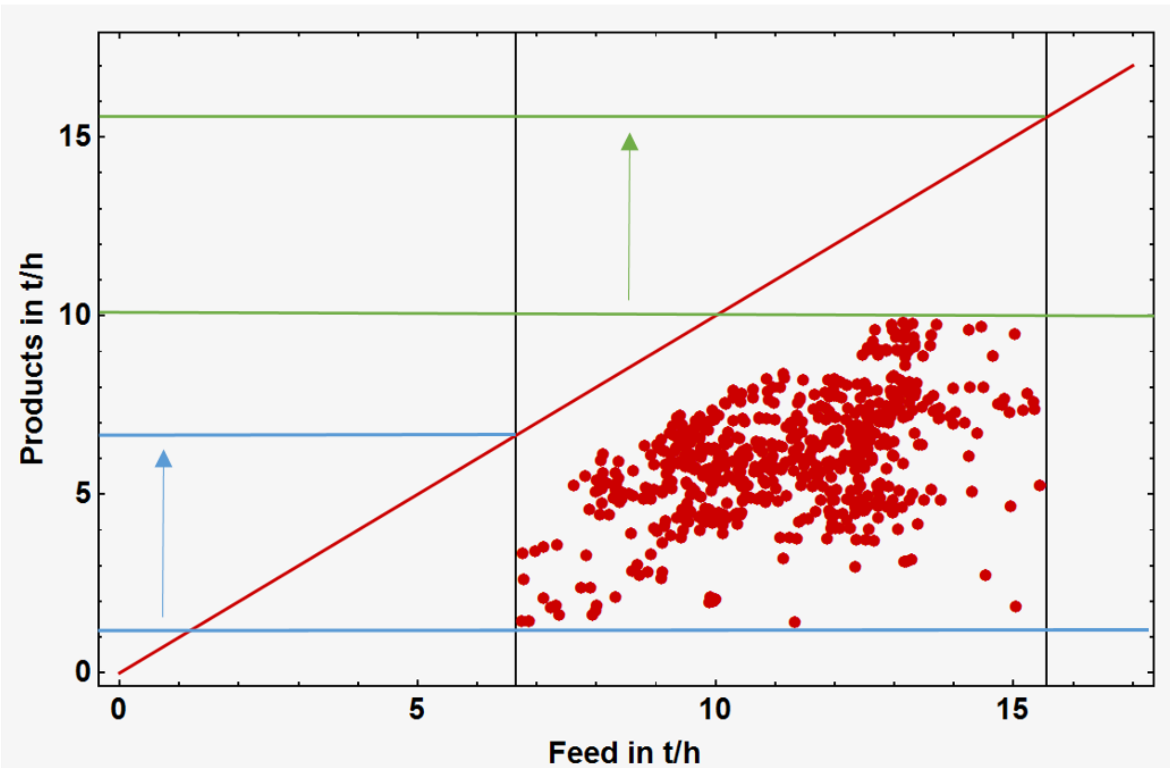

Figure 4-2: Assigning new stream ranges to an exemplary stream

streams have to be assigned with new stream ranges, exemplary depicted in figure 4-2. The lower and upper stream range limits are adjusted to the corresponding values of the regression line at the minimum and maximum feed mass flow rate of this plant. Without these new stream ranges the MILP might not be able to find a solution.

Due to confidentiality, all names for the production plants, streams and products are anonymized. Products are describe by upper-case letters, i.e. “Product A”. Plants are depicted with consecutive numbers, i.e. “Plant 1”. The streams nomenclature consist of two numbers, where the first one describes the associated plant and the second one is a sequential number, i.e. “Stream 1-1”. Manually added streams are buffer streams, i.e. “Buffer Stream 1-1” and additional feed streams, i.e. “Additional Feed Plant 1”. For plants with more than one feed stream, the nomenclature of the additional feed streams is extended by a dot and a consecutive number, i.e. “Additional Feed Plant 15.1”. Streams, which are added by the optimization model, start with a lower-case letter and consist just of one sequential number, i.e. “stream1”.

The objective function for case 0 is to minimize the mass flow rates of all added streams. As additional constraints equations are defined, which allow the feed streams to vary 1 % around the measured data from August 31st, 2016 and February 16th, 2016, respectively. In table 4-1, all buffer and additional feed streams, whose mass flow rates are not zero, are depicted. In the appendix in table A.1 and A.2, all streams inside the refinery with their measured mass flow rates of the corresponding day, the

Table 4-1: Added streams for recomputing the historical measurement data with the mass flow rates in t/h

Streams	**Mass Flow Rate**	
	Summer	**Winter**
Additional Feed Plant 1	—	32.931
Buffer Stream 1-1	1.757	—
Buffer Stream 1-2	2.268	2.596
Buffer Stream 1-11	—	9.029
Buffer Stream 9-1	—	2.936
Additional Feed Plant 11	4.294	—
Additional Feed Plant 12	—	9.888
Additional Feed Plant 14	9.549	—
Additional Feed Plant 15.1	3.697	—
Buffer Stream 15-8	9.240	13.221
Additional Feed Plant 15.2	5.656	—
Additional Feed Plant 22	—	3.667
Additional Feed Plant 29	0.003	—

calculated MILP value, and the relative and absolute deviations are listed for summer and winter, respectively.

Most of the calculated values of the optimization model accord with the historical measurement data. A lot of outliers are utility streams, which are simulated but are no further part of this work. The utility network is simulated and optimized by Tomaschitz [12]. For the deviation of the product streams, various reasons are possible. As described above, regression lines, which do not represent the measured data accurately cannot recompute the actual measured data. Also, if the measured data varies essentially from the regression line at this day, the computed value will deviate significantly, even though the feed mass flow rate is very similar. Furthermore, certain production plants of the refinery have essential different operation modes, but as a simplification they are implemented in the OptiApp as various plants. Those plants cannot be assigned with the additional constraint of the feed stream mass flow rate. As a result, the computed feed mass flow rate differs from the measured one, and therefore, also all product streams deviate. Further information about this approach can be found in [8].

The overall result of the recomputed historical measurement data is satisfying. For summer and winter operation mode, only a few added streams have to be used. The large additional mass flow rate for plant 1 can be explained by a substandard feed amount at February 16th, 2016. The following differences between computed and measured data mainly lead back to even this extraordinary feed amount of plant 1. In the summer operation mode, there are no such large outliers, which depicts a very constant operation mode. The good results show the high functionality of the OptiApp and the optimizing model. All deviations can be explained and are comprehensible, due to the simplifications and assumptions made in this model. With this outcome, the MILP and the set of linear equations are validated and can be used for further optimization. In the following chapters different case studies are performed.

4.2 Case 1 - No New Plants

After validating the optimization model by recomputing the historical measurement data from August 31st, 2016 and February 16th, 2016 for summer and winter operation mode, respectively, different virtual case studies are compiled. In case 1, two essential changes are made compared to the actual production network. First, three plants are exemplarily turned off and their streams are re-routed. Besides disconnecting those plants, no new ones are implemented into the production network. Second, certain product mass flow rates are regulated due to estimations for the future market demand. These estimations are made on the basis of the trends of the last years and their expected development.

Products A and B consist of several streams, which are blended into the right composition. In order to change the mass flow rate of the final product, the minimum and maximum mass flow rate, and the ratio between those streams have to be regulated. As the ratio between those streams is essential for the final product quality, tight additional constraints have to be set, whereby various plants are affected. Due to the high interconnection of the production plants inside the refinery and the predefined product mass flow rates, it is necessary to include additional feed and buffer streams with storage tanks, analog to case 0. These additional streams are minimized by the optimization algorithm.

The plants 16, 22 and 28 are purification plants, which increase the values of the products A and B. As it is also possible to sell these products without this purification step and due to the cost-benefit ratio of these plants, it was decided to turn them off exemplarily. All streams entering plant 16, 22 or 28 are re-routed directly towards the blenders. To reach a mass flow rate of 67.5 t/h of product C, plant 1 has to be operated at the upper mass flow limit, but the default stream ranges do not have to be changed. However, the mass flow rate of stream 2-4 has to be increased significantly in order to produce 85 t/h of product D. Therefore, the stream range limits of all streams of plant 2 have to be expanded and the regression line is extrapolated, which holds the risk that the actual plant is not able to process this mass flow rates.

As mentioned earlier, plants 18, 19 and 20 are in fact just essential different operation modes of one purification plant, which are implemented in the OptiApp as different plants for simplification reasons. An additional constraint prevents the case that more than one of those plants are switched on during the optimization. Which particular plant is switched on, is incumbent on the MILP and is not further predefined. All MILP settings are itemized below.

- **Objective:**
  - Minimize additional feed and buffer streams
  - Maximize mass flow rates of product C and D
- **New stream ranges:**
  - Upper stream range of all streams of plant 2 expanded

  - Streams, where the regression line does not meet the data area

- **Re-routing streams:**
  - Feed streams of plant 16, 22 and 28 re-routed directly towards the corresponding blenders

- **Fixed on/off:**
  - Plant 1 to 15, 17, 21, 23 to 27, 29 and 30 - on
  - Plant 16, 22 and 28 - off
  - Plant 18, 19 and 20 - not defined

- **Additional constraints:**
  - $0 \leq$ “Plant18Switch” + “Plant19Switch” + “Plant20Switch” ≤ 1
  - 345 t/h $\leq$ Stream 12-5 + Stream 13-5 $\leq$ 350 t/h
  - 50 t/h $\leq$ Stream 15-4 + Stream 19-3 $\leq$ 60 t/h
  - 480 t/h $\leq \sum$ Streams 12-5, 13-5, 15-4, 19-3, 23-2 $\leq$ 485 t/h
  - 60 t/h $\leq$ Stream 8-1 + Stream 21-4 + Stream 21-5 $\leq$ 75 t/h
  - 15 t/h $\leq$ Stream 9-7 + Stream 9-13 $\leq$ 30 t/h
  - 95 t/h $\leq \sum$ Streams 8-1, 9-7, 9-13, 21-4, 21-5 $\leq$ 105 t/h

The computed mass flow rates of all streams, which are blended for products A and B are depicted in table 4-2 and table 4-3, respectively. For the production of 67.5 t/h of product C and 85 t/h of product D, additional feed streams for plant 1 and 2 are necessary, respectively. Table 4-4 shows all needed additional feed and buffer streams with their mass flow rates for case 1. All additional constraints are fulfilled. The full results of case 1 are listed in the appendix in table A.3 and A.4 for summer and winter, respectively.

Excluding the few additional streams, which are needed for small mass flow rates, table 4-4 shows clearly the necessity for additional feed streams for plant 1 and 2, in summer even more than in winter. This is the result of the predefined high mass flow rates of product C and D, respectively. The additional feed, which is required in plant 1 and 2, and further limiting additional constraints for several other streams result in enormous buffer stream mass flow rates for stream 15-8 and 30-4. Stream

Table 4-2: Stream mass flow rates and stream ranges in t/h of product A for summer and winter operation mode in case 1

	Summer			**Winter**		
Streams	**MILP**	**Stream Range Min**	**Stream Range Max**	**MILP**	**Stream Range Min**	**Stream Range Max**
Stream 12-5	105.93	105.39	157.00	116.14	116.14	157.78
Stream 13-5	244.07	122.21	286.36	233.86	146.56	286.79
Stream 15-4	26.20	13.29	46.76	19.15	8.81	48.68
Stream 19-3	33.80	30.00	76.00	40.85	40.85	76.13
Stream 23-2	75.00	41.42	79.99	75.00	36.62	81.02

Table 4-3: Stream mass flow rates and stream ranges in t/h of product B for summer and winter operation mode in case 1

	Summer			**Winter**		
Streams	**MILP**	**Stream Range Min**	**Stream Range Max**	**MILP**	**Stream Range Min**	**Stream Range Max**
Stream 8-1	8.99	0.01	25.00	13.08	1.45	19.41
Stream 9-7	9.69	7.00	35.00	17.46	7.00	36.00
Stream 9-13	20.31	12.00	40.00	12.54	12.00	40.00
Stream 21-4	18.08	12.16	79.93	13.61	13.56	79.37
Stream 21-5	47.93	40.00	125.00	48.31	40.00	125.00

Table 4-4: Additional feed and buffer streams in t/h for case 1

Streams	**Mass Flow Rate Summer**	**Mass Flow Rate Winter**
Additional Feed Plant 1	43.60	19.95
Additional Feed Plant 2	47.47	43.79
Buffer Stream 1-2	2.08	1.79
Additional Feed Plant 6	2.01	3.68
Buffer Stream 15-8	81.09	55.00
Buffer Stream 14-12	2.04	—
Additional Feed Plant 23	5.98	21.04
Additional Feed Plant 25	1.73	—
Additional Feed Plant 27	3.15	—
Buffer Stream 30-4	55.81	43.16

15-8 is a feed stream for plant 9. The throughput of plant 9 is limited by the mass flow rates of stream 9-7 and 9-13, which are both part of product B. The streams 21-4 and 21-5 are also part of product B, and therefore, the throughput of plant 21 is limited by the mass flow rates of those two streams. Due to this limitation, plant 21 operates near the lower stream range limit. As a result, stream 30-4 has to feed a storage tank, instead of providing all its output to plant 21. In the winter operation mode of plant 9, the ratio between stream 9-7 and 9-13 is changed. This offers the possibility to increase the throughput of plant 9 significantly and thereby, reducing the buffer stream amount of stream 15-8. The quality of product B is unchanged as the sum of stream 9-7 and 9-13 is the same as in summer operation mode.

Comparing summer and winter operation mode, it attracts attention that especially the necessity of additional feed for plant 23 has increased enormously in winter. This is another result of the different operation mode of plant 15, which provides less feed for plant 23 in winter than in summer. In table 4-2, it is also visible that the winter mass flow rate of stream 15-4 is considerably lower than in summer. In contrast, stream 19-3 increased the mass flow rate about the same amount as the one of stream 15-4 decreased. For the quality of product A, the sum of both streams proportional to stream 23-2, and the sum of stream 12-5 and 13-5 is important. The same phenomenon as for stream 15-4 and 19-3 occurs with the streams 12-5 and 13-5. As plant 12 is operated at the lower stream range limit, which is for stream 12-5 more than 10 t/h lower in summer than in winter, stream 13-5 has to cover the remaining difference until the predefined mass flow rate of at least 345 t/h is reached. In contrast to plant 23, plant 1 benefits in winter operation mode from the higher throughput of plant 9, where output streams feed to some extend plant 1. The higher amount of feed for plant 1 reduces the need of additional feed in winter by more than 50 %.

4.3 Case 2 - Maximum Yield for Product C

The general idea of case 2 is the maximization of the production of product C. Therefore, the production network of the refinery is extended for this case study by an OCM and a P2H2 plant, as discussed in chapter 2. The OCM plant is fed with methane and oxygen, which is converted into ethane, ethylene, carbon monoxide, stack gas, and waste water. While the ethane stream is lead to plant 2, the unconverted methane is burned for generation of electricity. The produced electrical power is used for the P2H2 plant, where water is electrolysed to gain hydrogen and oxygen. While the hydrogen can be sold, the oxygen is lead back to the OCM plant. With those two new plants it is possible to increase the mass flow rate of product C significantly. For the implementation of those two new production plants into the network of the refinery, their streams and the associated linear equations have to be defined.

In contrast to case 1, in case 2, the stream range limits of plant 2 are not expanded. This implicates a much lower mass flow rate of product D. The defined additional constraints of case 1 persist as the demanded mass flow rates for product A and B are also the same as in the previous case. The additional constraints are extended with the definitions for the OCM and P2H2 plant.

On the other side, the plants 16, 22 and 28, which were turned off in case 1, are also shut down in this case. Their feed streams are re-routed directly towards the blenders. For plants 18, 19 and 20 apply the same restrictions as in case 1, so only one of them may be switched on at a time. This is also defined by an additional constraint.

- **Objective:**
  - Minimize additional feed and buffer streams
  - Maximize mass flow rates of product C and D
- **New plants:** Implementing OCM and P2H2 plants into the production network
- **New streams:** Generating streams of OCM and P2H2 plants
- **New functions:** Defining linear equations for streams of OCM and P2H2 plants
- **New stream ranges:** For streams, where the regression line does not meet the data area
- **Re-routing streams:** Feed streams of plant 16, 22 and 28 re-routed directly towards the corresponding blenders
- **Fixed on/off:**
  - Plant 1 to 15, 17, 21, 23 to 27, 29, 30, OCM and P2H2 - on
  - Plant 16, 22 and 28 - off
  - Plant 18, 19 and 20 - not defined
- **Additional constraints:**
  - $0 \leq$ “Plant18Switch” + “Plant19Switch” + “Plant20Switch” ≤ 1

- 345 t/h $\leq$ Stream 12-5 + Stream 13-5 $\leq$ 350 t/h
- 50 t/h $\leq$ Stream 15-4 + Stream 19-3 $\leq$ 60 t/h
- 480 t/h $\leq \sum$ Streams 12-5, 13-5, 15-4, 19-3, 23-2 $\leq$ 485 t/h
- 60 t/h $\leq$ Stream 8-1 + Stream 21-4 + Stream 21-5 $\leq$ 75 t/h
- 15 t/h $\leq$ Stream 9-7 + Stream 9-13 $\leq$ 30 t/h
- 95 t/h $\leq \sum$ Streams 8-1, 9-7, 9-13, 21-4, 21-5 $\leq$ 105 t/h
- 180 t/h $\leq$ Stream OCM-1 $\leq$ 205 t/h
- Stream OCM-EL == Stream P2H2-EL

The results of optimization case 2 fulfill all predefined constraints and objective functions. The mass flow rates of all streams for products A and B are listed in table 4-5 and 4-6, respectively. Due to the implementation of the OCM plant, the mass flow rate for product C increased significantly to 124.9 t/h in summer and 122.6 t/h in winter operation mode. Only 50.1 t/h in summer and 50.6 t/h in winter of product D are produced in this case, due to the default stream range limits for plant 2. All additional feed and buffer streams are listed in table 4-7. The entire list of streams and their mass flow rates are depicted in the appendix in table A.5 and A.6 for summer and winter, respectively.

As the additional constraints for products A and B did not change in comparison to case 1, the computed results are identical with one exception. In winter operation mode of case 2, plant 13 is operated with less throughput than in case 1, therefore stream 13-5 produces 5 t/h less compared to the previous case. By this change the total mass flow rate of product A reduces to 480 t/h.

The implementation of the OCM plant increased the total mass flow rate of product C significantly. The objective function to maximize the mass flow rate of product C implicates that plant 1 and the OCM plant are operated at the upper throughput limit. Due to the additional ethane stream from the OCM plant towards plant 1, the necessity of additional feed dropped significantly to 12.65 t/h in summer operation mode. In winter operation mode no additional feed is necessary for plant 1, as the throughput of plant 9 is considerably higher, which provides more feed for plant 1 as well. 67.5 t/h of product C in summer and 65.2 t/h in winter, respectively, are produced in plant 1. The OCM plant is able to produce 57.4 t/h of product C. In contrast to plant 1, there is just one operation mode for the OCM plant, so the produced amounts do

Table 4-5: Stream mass flow rates and stream ranges in t/h of product A for summer and winter operation mode in case 2

	Summer			**Winter**		
Streams	**MILP**	**Stream Range**		**MILP**	**Stream Range**	
		Min	**Max**		**Min**	**Max**
Stream 12-5	105.93	105.39	157.00	116.14	116.14	157.78
Stream 13-5	244.07	122.21	286.36	228.86	146.56	286.79
Stream 15-4	26.20	13.29	46.76	19.15	8.81	48.68
Stream 19-3	33.80	30.00	76.00	40.85	40.85	76.13
Stream 23-2	75.00	41.42	79.99	75.00	36.62	81.02

Table 4-6: Stream mass flow rates and stream ranges in t/h of product B for summer and winter operation mode in case 2

	Summer			**Winter**		
Streams	**MILP**	**Stream Range**		**MILP**	**Stream Range**	
		Min	**Max**		**Min**	**Max**
Stream 8-1	8.99	0.01	25.00	9.09	1.45	19.41
Stream 9-7	9.69	7.00	35.00	17.46	7.00	36.00
Stream 9-13	20.31	12.00	40.00	12.54	12.00	40.00
Stream 21-4	18.08	12.16	79.93	15.14	13.56	79.37
Stream 21-5	47.93	40.00	125.00	50.77	40.00	125.00

Table 4-7: Additional feed and buffer streams in t/h for case 2

Streams	**Mass Flow Rate**	
	Summer	**Winter**
Additional Feed Plant 1	12.65	—
Additional Feed Plant 2	12.18	8.98
Buffer Stream 1-2	2.08	1.79
Additional Feed Plant 6	2.01	3.59
Buffer Stream 15-8	81.09	54.98
Buffer Stream 14-12	2.04	—
Additional Feed Plant 23	5.98	21.00
Additional Feed Plant 25	1.73	—
Additional Feed Plant 27	3.15	—
Buffer Stream 30-4	55.81	38.95

not vary between summer and winter.

105 MW of electrical power, generated at the OCM plant by burning unconverted methane, are used in the P2H2 plant for electrolyzing 23.3 t/h of water and producing 2.6 t/h of hydrogen and 20.7 t/h oxygen, which are lead back to the OCM plant.

In table 4-7, the additional feed and buffer streams are depicted. There are the same streams listed as in case 1. Even though the exact mass flow rates differ between the cases as the additional constraints are not fully identical, the overall trend is the same. It is clearly visible that in winter less storage tanks are needed, which indicates a much more constant operation mode.

4.4 Case 3 - Future-Oriented Production

Case 3 is a further development and combination of case 1 and 2. As done in both previous cases, plants 16, 22 and 28 remain shut down in case 3. The OCM and P2H2 plant persist implemented into the production plant network, as described in case 2.

The mass flow rate of product A also stays the same as in both other cases. For product B the mass flow rate is decreased a little bit further. Therefore, the additional constraints have to be set even tighter. Limiting streams 9-7 and 9-13 in order to keep the right ratio for product B, also limits the whole plant 9. Other intermediate products of plant 9, i.e. stream 9-1, are feed streams for plant 1, which needs virtual additional feed to be able to produce the predefined mass flow rate of product C.

To avoid this opposing trend, new splitters are implemented, which divide the streams 9-7 and 9-13. While one part of those two streams is still feeding the product blender for product B, further named stream 9-7-B and 9-13-B, the excess mass flow rates are lead to plant 1, which are named stream 9-7-1 and 9-13-1. By this extension, it is possible to operate plant 9 at a higher throughput, and therefore, provide more feed for plant 1. Besides stream 9-7-1 and 9-13-1, stream 9-1 is also a feed stream for plant 1. The total mass flow rate of stream 9-7-B and 9-13-B is regulated by an additional constraint, as well as their ratio among each other. The ratio varies between summer and winter operation mode but is the same as in case 1 and 2, respectively.

The production of product C is decreased compared to case 2. The combined mass flow rate of product C from plant 1 and the OCM plant is limited to 70 t/h. This constraint causes a much lower throughput of plant 1 and the OCM plant. On the one side, less throughput of plant 1 reduces the additional feed needed, on the other side, this implicates less intermediate product of stream 1-1, which is a feed stream for plant 2.

In order to produce the same mass flow rate of product D as in case 1, the stream range limits of plant 2 are extended again. This demanded amount of product D and the lower throughput of plant 1, which causes less feed for plant 2, increases the necessity of additional feed for plant 2.

- **Objective:**
  - Minimize additional feed and buffer streams
  - Maximize mass flow rate of product D
- **New plants:** Implementing OCM and P2H2 plants into the production network
- **New streams:**
  - Generating streams of OCM and P2H2 plants
  - Generating stream 9-7-1 and 9-13-1
- **New functions:** Defining linear equations for streams of OCM and P2H2 plants
- **New stream ranges:**
  - Expansion of upper stream ranges for all streams of plant 2
  - For streams, where the regression line does not meet the data area
- **Re-routing streams:**
  - Feed streams of plant 16, 22 and 28 re-routed directly towards the blenders
  - Generation of buffer streams
- **Fixed on/off:**
  - Plant 1 to 15, 17, 21, 23 to 27, 29, 30, OCM and P2H2 - on
  - Plant 16, 22 and 28 - off
  - Plant 18, 19 and 20 - not defined
- **Additional constraints:**
  - $0 \leq$ "Plant18Switch" + "Plant19Switch" + "Plant20Switch" ≤ 1

- $345\,t/h \leq$ Stream 12-5 + Stream 13-5 $\leq 350\,t/h$
- $50\,t/h \leq$ Stream 15-4 + Stream 19-3 $\leq 60\,t/h$
- $475\,t/h \leq \sum$ Streams 12-5, 13-5, 15-4, 19-3, 23-2 $\leq 485\,t/h$
- $60\,t/h \leq$ Stream 8-1 + Stream 21-4 + Stream 21-5 $\leq 75\,t/h$
- $20\,t/h \leq$ Stream 9-7 + Stream 9-13 $\leq 20.5\,t/h$
- $95\,t/h \leq \sum$ Streams 8-1, 9-7, 9-13, 21-4, 21-5 $\leq 105\,t/h$
- $2 \cdot$ Stream 9-7-B == Stream 9-13-B
- $80\,t/h \leq$ Stream OCM-1 $\leq 205\,t/h$
- $60\,t/h \leq$ Stream OCM-4 + Stream 1-5 $\leq 70\,t/h$
- Stream OCM-EL == Stream P2H2-EL

All objective functions and constraints formulated for case 3 are fulfilled by the presented results of the MILP. The mass flow rates for product A and B are depicted in table 4-8 and 4-9, respectively. As the total mass flow rate of product C is limited to 70 t/h in this case due to an additional constraint, there is no difference between summer and winter operation mode. Stream 1-5 provides 47.6 t/h, and the remaining 22.4 t/h are produced in the OCM plant. Due to the expanded stream range limits for plant 2, the total mass flow rate of product D is 85 t/h. Several additional feed and buffer streams are necessary for this optimization case, which are all listed in table 4-10. The entire list of all streams with their mass flow rates are depicted in the appendix in table A.7 and A.8 for summer and winter, respectively.

For product A the additional constraints did not change compared to case 1 or 2. Consequently, the mass flow rates, which are blended for product A are very similar. In the winter operation mode of case 3, a slightly lower mass flow rate of product A is produced. The reason for that is less throughput of plant 13, which can be seen as the mass flow rate of stream 13-5 is significantly lower than in summer operation mode, depicted in table 4-8.

The implementation of extra streams from plant 9 towards plant 1, where parts of stream 9-7 and 9-13 can be fed into plant 1, offers the possibility to decrease the production of product B even further without limiting the rest of the highly cross-linked network too much. By this extension it is possible, at least in the summer operation mode, to operate plant 9 at a considerable higher throughput. In combination with a

Table 4-8: Stream mass flow rates and stream ranges in t/h of product A for summer and winter operation mode in case 3

	Summer			**Winter**		
Streams	**MILP**	**Stream Range**		**MILP**	**Stream Range**	
		Min	**Max**		**Min**	**Max**
Stream 12-5	105.93	105.39	157.00	129.41	116.14	157.78
Stream 13-5	244.07	122.21	286.36	215.59	146.56	286.79
Stream 15-4	26.20	13.29	46.76	16.61	8.81	48.68
Stream 19-3	33.80	30.00	76.00	40.85	40.85	76.13
Stream 23-2	75.00	41.42	79.99	75.00	36.62	81.02

Table 4-9: Stream mass flow rates and stream ranges in t/h of product B for summer and winter operation mode in case 3

	Summer			**Winter**		
Streams	**MILP**	**Stream Range**		**MILP**	**Stream Range**	
		Min	**Max**		**Min**	**Max**
Stream 8-1	8.00	8.00	25.00	9.09	1.45	19.41
Stream 9-7-B	6.83	5.00	35.00	11.67	7.00	36.00
Stream 9-13-B	13.67	12.00	40.00	8.33	12.00	40.00
Stream 21-4	18.42	12.16	79.93	15.14	13.56	79.37
Stream 21-5	48.58	40.00	125.00	50.77	40.00	125.00

Table 4-10: Additional feed and buffer streams in t/h for case 3

Streams	**Mass Flow Rate**	
	Summer	**Winter**
Additional Feed Plant 2	45.472	52.829
Buffer Stream 5-2	0.195	—
Additional Feed Plant 6	1.970	3.613
Additional Feed Plant 7	—	0.501
Buffer Stream 13-2	2.227	—
Buffer Stream 14-12	5.927	—
Buffer Stream 15-8	—	51.713
Buffer Stream 21-4	0.372	—
Additional Feed Plant 23	5.352	25.812
Buffer Stream 25-3	1.660	—
Buffer Stream 26-3	0.990	—
Additional Feed Plant 27	3.153	—
Buffer Stream 27-3	5.103	—
Buffer Stream 30-4	50.367	40.356

lower throughput of plant 1, no additional feed is necessary any more. Even though the total mass flow rate of product B was decreased to 95 t/h, the ratio of the individual streams, which are blended, is still the same as in the two previous cases.

The total mass flow rate of product C was decreased to 70 t/h, which resulted in lower throughput of plant 1, as mentioned earlier. As the throughput of the OCM plant also was reduced, less electrical energy was produced. Consequently, only 1.01 t/h of hydrogen is produced in the P2H2 plant.

With 85 t/h of product D, the same mass flow rate as in case 1 was accomplished. This significant increase causes the necessity of additional feed for plant 2. The reduction of the throughput of plant 1, and therefore, less mass flow rate of stream 1-5, reinforces this requirement. The result is that 48 % of the feed needed to produce the predefined mass flow rate of product D, can not be provided by the other production plants.

As depicted in table 4-10, the summer operation mode of case 3 needs much more additional feed and buffer streams. Reasons for the two enormous stream flow rates of the additional feed for plant 2 and the buffer for stream 30-4 are described above. Neglecting those two streams, all other streams have lower mass flow rates than 6 t/h, which indicate a very constant operation mode.

In the winter operation mode of case 3, only six additional streams are needed for the optimization. The drawback of this is in fact that those streams have significant mass flow rates. In contrast to the two previous cases, in case 3 the summer operation mode is the more favourable one.

5 Conclusion and Outlook

Based on the work of Pöllabauer [8], the OptiApp is expanded during this thesis. While the original idea was to develop a meaningful model for different operation modes of production networks based on a small amount of representative historical measurement data, it is now possible to use data from several years. Extending the basic population increases the reliability of the model.

The import of different refinery data and the combination into one dataset is the basis for further processing steps. As the generation of a new dataset is labor- and time-intensive, a possibility to extend existing datasets is created. After the import into Wolfram Mathematica®, the measurement data can be filtered for single operation modes. By the usage of a multiplicity of filter setting possibilities, different objective functions and constraints can be fulfilled.

As a simulative model is just as meaningful as the selected data it is based on, the data import and filter settings are of major importance. With the filtered data a set of linear equations is computed, which describes the dependencies of output from input streams for every plant inside the refinery. Using the optimizing model, which was developed by Mayer [6] and is based on the mixed-integer-linear-programming algorithm, different case studies are simulated.

Before any case study is computed, the optimizing model and the sets of linear equations are verified by recomputing historical measurement data for each operation mode. Since a highly cross-linked production network as a refinery seldom is operated in a total constant and continuous mode, the implementation of storage tanks is indispensable. The results of case 0, where only eight and seven additional feed or buffer streams are necessary for summer and winter operation mode, respectively, show the reliability of the optimizing model as well as the sets of linear equations.

The cases 1 to 3 are virtual studies, to show the high functionality of the OptiApp in combination with the optimizing model. In each case study, individual objections and constraints are set, existing production plants are explicitly switched on or off, virtual new ones are added in case 2 and 3, streams are re-routed or supplied with new linear equations. Optimizing each plant inside the refinery individually would implicate the risk that an optimal operation mode for one plant may limit the following one. Therefore, the highest priority is the optimization of the production network in its entirety.

The results of the optimizing model vastly depend on used measurement data and settings for the data filter and the regression lines. The usage of hour or minute-averaged instead of daily-averaged data would offer the possibility for even better representation of the behavior of every single production plant and its operation modes. It is anticipated that the influence of different crude oil mixtures is more visible with more detailed data.

Including the storage tanks into the system boundaries of the OptiApp would complete the optimizing model. In combination with measurement data of the corresponding streams, the reliability of the computed result would increase even further.

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Appendix

Table A.1: Case 0 Summer

Stream	Measured Value	MILP Value	abs. Dev.	rel. Dev.
Stream 1-1	31,05	33,28	2,23	7,18
Stream 2-1	52,78	53,31	0,53	1,00
Stream 2-2	0,49	0,51	0,02	4,45
Stream 2-3	3,82	3,99	0,17	4,36
Stream 2-4	49,93	49,33	-0,60	-1,21
Stream 1-2	22,11	23,09	0,98	4,45
Stream 1-3	0,00	2,75	0,00	0,00
Stream 1-4	12,69	16,19	3,49	27,53
Stream 1-5	58,78	65,02	6,24	10,61
Stream 1-6	195,15	193,19	-1,95	-1,00
Stream 1-7	2,51	3,95	1,44	57,55
Stream 1-8	3,10	6,43	3,34	107,70
Stream 1-9	1,29	1,99	0,70	54,54
Stream 1-10	72,09	52,61	-19,49	-27,03
Stream 1-11	31,00	37,12	6,12	19,75
Stream 1-12	40,53	61,39	20,86	51,48
Stream 1-13	0,00	0,15	0,00	0,00
Stream 1-14	18,96	7,58	-11,39	-60,05
Stream 1-15	0,00	10,06	10,06	1,31E+06
Stream 1-16	8,04	5,36	-2,68	-33,36
Stream 3-1	52,03	52,55	0,52	1,00
Stream 3-2	23,84	26,05	2,21	9,26
Stream 3-3	28,19	26,50	-1,69	-5,98
Stream 4-1	6,18	6,24	0,06	1,00
Stream 4-2	6,18	6,24	0,06	1,00
Stream 4-3	0,06	0,05	-0,01	-16,97
Stream 4-4	0,52	0,46	-0,06	-10,63
Stream 4-5	0,35	0,36	0,01	2,99
Stream 5-1	0,25	0,21	-0,04	-15,10
Stream 5-2	0,38	0,23	-0,15	-39,98
Stream 5-3	6,76	6,67	-0,09	-1,37
Stream 5-4	20,62	20,82	0,21	1,00
Stream 5-5	1,60	0,70	-0,90	-56,14

Table A.1: Case 0 Summer continued

Stream	Measured Value	MILP Value	abs. Dev.	rel. Dev.
Stream 5-6	12,70	13,75	1,05	8,30
Stream 5-7	14,46	13,72	-0,74	-5,10
Stream 6-1	11,84	8,72	-3,11	-26,29
Stream 6-2	6,92	8,72	1,81	26,11
Stream 7-1	9,28	9,19	-0,09	-1,00
Stream 7-2	10,11	9,19	-0,92	-9,13
EL Plant 1	5,34	4,89	-0,45	-8,51
EL Plant 5	1,78	1,76	-0,02	-1,23
EL Plant 7	1,58	1,56	-0,02	-1,29
EL Plant 9	9,06	7,60	-1,46	-16,09
EL Plant 10	0,79	0,72	-0,07	-8,48
EL Plant 11	1,00	0,95	-0,04	-4,43
EL Plant 12	1,54	1,45	-0,09	-6,15
EL Plant 13	2,87	3,13	0,26	9,13
EL Plant 14	1,27	1,26	-0,01	-0,57
EL Plant 15	1,15	1,79	0,64	55,68
EL Plant 16	0,42	0,46	0,04	10,69
EL Plant 18	2,42	2,11	-0,31	-12,90
EL Plant 19	2,42	0,00	0,00	0,00
EL Plant 20	2,42	0,00	0,00	0,00
EL Plant 21	0,72	0,65	-0,07	-9,51
EL Plant 22	4,51	4,14	-0,36	-8,08
EL Plant 23	0,31	0,30	-0,01	-3,92
EL Plant 24	5,16	8,38	3,22	62,48
EL Plant 26	0,76	0,71	-0,04	-5,70
EL Plant 28	0,29	0,27	-0,01	-4,79
EL Plant 29	0,18	0,18	0,00	0,32
Stream 8-2	18,77	16,97	-1,80	-9,57
Stream 8-3	43,34	42,91	-0,43	-1,00
Stream 8-4	10,15	9,64	-0,51	-5,01
Stream 8-5	25,22	25,94	0,72	2,86
Stream 9-1	22,18	21,79	-0,39	-1,76
Stream 9-2	30,35	29,61	-0,74	-2,45
Stream 9-3	152,37	153,89	1,52	1,00
Stream 9-4	4,45	7,11	2,66	59,73

Table A.1: Case 0 Summer continued

Stream	Measured Value	MILP Value	abs. Dev.	rel. Dev.
Stream 9-5	12,58	13,01	0,43	3,41
Stream 9-6	15,00	16,41	1,41	9,40
Stream 9-7	22,78	26,14	3,36	14,73
Stream 9-8	0,00	0,45	0,00	0,00
Stream 9-9	1,92	12,53	10,61	551,13
Stream 9-10	11,41	10,47	-0,94	-8,26
Stream 9-11	0,00	0,09	0,09	3,07E+03
Stream 9-12	8,36	10,25	1,88	22,53
Stream 9-13	30,51	29,57	-0,94	-3,09
Stream 10-1	81,90	57,81	-24,09	-29,41
Stream 10-2	136,54	135,17	-1,37	-1,00
Stream 10-3	1,60	1,45	-0,15	-9,17
Stream 10-4	4,46	4,22	-0,24	-5,47
Stream 10-5	4,45	4,55	0,10	2,22
Stream 10-6	7,18	5,54	-1,64	-22,80
Stream 10-7	3,03	6,11	3,08	101,60
Stream 10-8	53,77	71,25	17,48	32,51
Stream 11-1	194,46	150,39	-44,06	-22,66
Stream 11-2	2,42	1,36	-1,06	-43,89
Stream 11-3	0,04	1,23	1,19	2,86E+03
Stream 11-4	0,00	0,00	0,00	0,00
Stream 11-5	7,47	6,30	-1,17	-15,70
Stream 11-6	0,26	1,50	1,25	482,22
Stream 11-7	77,19	48,47	-28,72	-37,21
Stream 11-8	126,93	100,42	-26,51	-20,88
Stream 12-1	158,59	157,01	-1,59	-1,00
Stream 12-2	0,68	0,68	0,01	0,89
Stream 12-3	1,56	0,57	-0,99	-63,51
Stream 12-4	0,22	0,31	0,09	39,73
Stream 12-5	154,22	152,10	-2,12	-1,38
Stream 12-6	0,22	0,23	0,01	5,83
Stream 12-7	1,20	1,11	-0,09	-7,48
Stream 12-8	5,42	4,34	-1,09	-20,02
Stream 13-1	0,07	2,15	2,08	3,06E+03
Stream 13-2	9,48	7,99	-1,49	-15,70

Table A.1: Case 0 Summer continued

Stream	Measured Value	MILP Value	abs. Dev.	rel. Dev.
Stream 13-3	281,80	278,98	-2,82	-1,00
Stream 13-4	0,48	0,61	0,13	26,44
Stream 13-5	260,05	264,63	4,58	1,76
Stream 13-6	1,67	2,07	0,39	23,55
Stream 13-7	5,32	3,33	-1,99	-37,36
Stream 13-8	6,77	6,02	-0,75	-11,03
Stream 13-9	1,60	4,21	2,62	163,78
Stream 14-1	5,28	3,86	-1,43	-26,99
Stream 14-2	241,13	238,72	-2,41	-1,00
Stream 14-3	0,31	0,57	0,26	82,46
Stream 14-4	3,54	3,19	-0,35	-9,99
Stream 14-5	3,66	4,47	0,81	22,02
Stream 14-6	0,54	0,65	0,11	20,33
Stream 14-7	3,51	3,28	-0,23	-6,51
Stream 14-8	4,27	4,24	-0,04	-0,87
Stream 14-9	0,00	0,00	0,00	0,00
Stream 14-10	0,00	0,24	0,00	0,00
Stream 14-11	4,02	3,73	-0,29	-7,10
Stream 15-1	31,74	29,68	-2,06	-6,49
Stream 15-2	3,06	3,07	0,01	0,27
Stream 15-3	40,22	56,02	15,79	39,26
Stream 15-4	39,46	36,00	-3,46	-8,77
Stream 15-5	9,03	9,61	0,58	6,41
Stream 15-6	260,01	257,41	-2,60	-1,00
Stream 15-7	2,07	1,93	-0,14	-6,74
Stream 15-8	160,67	151,07	-9,60	-5,97
Stream 15-9	13,21	12,06	-1,15	-8,73
Stream 15-10	27,69	27,42	-0,28	-1,00
Stream 14-12	225,08	227,21	2,13	0,95
Stream 16-1	38,71	38,32	-0,39	-1,00
Stream 16-2	0,82	0,69	-0,13	-15,85
Stream 16-3	12,25	10,73	-1,51	-12,36
Stream 16-4	10,80	7,27	-3,53	-32,69
Stream 16-5	14,08	12,69	-1,39	-9,88
Stream 16-6	0,70	0,93	0,22	31,55

Table A.1: Case 0 Summer continued

Stream	Measured Value	MILP Value	abs. Dev.	rel. Dev.
Stream 16-7	38,66	47,38	8,72	22,56
Stream 16-8	0,26	0,12	-0,14	-54,51
Stream 16-9	5,68	5,20	-0,48	-8,51
Stream 16-10	0,01	0,24	0,23	1,92E+03
Stream 16-11	1,44	1,57	0,14	9,51
Stream 16-12	5,98	4,89	-1,09	-18,27
Stream 17-1	2,47	2,15	-0,32	-12,88
Stream 17-2	17,94	12,25	-5,69	-31,70
Stream 17-3	24,21	17,38	-6,83	-28,21
Stream 17-4	3,53	2,97	-0,56	-15,75
Stream 17-5	2,20	1,58	-0,62	-28,12
Stream 18-1	13,39	10,41	-2,98	-22,28
Stream 18-2	0,27	0,51	0,24	87,28
Stream 18-3	43,63	38,75	-4,88	-11,19
Stream 18-4	55,87	50,55	-5,32	-9,52
Stream 18-5	2,09	2,34	0,25	11,80
Stream 18-6	1,53	1,59	0,07	4,33
Stream 18-7	0,15	0,05	-0,10	-65,89
Stream 18-8	2,13	0,84	-1,29	-60,47
Stream 19-1	13,39	0,00	0,00	0,00
Stream 19-2	0,27	0,00	0,00	0,00
Stream 19-3	43,63	0,00	0,00	0,00
Stream 19-4	55,87	0,00	0,00	0,00
Stream 19-5	2,09	0,00	0,00	0,00
Stream 19-6	1,53	0,00	0,00	0,00
Stream 19-7	0,15	0,00	0,00	0,00
Stream 19-8	2,13	0,00	0,00	0,00
Stream 20-1	13,39	0,00	0,00	0,00
Stream 20-2	0,27	0,00	0,00	0,00
Stream 20-3	43,63	0,00	0,00	0,00
Stream 20-4	55,87	0,00	0,00	0,00
Stream 20-5	2,09	0,00	0,00	0,00
Stream 20-6	1,53	0,00	0,00	0,00
Stream 20-7	0,15	0,00	0,00	0,00
Stream 20-8	2,13	0,00	0,00	0,00

Table A.1: Case 0 Summer continued

Stream	Measured Value	MILP Value	abs. Dev.	rel. Dev.
Stream 21-1	2,23	1,30	-0,93	-41,74
Stream 21-2	130,10	130,18	0,08	0,06
Stream 21-3	6,11	2,73	-3,38	-55,34
Stream 21-4	7,28	0,69	-6,59	-90,52
Stream 21-5	48,76	38,41	-10,35	-21,22
Stream 21-6	85,19	85,75	0,57	0,67
Stream 21-7	3,04	1,30	-1,74	-57,13
Stream 22-1	83,33	82,50	-0,83	-1,00
Stream 22-2	2,08	3,44	1,36	65,24
Stream 22-3	0,41	2,44	2,03	489,91
Stream 22-4	6,69	6,14	-0,55	-8,17
Stream 22-5	6,69	6,14	-0,55	-8,17
Stream 22-6	5,31	4,07	-1,24	-23,42
Stream 22-7	18,85	20,66	1,81	9,58
Stream 22-8	67,34	74,46	7,13	10,58
Stream 22-9	0,15	2,15	2,01	1,38E+03
Stream 23-1	5,54	3,11	-2,42	-43,75
Stream 23-2	70,34	69,90	-0,45	-0,64
Stream 23-3	76,46	75,69	-0,76	-1,00
Stream 23-4	3,51	2,61	-0,90	-25,70
Stream 23-5	0,22	0,08	-0,14	-65,37
Stream 23-6	1,37	1,35	-0,03	-2,09
Stream 23-7	2,20	1,87	-0,33	-14,94
Stream 24-1	228,20	219,48	-8,72	-3,82
Stream 24-2	1012,96	1023,09	10,13	1,00
Stream 24-3	12,60	13,22	0,62	4,94
Stream 24-4	64,20	51,62	-12,59	-19,61
Stream 24-5	196,07	161,67	-34,39	-17,54
Stream 24-6	223,15	265,28	42,13	18,88
Stream 24-7	14,65	10,87	-3,78	-25,81
Stream 24-8	0,11	0,50	0,39	355,17
Stream 24-9	0,02	0,90	0,88	3,58E+03
Stream 24-10	20,37	17,06	-3,31	-16,26
Stream 24-11	4,25	4,31	0,06	1,43
Stream 24-12	240,86	281,27	40,41	16,78

Table A.1: Case 0 Summer continued

Stream	Measured Value	MILP Value	abs. Dev.	rel. Dev.
Stream 24-13	36,74	28,59	-8,15	-22,18
Stream 25-1	7,54	7,47	-0,08	-1,00
Stream 25-2	4,49	3,72	-0,77	-17,22
Stream 25-3	2,65	3,75	1,10	41,67
Stream 26-1	2,52	2,54	0,03	1,00
Stream 26-2	1,80	0,03	-1,77	-98,58
Stream 26-3	7,99	2,52	-5,47	-68,47
Stream 27-1	23,23	12,08	-11,15	-48,02
Stream 27-2	0,85	5,44	4,59	542,59
Stream 27-3	3,02	6,64	3,62	120,06
Stream 28-1	72,69	73,42	0,73	1,00
Stream 28-2	0,83	1,47	0,63	75,99
Stream 28-3	1,99	2,09	0,10	5,17
Stream 28-4	30,00	30,50	0,50	1,67
Stream 28-5	1,40	1,49	0,09	6,61
Stream 28-6	1,78	1,68	-0,10	-5,49
Stream 28-7	2,09	2,07	-0,02	-1,10
Stream 28-8	15,66	17,82	2,16	13,78
Stream 28-9	5,47	5,72	0,25	4,56
Stream 28-10	47,67	46,33	-1,34	-2,82
Stream 29-1	16,60	15,85	-0,75	-4,51
Stream 29-2	37,50	37,13	-0,38	-1,00
Stream 29-3	8,70	8,02	-0,68	-7,79
Stream 29-4	13,17	13,26	0,09	0,66
Stream 30-1	176,98	132,51	-44,47	-25,13
Stream 30-2	31,05	18,87	-12,18	-39,23
Stream 30-3	15,61	2,43	-13,18	-84,43
Stream 30-4	124,88	111,21	-13,67	-10,95

Table A.2: Case 0 Winter

Stream	Measured Value	MILP Value	abs. Dev.	rel. Dev.
Stream 1-1	31,05	31,24	0,19	0,61
Stream 2-1	52,78	50,90	-1,89	-3,57
Stream 2-2	0,49	0,61	0,11	22,94
Stream 2-3	3,82	4,19	0,38	9,84
Stream 2-4	49,93	46,70	-3,23	-6,46
Stream 1-2	22,11	21,81	-0,30	-1,37
Stream 1-3	0,00	3,06	0,00	0,00
Stream 1-4	12,69	15,65	2,95	23,26
Stream 1-5	58,78	60,08	1,30	2,21
Stream 1-6	195,15	180,61	-14,53	-7,45
Stream 1-7	2,51	3,94	1,44	57,25
Stream 1-8	3,10	5,48	2,38	76,90
Stream 1-9	1,29	1,95	0,67	51,80
Stream 1-10	72,09	56,76	-15,33	-21,27
Stream 1-11	31,00	35,03	4,03	13,00
Stream 1-12	40,53	54,48	13,95	34,42
Stream 1-13	0,00	0,00	0,00	0,00
Stream 1-14	18,96	13,48	-5,48	-28,92
Stream 1-15	0,00	10,24	10,24	1,34E+06
Stream 1-16	8,04	4,33	-3,71	-46,10
Stream 3-1	52,03	54,66	2,63	5,05
Stream 3-2	23,84	27,23	3,39	14,22
Stream 3-3	28,19	27,43	-0,76	-2,71
Stream 4-1	6,18	0,54	-5,64	-91,32
Stream 4-2	6,18	0,54	-5,64	-91,32
Stream 4-3	0,06	0,04	-0,02	-36,29
Stream 4-4	0,52	0,39	-0,13	-24,31
Stream 4-5	0,35	0,37	0,03	8,09
Stream 5-1	0,25	0,26	0,01	5,85
Stream 5-2	0,38	0,25	-0,12	-32,44
Stream 5-3	6,76	6,17	-0,59	-8,76
Stream 5-4	20,62	19,21	-1,41	-6,83
Stream 5-5	1,60	0,59	-1,01	-63,37
Stream 5-6	12,70	13,60	0,90	7,07
Stream 5-7	14,46	12,52	-1,93	-13,37

Table A.2: Case 0 Winter continued

Stream	Measured Value	MILP Value	abs. Dev.	rel. Dev.
Stream 6-1	11,84	8,30	-3,54	-29,92
Stream 6-2	6,92	8,30	1,38	19,90
Stream 7-1	9,28	7,54	-1,74	-18,78
Stream 7-2	10,11	7,54	-2,57	-25,45
EL Plant 1	5,34	4,77	-0,57	-10,63
EL Plant 5	1,78	1,67	-0,11	-6,13
EL Plant 7	1,58	1,37	-0,21	-13,46
EL Plant 9	9,06	9,41	0,35	3,83
EL Plant 10	0,79	0,80	0,01	0,93
EL Plant 11	1,00	0,97	-0,02	-2,45
EL Plant 12	1,54	1,51	-0,03	-2,22
EL Plant 13	2,87	2,82	-0,05	-1,59
EL Plant 14	1,27	1,34	0,08	5,95
EL Plant 15	1,15	1,34	0,19	16,52
EL Plant 16	0,42	0,49	0,07	16,59
EL Plant 18	2,42	0,00	0,00	0,00
EL Plant 19	2,42	2,10	-0,31	-13,01
EL Plant 20	2,42	0,00	0,00	0,00
EL Plant 21	0,72	0,68	-0,04	-6,20
EL Plant 22	4,51	4,34	-0,17	-3,73
EL Plant 23	0,31	0,30	-0,02	-5,57
EL Plant 24	5,16	5,00	-0,17	-3,20
EL Plant 26	0,76	0,81	0,06	7,76
EL Plant 28	0,29	0,28	-0,01	-2,95
EL Plant 29	0,18	0,17	-0,01	-6,48
Stream 8-2	18,77	15,86	-2,90	-15,48
Stream 8-3	43,34	42,32	-1,02	-2,36
Stream 8-4	10,15	10,41	0,26	2,57
Stream 8-5	25,22	26,46	1,24	4,91
Stream 9-1	22,18	22,59	0,42	1,89
Stream 9-2	30,35	29,85	-0,50	-1,65
Stream 9-3	152,37	155,62	3,25	2,13
Stream 9-4	4,45	6,80	2,35	52,78
Stream 9-5	12,58	12,04	-0,54	-4,33
Stream 9-6	15,00	18,24	3,23	21,55

Table A.2: Case 0 Winter continued

Stream	Measured Value	MILP Value	abs. Dev.	rel. Dev.
Stream 9-7	22,78	28,21	5,43	23,84
Stream 9-8	0,00	0,17	0,00	0,00
Stream 9-9	1,92	17,96	16,04	833,10
Stream 9-10	11,41	9,06	-2,35	-20,62
Stream 9-11	0,00	0,56	0,55	1,87E+04
Stream 9-12	8,36	9,51	1,14	13,69
Stream 9-13	30,51	28,37	-2,14	-7,01
Stream 10-1	81,90	60,66	-21,24	-25,93
Stream 10-2	136,54	115,44	-21,10	-15,46
Stream 10-3	1,60	1,41	-0,19	-11,89
Stream 10-4	4,46	3,07	-1,39	-31,17
Stream 10-5	4,45	4,43	-0,02	-0,53
Stream 10-6	7,18	6,24	-0,94	-13,13
Stream 10-7	3,03	8,15	5,12	168,94
Stream 10-8	53,77	46,62	-7,15	-13,30
Stream 11-1	194,46	133,81	-60,64	-31,19
Stream 11-2	2,42	2,17	-0,24	-10,01
Stream 11-3	0,04	0,79	0,75	1,79E+03
Stream 11-4	0,00	0,02	0,00	0,00
Stream 11-5	7,47	4,23	-3,25	-43,44
Stream 11-6	0,26	1,34	1,08	418,04
Stream 11-7	77,19	40,12	-37,07	-48,02
Stream 11-8	126,93	92,36	-34,58	-27,24
Stream 12-1	158,59	151,59	-7,00	-4,41
Stream 12-2	0,68	0,68	0,00	-0,10
Stream 12-3	1,56	0,41	-1,15	-73,45
Stream 12-4	0,22	0,29	0,07	32,81
Stream 12-5	154,22	146,55	-7,67	-4,97
Stream 12-6	0,22	0,37	0,15	71,26
Stream 12-7	1,20	1,05	-0,15	-12,49
Stream 12-8	5,42	4,63	-0,79	-14,63
Stream 13-1	0,07	1,36	1,29	1,90E+03
Stream 13-2	9,48	5,67	-3,81	-40,17
Stream 13-3	281,80	226,24	-55,56	-19,72
Stream 13-4	0,48	0,64	0,16	33,07

Table A.2: Case 0 Winter continued

Stream	Measured Value	MILP Value	abs. Dev.	rel. Dev.
Stream 13-5	260,05	216,46	-43,58	-16,76
Stream 13-6	1,67	1,94	0,27	16,13
Stream 13-7	5,32	3,11	-2,21	-41,53
Stream 13-8	6,77	5,18	-1,58	-23,37
Stream 13-9	1,60	2,75	1,15	72,11
Stream 14-1	5,28	2,68	-2,61	-49,33
Stream 14-2	241,13	239,24	-1,89	-0,78
Stream 14-3	0,31	0,64	0,32	102,98
Stream 14-4	3,54	1,62	-1,93	-54,36
Stream 14-5	3,66	4,18	0,52	14,17
Stream 14-6	0,54	0,99	0,45	82,49
Stream 14-7	3,51	3,22	-0,29	-8,21
Stream 14-8	4,27	4,19	-0,08	-1,86
Stream 14-9	0,00	0,08	0,00	0,00
Stream 14-10	0,00	0,08	0,00	0,00
Stream 14-11	4,02	5,64	1,62	40,34
Stream 15-1	31,74	20,82	-10,91	-34,39
Stream 15-2	3,06	3,12	0,06	1,97
Stream 15-3	40,22	51,41	11,19	27,81
Stream 15-4	39,46	35,49	-3,96	-10,05
Stream 15-5	9,03	9,73	0,70	7,75
Stream 15-6	260,01	258,19	-1,81	-0,70
Stream 15-7	2,07	2,01	-0,06	-2,99
Stream 15-8	160,67	155,79	-4,88	-3,04
Stream 15-9	13,21	13,05	-0,16	-1,22
Stream 15-10	27,69	18,37	-9,32	-33,65
Stream 14-12	225,08	230,77	5,69	2,53
Stream 16-1	38,71	42,08	3,37	8,72
Stream 16-2	0,82	0,65	-0,17	-20,28
Stream 16-3	12,25	12,64	0,39	3,18
Stream 16-4	10,80	8,26	-2,54	-23,48
Stream 16-5	14,08	13,88	-0,20	-1,44
Stream 16-6	0,70	1,19	0,49	69,70
Stream 16-7	38,66	52,03	13,37	34,57
Stream 16-8	0,26	0,23	-0,02	-8,70

Table A.2: Case 0 Winter continued

Stream	Measured Value	MILP Value	abs. Dev.	rel. Dev.
Stream 16-9	5,68	5,20	-0,47	-8,36
Stream 16-10	0,01	0,16	0,15	1,24E+03
Stream 16-11	1,44	1,36	-0,08	-5,22
Stream 16-12	5,98	4,58	-1,39	-23,32
Stream 17-1	2,47	2,06	-0,41	-16,67
Stream 17-2	17,94	8,32	-9,62	-53,62
Stream 17-3	24,21	13,83	-10,39	-42,90
Stream 17-4	3,53	3,44	-0,08	-2,40
Stream 17-5	2,20	2,17	-0,03	-1,44
Stream 18-1	13,39	0,00	0,00	0,00
Stream 18-2	0,27	0,00	0,00	0,00
Stream 18-3	43,63	0,00	0,00	0,00
Stream 18-4	55,87	0,00	0,00	0,00
Stream 18-5	2,09	0,00	0,00	0,00
Stream 18-6	1,53	0,00	0,00	0,00
Stream 18-7	0,15	0,00	0,00	0,00
Stream 18-8	2,13	0,00	0,00	0,00
Stream 19-1	13,39	7,21	-6,18	-46,14
Stream 19-2	0,27	0,50	0,23	83,57
Stream 19-3	43,63	40,85	-2,78	-6,37
Stream 19-4	55,87	49,55	-6,32	-11,31
Stream 19-5	2,09	2,57	0,48	22,82
Stream 19-6	1,53	1,50	-0,02	-1,52
Stream 19-7	0,15	0,50	0,35	234,28
Stream 19-8	2,13	0,50	-1,63	-76,70
Stream 20-1	13,39	0,00	0,00	0,00
Stream 20-2	0,27	0,00	0,00	0,00
Stream 20-3	43,63	0,00	0,00	0,00
Stream 20-4	55,87	0,00	0,00	0,00
Stream 20-5	2,09	0,00	0,00	0,00
Stream 20-6	1,53	0,00	0,00	0,00
Stream 20-7	0,15	0,00	0,00	0,00
Stream 20-8	2,13	0,00	0,00	0,00
Stream 21-1	2,23	1,45	-0,78	-34,94
Stream 21-2	130,10	145,38	15,28	11,74

Table A.2: Case 0 Winter continued

Stream	Measured Value	MILP Value	abs. Dev.	rel. Dev.
Stream 21-3	6,11	3,36	-2,75	-44,99
Stream 21-4	7,28	1,36	-5,92	-81,31
Stream 21-5	48,76	42,61	-6,15	-12,60
Stream 21-6	85,19	95,35	10,16	11,93
Stream 21-7	3,04	1,24	-1,79	-59,01
Stream 22-1	83,33	99,02	15,68	18,82
Stream 22-2	2,08	3,26	1,18	56,54
Stream 22-3	0,41	2,40	1,99	480,28
Stream 22-4	6,69	6,13	-0,56	-8,43
Stream 22-5	6,69	6,13	-0,56	-8,43
Stream 22-6	5,31	5,62	0,31	5,75
Stream 22-7	18,85	21,48	2,63	13,94
Stream 22-8	67,34	91,34	24,00	35,64
Stream 22-9	0,15	2,01	1,87	1,28E+03
Stream 23-1	5,54	3,94	-1,60	-28,93
Stream 23-2	70,34	76,44	6,10	8,67
Stream 23-3	76,46	82,99	6,53	8,54
Stream 23-4	3,51	2,61	-0,90	-25,55
Stream 23-5	0,22	0,00	0,00	0,00
Stream 23-6	1,37	1,43	0,06	4,17
Stream 23-7	2,20	1,95	-0,25	-11,20
Stream 24-1	228,20	195,76	-32,44	-14,21
Stream 24-2	1012,96	930,49	-82,46	-8,14
Stream 24-3	12,60	13,66	1,06	8,39
Stream 24-4	64,20	54,94	-9,27	-14,43
Stream 24-5	196,07	150,81	-45,25	-23,08
Stream 24-6	223,15	237,49	14,34	6,42
Stream 24-7	14,65	10,06	-4,59	-31,35
Stream 24-8	0,11	2,20	2,09	1,88E+03
Stream 24-9	0,02	2,03	2,01	8,20E+03
Stream 24-10	20,37	17,24	-3,14	-15,39
Stream 24-11	4,25	3,93	-0,32	-7,52
Stream 24-12	240,86	249,25	8,39	3,48
Stream 24-13	36,74	28,26	-8,47	-23,07
Stream 25-1	7,54	7,30	-0,24	-3,17

Table A.2: Case 0 Winter continued

Stream	**Measured Value**	**MILP Value**	**abs. Dev.**	**rel. Dev.**
Stream 25-2	4,49	3,86	-0,63	-13,94
Stream 25-3	2,65	3,44	0,79	29,92
Stream 26-1	2,52	2,05	-0,47	-18,62
Stream 26-2	1,80	0,02	-1,77	-98,86
Stream 26-3	7,99	2,03	-5,96	-74,60
Stream 27-1	23,23	12,50	-10,73	-46,20
Stream 27-2	0,85	5,38	4,53	535,46
Stream 27-3	3,02	7,12	4,10	136,06
Stream 28-1	72,69	65,14	-7,55	-10,39
Stream 28-2	0,83	1,21	0,37	44,83
Stream 28-3	1,99	1,63	-0,36	-17,95
Stream 28-4	30,00	33,89	3,89	12,98
Stream 28-5	1,40	1,30	-0,10	-6,95
Stream 28-6	1,78	2,20	0,42	23,54
Stream 28-7	2,09	2,84	0,75	35,75
Stream 28-8	15,66	14,93	-0,73	-4,68
Stream 28-9	5,47	5,19	-0,28	-5,12
Stream 28-10	47,67	42,19	-5,48	-11,50
Stream 29-1	16,60	11,45	-5,15	-31,03
Stream 29-2	37,50	26,00	-11,50	-30,67
Stream 29-3	8,70	5,53	-3,17	-36,46
Stream 29-4	13,17	9,03	-4,15	-31,48
Stream 30-1	176,98	169,98	-7,00	-3,96
Stream 30-2	31,05	28,51	-2,54	-8,18
Stream 30-3	15,61	10,30	-5,30	-33,98
Stream 30-4	124,88	131,17	6,28	5,03

Table A.3: Case 1 Summer

Streams	**MILP Value**	**Min**	**Max**
Additional Feed Plant 1	43,60	0,00	∞
Stream 1-1	34,60	11,00	35,00
Buffer Stream 1-1	0,00	0,00	∞
Additional Feed Plant 2	47,47	0,00	∞
Stream 2-1	89,35	31,00	100,00
Stream 2-2	0,25	0,10	5,00
Stream 2-3	4,35	1,50	20,00
Buffer Stream 2-3	0,00	0,00	∞
Stream 2-4	85,00	25,00	85,00
Buffer Stream 2-4	0,00	0,00	∞
Stream 1-2	23,87	7,78	29,16
Buffer Stream 1-2	2,08	0,00	∞
Stream 1-3	2,97	0,00	9,56
Buffer Stream 1-3	0,00	0,00	∞
Stream 1-4	16,89	5,29	16,89
Buffer Stream 1-4	0,00	0,00	∞
Stream 1-5	67,54	20,89	67,86
Buffer Stream 1-5	0,00	0,00	∞
Stream 1-6	201,09	63,89	203,02
Stream 1-7	4,11	0,10	5,00
Buffer Stream 1-7	0,00	0,00	∞
Stream 1-8	6,89	0,00	7,36
Buffer Stream 1-8	0,00	0,00	∞
Stream 1-9	2,02	0,48	4,09
Stream 1-10	51,19	7,67	126,13
Stream 1-11	38,65	5,45	41,02
Buffer Stream 1-11	0,00	0,00	∞
Stream 1-12	62,57	0,31	73,58
Stream 1-13	0,16	0,00	2,65
Stream 1-14	7,93	0,00	62,27
Stream 1-15	8,04	0,00	89,32
Stream 1-16	5,57	0,00	9,75
Buffer Stream 1-16	0,00	0,00	∞
Stream 3-1	41,78	39,33	70,19
Stream 3-2	19,06	19,06	39,92

Table A.3: Case 1 Summer continued

Streams	MILP Value	Min	Max
Buffer Stream 3-2	0,00	0,00	∞
Stream 3-3	22,72	19,53	33,78
Buffer Stream 3-3	0,00	0,00	∞
Additional Feed Plant 4	0,00	0,00	∞
Stream 4-1	3,67	3,67	9,85
Buffer Stream 4-1	0,00	0,00	∞
Stream 4-2	3,67	3,67	9,85
Stream 4-3	0,05	0,02	0,08
Stream 4-4	0,49	0,28	0,54
Stream 4-5	0,35	0,26	0,44
Stream 5-1	0,22	0,06	0,38
Buffer Stream 5-1	0,00	0,00	∞
Stream 5-2	0,24	0,10	0,39
Buffer Stream 5-2	0,00	0,00	∞
Additional Feed Plant 5	0,00	0,00	∞
Stream 5-3	6,90	2,65	8,36
Buffer Stream 5-3	0,00	0,00	∞
Stream 5-4	21,79	9,13	21,79
Stream 5-5	0,71	0,00	1,80
Stream 5-6	14,07	7,51	15,32
Stream 5-7	14,43	5,85	16,37
Buffer Stream 5-7	0,00	0,00	∞
Additional Feed Plant 6	2,01	0,00	∞
Stream 6-1	5,19	5,19	15,57
Stream 6-2	5,19	1,00	16,00
Buffer Stream 6-2	0,00	0,00	∞
Additional Feed Plant 7	0,00	0,00	∞
Stream 7-1	4,44	3,17	15,65
Stream 7-2	4,44	4,14	14,98
Buffer Stream 7-2	0,00	0,00	∞
EL Plant 1	4,93	2,62	6,09
EL Plant 5	1,79	0,75	1,90
EL Plant 7	1,47	1,04	1,75
EL Plant 9	9,61	0,50	9,90
EL Plant 10	0,69	0,61	0,81

Table A.3: Case 1 Summer continued

Streams	MILP Value	Min	Max
EL Plant 11	0,95	0,62	1,06
EL Plant 12	1,29	1,00	1,62
EL Plant 13	3,01	2,15	3,71
EL Plant 14	1,20	0,58	1,69
EL Plant 15	0,87	0,80	2,53
EL Plant 16	0,00	0,00	0,00
EL Plant 18	0,00	0,00	∞
EL Plant 19	2,08	0,00	∞
EL Plant 20	0,00	0,00	∞
EL Plant 21	0,58	0,28	0,94
EL Plant 22	0,00	0,00	0,00
EL Plant 23	0,31	0,14	0,35
EL Plant 24	4,72	4,72	420,04
EL Plant 26	0,63	0,00	0,90
EL Plant 28	0,00	0,00	0,00
EL Plant 29	0,19	0,11	0,24
Additional Feed Plant 8	0,00	0,00	∞
Stream 8-1	8,99	0,01	25,00
Buffer Stream 8-1	0,00	0,00	∞
Stream 8-2	3,90	0,00	∞
Stream 8-3	26,02	15,00	55,00
Stream 8-4	7,41	0,01	14,00
Stream 8-5	17,03	0,01	30,00
Buffer Stream 8-5	0,00	0,00	∞
Additional Feed Plant 9	0,00	0,00	∞
Stream 9-1	7,27	5,00	23,00
Buffer Stream 9-1	0,00	0,00	∞
Stream 9-2	11,59	10,00	32,00
Buffer Stream 9-2	0,00	0,00	∞
Stream 9-3	55,21	50,00	161,00
Stream 9-4	0,20	0,01	10,00
Buffer Stream 9-4	0,00	0,00	∞
Stream 9-5	1,46	0,00	18,90
Buffer Stream 9-5	0,00	0,00	∞
Stream 9-6	1,97	1,00	24,00

Table A.3: Case 1 Summer continued

Streams	MILP Value	Min	Max
Buffer Stream 9-6	0,00	0,00	∞
Stream 9-7	9,69	7,00	35,00
Buffer Stream 9-7	0,00	0,00	∞
Stream 9-8	0,16	0,00	4,73
Stream 9-9	20,46	1,90	25,00
Stream 9-10	3,76	0,43	18,72
Stream 9-11	11,66	0,01	15,00
Stream 9-12	2,71	2,00	12,00
Buffer Stream 9-12	0,00	0,00	∞
Stream 9-13	20,31	12,00	40,00
Buffer Stream 9-13	0,00	0,00	∞
Additional Feed Plant 10	0,00	0,00	∞
Stream 10-1	38,39	19,40	89,64
Buffer Stream 10-1	0,00	0,00	∞
Stream 10-2	86,87	82,77	157,30
Stream 10-3	1,08	0,75	1,93
Stream 10-4	2,40	0,00	10,16
Stream 10-5	4,74	4,26	5,00
Stream 10-6	4,34	0,11	9,10
Stream 10-7	5,63	2,01	18,95
Buffer Stream 10-7	0,00	0,00	∞
Stream 10-8	42,85	22,26	105,95
Buffer Stream 10-8	0,00	0,00	∞
Additional Feed Plant 11	0,00	0,00	∞
Stream 11-1	150,39	115,63	235,89
Stream 11-2	1,36	0,00	8,12
Stream 11-3	1,23	0,00	4,06
Stream 11-4	0,00	0,00	0,75
Stream 11-5	6,30	0,00	23,06
Stream 11-6	1,50	0,00	2,50
Buffer Stream 11-6	0,00	0,00	∞
Stream 11-7	48,47	29,65	89,35
Buffer Stream 11-7	0,00	0,00	∞
Stream 11-8	100,42	79,11	173,34
Buffer Stream 11-8	0,00	0,00	∞

Table A.3: Case 1 Summer continued

Streams	MILP Value	Min	Max
Additional Feed Plant 12	0,00	0,00	∞
Stream 12-1	110,16	106,89	159,68
Stream 12-2	0,52	0,43	0,87
Stream 12-3	0,40	0,40	2,00
Buffer Stream 12-3	0,00	0,00	∞
Stream 12-4	0,32	0,12	1,46
Stream 12-5	105,93	105,39	157,00
Buffer Stream 12-5	0,00	0,00	∞
Stream 12-6	0,27	0,14	0,37
Stream 12-7	1,05	0,96	1,24
Stream 12-8	3,84	2,10	10,74
Buffer Stream 12-8	0,00	0,00	∞
Stream 12-9	1,91	0,00	3,00
Buffer Stream 12-9	0,00	0,00	∞
Additional Feed Plant 13	0,00	0,00	∞
Stream 13-1	6,96	0,28	11,01
Buffer Stream 13-1	0,00	0,00	∞
Stream 13-2	256,71	130,33	300,10
Stream 13-3	0,56	0,15	1,57
Stream 13-4	244,07	122,21	286,36
Buffer Stream 13-4	0,00	0,00	∞
Stream 13-5	2,00	0,89	8,13
Stream 13-6	3,42	0,00	7,14
Stream 13-7	5,63	4,03	6,91
Stream 13-8	3,77	0,70	5,00
Buffer Stream 13-8	0,00	0,00	∞
Additional Feed Plant 14	0,00	0,00	∞
Stream 14-1	2,30	0,00	7,43
Buffer Stream 14-1	0,00	0,00	∞
Stream 14-2	196,85	137,65	251,76
Stream 14-3	0,48	0,22	1,03
Stream 14-4	2,10	0,06	7,79
Buffer Stream 14-4	0,00	0,00	∞
Stream 14-5	2,33	0,00	7,37
Buffer Stream 14-5	0,00	0,00	∞

Table A.3: Case 1 Summer continued

Streams	MILP Value	Min	Max
Stream 14-6	1,63	0,00	5,36
Stream 14-7	2,19	0,00	4,50
Stream 14-8	3,01	0,00	5,53
Stream 14-9	0,01	0,00	3,13
Stream 14-10	0,17	0,00	3,70
Stream 14-11	3,86	0,00	9,79
Stream 15-1	10,05	8,23	35,40
Buffer Stream 15-1	0,00	0,00	∞
Stream 15-2	2,74	2,17	4,22
Stream 15-3	49,04	33,09	85,45
Buffer Stream 15-3	0,00	0,00	∞
Stream 15-4	26,20	13,29	46,76
Buffer Stream 15-4	0,00	0,00	∞
Stream 15-5	9,49	7,10	10,61
Additional Feed Plant 15-1	0,00	0,00	∞
Stream 15-6	210,79	171,22	281,17
Stream 15-7	1,91	1,40	2,21
Stream 15-8	127,38	89,95	196,60
Buffer Stream 15-8	81,09	0,00	∞
Stream 15-9	8,92	7,88	15,30
Buffer Stream 15-9	0,00	0,00	∞
Additional Feed Plant 15-2	0,00	0,00	∞
Stream 15-10	10,80	2,57	31,33
Stream 15-11	190,11	134,65	245,05
Buffer Stream 15-11	2,04	0,00	∞
Additional Feed Plant 16	0,00	0,00	∞
Stream 16-1	0,00	0,00	0,00
Stream 16-2	0,00	0,00	0,00
Stream 16-3	0,00	0,00	0,00
Stream 16-4	0,00	0,00	0,00
Buffer Stream 16-4	0,00	0,00	∞
Buffer Stream 16-3	0,00	0,00	∞
Stream 16-5	0,00	0,00	0,00
Buffer Stream 16-5	0,00	0,00	∞
Stream 16-6	0,00	0,00	0,00

Table A.3: Case 1 Summer continued

Streams	MILP Value	Min	Max
Buffer Stream 16-6	0,00	0,00	∞
Stream 16-7	0,00	0,00	0,00
Stream 16-8	0,00	0,00	0,00
Stream 16-9	0,00	0,00	0,00
Stream 16-10	0,00	0,00	0,00
Buffer Stream 16-10	0,00	0,00	∞
Stream 16-11	0,00	0,00	0,00
Buffer Stream 16-11	0,00	0,00	∞
Stream 16-12	0,00	0,00	0,00
Buffer Stream 16-12	0,00	0,00	∞
Stream 16-13	1,80	0,98	3,00
Buffer Stream 16-13	0,00	0,00	∞
Additional Feed Plant 17	0,00	0,00	∞
Stream 17-1	7,11	4,80	27,03
Buffer Stream 17-1	0,00	0,00	∞
Stream 17-2	11,01	9,45	34,41
Stream 17-3	2,10	0,56	7,33
Buffer Stream 17-3	0,00	0,00	∞
Stream 17-4	1,05	0,00	3,82
Additional Feed Plant 18	0,00	0,00	∞
Stream 18-1	0,00	0,00	∞
Buffer Stream 18-1	0,00	0,00	∞
Stream 18-2	0,00	0,00	∞
Buffer Stream 18-2	0,00	0,00	∞
Stream 18-3	0,00	0,00	∞
Buffer Stream 18-3	0,00	0,00	∞
Stream 18-4	0,00	0,00	∞
Stream 18-5	0,00	0,00	∞
Stream 18-6	0,00	0,00	∞
Stream 18-7	0,00	0,00	∞
Buffer Stream 18-7	0,00	0,00	∞
Stream 18-8	0,00	0,00	∞
Buffer Stream 18-8	0,00	0,00	∞
Switch Plant 18	0,00	0,00	1,00
Additional Feed Plant 19	0,00	0,00	∞

Table A.3: Case 1 Summer continued

Streams	MILP Value	Min	Max
Stream 19-1	5,36	0,00	∞
Buffer Stream 19-1	0,00	0,00	∞
Stream 19-2	0,40	0,00	∞
Buffer Stream 19-2	0,00	0,00	∞
Stream 19-3	33,80	0,00	∞
Buffer Stream 19-3	0,00	0,00	∞
Stream 19-4	40,00	0,00	∞
Stream 19-5	2,39	0,00	∞
Stream 19-6	1,58	0,00	∞
Stream 19-7	0,04	0,00	∞
Buffer Stream 19-7	0,00	0,00	∞
Stream 19-8	0,40	0,00	∞
Buffer Stream 19-8	0,00	0,00	∞
Switch Plant 19	1,00	0,00	1,00
Additional Feed Plant 20	0,00	0,00	∞
Stream 20-1	0,00	0,00	∞
Buffer Stream 20-1	0,00	0,00	∞
Stream 20-2	0,00	0,00	∞
Buffer Stream 20-2	0,00	0,00	∞
Stream 20-3	0,00	0,00	∞
Buffer Stream 20-3	0,00	0,00	∞
Stream 20-4	0,00	0,00	∞
Stream 20-5	0,00	0,00	∞
Stream 20-6	0,00	0,00	∞
Stream 20-7	0,00	0,00	∞
Buffer Stream 20-7	0,00	0,00	∞
Stream 20-8	0,00	0,00	∞
Buffer Stream 20-8	0,00	0,00	∞
Switch Plant 20	0,00	0,00	1,00
Additional Feed Plant 21	0,00	0,00	∞
Stream 21-1	0,69	0,00	3,34
Buffer Stream 21-1	0,00	0,00	∞
Stream 21-2	69,21	50,00	187,00
Stream 21-3	1,45	0,01	7,50
Buffer Stream 21-3	0,00	0,00	∞

Table A.3: Case 1 Summer continued

Streams	MILP Value	Min	Max
Stream 21-4	0,37	0,01	9,00
Buffer Stream 21-4	0,00	0,00	∞
Stream 21-5	18,08	12,16	79,92
Stream 21-5-16	18,08	0,00	∞
Buffer Stream 21-5	0,00	0,00	∞
Stream 21-6	47,93	40,00	125,00
Stream 21-6-16	47,93	0,00	∞
Buffer Stream 21-6	0,00	0,00	∞
Stream 21-7	0,69	0,01	6,00
Buffer Stream 21-7	0,00	0,00	∞
Additional Feed Plant 22	0,00	0,00	∞
Stream 22-1	0,00	0,00	0,00
Stream 22-2	0,00	0,00	0,00
Buffer Stream 22-2	0,00	0,00	∞
Stream 22-3	0,00	0,00	0,00
Buffer Stream 22-3	0,00	0,00	∞
Stream 22-4	0,00	0,00	0,00
Stream 22-5	0,00	0,00	0,00
Stream 22-6	0,00	0,00	0,00
Stream 22-7	0,00	0,00	0,00
Stream 22-8	0,00	0,00	0,00
Buffer Stream 22-8	0,00	0,00	∞
Stream 22-9	0,00	0,00	0,00
Buffer Stream 22-9	0,00	0,00	∞
Additional Feed Plant 23	5,98	0,00	∞
Stream 23-1	3,34	0,79	9,98
Buffer Stream 23-1	0,00	0,00	∞
Stream 23-2	75,00	41,42	79,99
Buffer Stream 23-2	0,00	0,00	∞
Stream 23-3	81,22	46,31	84,97
Stream 23-4	2,80	1,00	5,00
Buffer Stream 23-4	0,00	0,00	∞
Stream 23-5	0,08	0,01	1,00
Buffer Stream 23-5	0,00	0,00	∞
Stream 23-6	1,47	0,45	2,17

Table A.3: Case 1 Summer continued

Streams	MILP Value	Min	Max
Stream 23-7	1,97	1,29	2,60
Stream 24-1	192,53	127,13	285,36
Buffer Stream 24-1	0,00	0,00	∞
Stream 24-2	903,99	812,61	1045,67
Stream 24-3	12,02	8,39	15,24
Stream 24-4	44,13	0,00	93,13
Buffer Stream 24-4	0,00	0,00	∞
Stream 24-5	150,16	110,69	206,53
Buffer Stream 24-5	0,00	0,00	∞
Stream 24-6	239,80	148,22	325,95
Buffer Stream 24-6	0,00	0,00	∞
Stream 24-7	9,13	2,69	17,31
Buffer Stream 24-7	0,00	0,00	∞
Stream 24-8	5,52	0,00	11,92
Stream 24-9	1,67	0,00	8,25
Stream 24-10	16,22	8,40	22,90
Stream 24-11	3,12	2,04	6,37
Buffer Stream 24-11	0,00	0,00	∞
Stream 24-12	237,26	150,61	410,77
Buffer Stream 24-12	0,00	0,00	∞
Stream 24-13	27,86	0,00	38,97
Buffer Stream 24-13	0,00	0,00	∞
Additional Feed Plant 25	1,73	0,00	∞
Stream 25-1	4,44	4,44	10,47
Stream 25-2	2,78	1,59	4,63
Buffer Stream 25-2	0,00	0,00	∞
Stream 25-3	1,66	1,11	6,40
Buffer Stream 25-3	0,00	0,00	∞
Additional Feed Plant 26	0,00	0,00	∞
Stream 26-1	3,94	0,70	3,94
Stream 26-2	0,04	0,01	3,00
Buffer Stream 26-2	0,00	0,00	∞
Stream 26-3	3,90	0,01	4,00
Buffer Stream 26-3	0,00	0,00	∞
Additional Feed Plant 27	3,15	0,00	∞

Table A.3: Case 1 Summer continued

Streams	MILP Value	Min	Max
Stream 27-1	11,63	11,63	33,26
Stream 27-2	5,24	0,01	15,00
Buffer Stream 27-2	0,00	0,00	∞
Stream 27-3	6,39	0,01	20,00
Buffer Stream 27-3	0,00	0,00	∞
stream1	169,62	0,00	∞
stream10	39,99	0,00	∞
stream100	2,80	0,00	∞
stream101	0,00	0,00	∞
stream102	0,00	0,00	∞
stream103	0,00	0,00	∞
stream104	0,08	0,00	∞
stream105	0,00	0,00	∞
stream106	0,00	0,00	∞
stream107	3,34	0,00	∞
stream108	75,00	0,00	∞
stream109	14,43	0,00	∞
stream11	132,51	0,00	∞
stream110	6,90	0,00	∞
stream111	0,22	0,00	∞
stream112	0,24	0,00	∞
stream113	8,99	0,00	∞
stream114	17,03	0,00	∞
stream115	13,82	0,00	∞
stream116	8,40	0,00	∞
stream117	16,43	0,00	∞
stream118	0,00	0,00	∞
stream119	0,00	0,00	∞
stream12	60,02	0,00	∞
stream120	0,00	0,00	∞
stream121	0,00	0,00	∞
stream122	0,00	0,00	∞
stream123	0,00	0,00	∞
stream124	0,00	0,00	∞
stream125	20,31	0,00	∞

Table A.3: Case 1 Summer continued

Streams	**MILP Value**	**Min**	**Max**
stream126	1,97	0,00	∞
stream127	9,69	0,00	∞
stream128	0,00	0,00	∞
stream129	0,20	0,00	∞
stream13	9,13	0,00	∞
stream130	1,46	0,00	∞
stream131	2,71	0,00	∞
stream132	0,00	0,00	∞
stream133	11,59	0,00	∞
stream134	0,00	0,00	∞
stream135	7,27	0,00	∞
stream136	67,54	0,00	∞
stream137	16,89	0,00	∞
stream138	4,11	0,00	∞
stream139	21,79	0,00	∞
stream14	86,87	0,00	∞
stream140	38,65	0,00	∞
stream141	6,89	0,00	∞
stream142	5,57	0,00	∞
stream143	34,60	0,00	∞
stream144	2,97	0,00	∞
stream145	0,00	0,00	∞
stream146	85,00	0,00	∞
stream147	4,35	0,00	∞
stream148	3,67	0,00	∞
stream149	5,19	0,00	∞
stream15	150,39	0,00	∞
stream150	0,00	0,00	∞
stream151	4,44	0,00	∞
stream152	6,39	0,00	∞
stream153	3,94	0,00	∞
stream154	1,30	0,00	∞
stream155	2,78	0,00	∞
stream156	1,66	0,00	∞
stream157	0,04	0,00	∞

Table A.3: Case 1 Summer continued

Streams	MILP Value	Min	Max
stream158	3,90	0,00	∞
stream16	3,12	0,00	∞
stream17	0,00	0,00	∞
stream18	19,06	0,00	∞
stream19	22,72	0,00	∞
stream2	30,18	0,00	∞
stream20	10,05	0,00	∞
stream21	8,92	0,00	∞
stream22	0,00	0,00	∞
stream23	26,20	0,00	∞
stream24	0,00	0,00	∞
stream25	49,04	0,00	∞
stream26	46,29	0,00	∞
stream27	3,84	0,00	∞
stream28	105,93	0,00	∞
stream29	0,40	0,00	∞
stream3	40,00	0,00	∞
stream30	244,07	0,00	∞
stream31	3,77	0,00	∞
stream32	1,91	0,00	∞
stream33	6,96	0,00	∞
stream34	188,07	0,00	∞
stream35	2,30	0,00	∞
stream36	2,10	0,00	∞
stream37	2,33	0,00	∞
stream38	0,40	0,00	∞
stream39	0,04	0,00	∞
stream4	44,13	0,00	∞
stream40	5,36	0,00	∞
stream41	33,80	0,00	∞
stream42	0,00	0,00	∞
stream43	0,40	0,00	∞
stream44	0,00	0,00	∞
stream45	0,00	0,00	∞
stream46	0,00	0,00	∞

Table A.3: Case 1 Summer continued

Streams	MILP Value	Min	Max
stream47	0,00	0,00	∞
stream48	0,00	0,00	∞
stream49	0,00	0,00	∞
stream5	0,00	0,00	∞
stream50	0,00	0,00	∞
stream51	0,00	0,00	∞
stream52	0,00	0,00	∞
stream53	0,00	0,00	∞
stream54	0,00	0,00	∞
stream55	0,00	0,00	∞
stream56	0,00	0,00	∞
stream57	0,00	0,00	∞
stream58	0,00	0,00	∞
stream59	0,00	0,00	∞
stream6	0,00	0,00	∞
stream60	0,00	0,00	∞
stream61	0,00	0,00	∞
stream62	1,80	0,00	∞
stream63	0,00	0,00	∞
stream64	7,11	0,00	∞
stream65	0,00	0,00	∞
stream66	2,10	0,00	∞
stream67	38,39	0,00	∞
stream68	0,00	0,00	∞
stream69	0,00	0,00	∞
stream7	27,86	0,00	∞
stream70	42,85	0,00	∞
stream71	0,00	0,00	∞
stream72	5,63	0,00	∞
stream73	1,50	0,00	∞
stream74	100,42	0,00	∞
stream75	0,00	0,00	∞
stream76	3,67	0,00	∞
stream77	44,80	0,00	∞
stream78	0,00	0,00	∞

Table A.3: Case 1 Summer continued

Streams	MILP Value	Min	Max
stream79	55,39	0,00	∞
stream8	0,00	0,00	∞
stream80	2,43	0,00	∞
stream81	18,87	0,00	∞
stream82	0,69	0,00	∞
stream83	0,69	0,00	∞
stream84	0,37	0,00	∞
stream85	0,00	0,00	∞
stream86	0,00	0,00	∞
stream87	1,45	0,00	∞
stream88	0,00	0,00	∞
stream89	0,00	0,00	∞
stream9	110,16	0,00	∞
stream90	0,00	0,00	∞
stream91	0,00	0,00	∞
stream92	0,00	0,00	∞
stream93	0,00	0,00	∞
stream94	0,00	0,00	∞
stream95	0,00	0,00	∞
stream96	0,00	0,00	∞
stream97	0,00	0,00	∞
stream98	0,00	0,00	∞
stream99	0,00	0,00	∞
Additional Feed Plant 28	0,00	0,00	∞
Stream 28-1	0,00	0,00	0,00
Stream 28-2	0,00	0,00	0,00
Buffer Stream 28-2	0,00	0,00	∞
Stream 28-3	0,00	0,00	0,00
Buffer Stream 28-3	0,00	0,00	∞
Stream 28-4	0,00	0,00	0,00
Stream 28-5	0,00	0,00	0,00
Stream 28-6	0,00	0,00	0,00
Stream 28-7	0,00	0,00	0,00
Stream 28-8	0,00	0,00	0,00
Buffer Stream 28-8	0,00	0,00	∞

Table A.3: Case 1 Summer continued

Streams	MILP Value	Min	Max
Stream 28-9	0,00	0,00	0,00
Buffer Stream 28-9	0,00	0,00	∞
Stream 28-10	0,00	0,00	0,00
Buffer Stream 28-10	0,00	0,00	∞
Additional Feed Plant 29	0,00	0,00	∞
Stream 29-1	16,43	7,43	19,15
Buffer Stream 29-1	0,00	0,00	∞
Stream 29-2	38,65	19,34	42,16
Stream 29-3	8,40	3,06	10,47
Buffer Stream 29-3	0,00	0,00	∞
Stream 29-4	13,82	6,66	16,67
Buffer Stream 29-4	0,00	0,00	∞
Additional Feed Plant 30	0,00	0,00	∞
Stream 30-1	132,51	132,51	242,16
Stream 30-2	18,87	12,44	37,27
Buffer Stream 30-2	0,00	0,00	∞
Stream 30-3	2,43	0,00	22,70
Buffer Stream 30-3	0,00	0,00	∞
Stream 30-4	111,21	102,21	180,00
Buffer Stream 30-4	55,81	0,00	∞

Table A.4: Case 1 Winter

Streams	**MILP Value**	**Min**	**Max**
Additional Feed Plant 1	14,59	0,00	∞
Stream 1-1	33,86	11,00	35,00
Buffer Stream 1-1	0,00	0,00	∞
Additional Feed Plant 2	43,79	0,00	∞
Stream 2-1	89,58	31,00	100,00
Stream 2-2	0,99	0,10	5,00
Stream 2-3	4,58	1,50	20,00
Buffer Stream 2-3	0,00	0,00	∞
Stream 2-4	85,00	25,00	85,00
Buffer Stream 2-4	0,00	0,00	∞
Stream 1-2	23,80	7,60	28,21
Buffer Stream 1-2	1,79	0,00	∞
Stream 1-3	3,33	0,00	9,42
Buffer Stream 1-3	0,00	0,00	∞
Stream 1-4	16,98	5,23	16,98
Buffer Stream 1-4	0,00	0,00	∞
Stream 1-5	65,18	22,86	66,97
Buffer Stream 1-5	0,00	0,00	∞
Stream 1-6	196,73	68,46	201,16
Stream 1-7	4,30	0,10	5,00
Buffer Stream 1-7	0,00	0,00	∞
Stream 1-8	6,10	0,00	8,32
Buffer Stream 1-8	0,00	0,00	∞
Stream 1-9	1,97	0,38	3,59
Stream 1-10	52,65	0,00	149,52
Stream 1-11	38,46	1,35	42,79
Buffer Stream 1-11	0,00	0,00	∞
Stream 1-12	55,16	17,53	68,89
Stream 1-13	0,00	0,00	1,00
Stream 1-14	14,68	0,00	54,99
Stream 1-15	10,24	0,00	91,18
Stream 1-16	4,72	0,00	8,60
Buffer Stream 1-16	0,00	0,00	∞
Stream 3-1	42,31	41,99	64,16
Stream 3-2	21,24	18,50	32,56

Table A.4: Case 1 Winter continued

Streams	**MILP Value**	**Min**	**Max**
Buffer Stream 3-2	0,00	0,00	∞
Stream 3-3	21,07	21,07	33,20
Buffer Stream 3-3	0,00	0,00	∞
Additional Feed Plant 4	0,00	0,00	∞
Stream 4-1	12,73	0,14	12,73
Buffer Stream 4-1	0,00	0,00	∞
Stream 4-2	12,73	0,14	12,73
Stream 4-3	0,05	0,00	0,07
Stream 4-4	0,41	0,10	0,63
Stream 4-5	0,46	0,10	0,51
Stream 5-1	0,29	0,07	0,33
Buffer Stream 5-1	0,00	0,00	∞
Stream 5-2	0,28	0,00	0,37
Buffer Stream 5-2	0,00	0,00	∞
Additional Feed Plant 5	0,00	0,00	∞
Stream 5-3	6,71	2,08	7,44
Buffer Stream 5-3	0,00	0,00	∞
Stream 5-4	22,01	9,26	22,01
Stream 5-5	0,48	0,00	1,80
Stream 5-6	14,35	7,21	16,01
Stream 5-7	14,73	5,16	16,37
Buffer Stream 5-7	0,00	0,00	∞
Additional Feed Plant 6	3,37	0,00	∞
Stream 6-1	6,76	6,76	15,45
Stream 6-2	6,76	1,42	9,79
Buffer Stream 6-2	0,00	0,00	∞
Additional Feed Plant 7	0,00	0,00	∞
Stream 7-1	4,87	3,16	13,80
Stream 7-2	4,87	4,87	14,95
Buffer Stream 7-2	0,00	0,00	∞
EL Plant 1	4,85	0,67	6,18
EL Plant 5	1,76	0,00	2,01
EL Plant 7	1,29	0,33	2,04
EL Plant 9	8,36	8,20	11,09
EL Plant 10	0,81	0,00	0,98

Table A.4: Case 1 Winter continued

Streams	MILP Value	Min	Max
EL Plant 11	0,95	0,00	1,20
EL Plant 12	1,42	0,88	47,79
EL Plant 13	2,95	2,15	4,15
EL Plant 14	1,10	0,79	1,82
EL Plant 15	0,85	0,76	2,52
EL Plant 16	0,00	0,00	0,00
EL Plant 18	2,05	0,00	∞
EL Plant 19	0,00	0,00	∞
EL Plant 20	0,00	0,00	∞
EL Plant 21	0,66	0,56	0,76
EL Plant 22	0,00	0,00	0,00
EL Plant 23	0,30	0,00	0,40
EL Plant 24	4,94	4,58	5,39
EL Plant 26	0,80	0,62	1,03
EL Plant 28	0,00	0,00	0,00
EL Plant 29	0,18	0,11	0,24
Additional Feed Plant 8	0,00	0,00	∞
Stream 8-1	13,08	1,45	19,41
Buffer Stream 8-1	0,00	0,00	∞
Stream 8-2	5,41	0,00	∞
Stream 8-3	36,08	27,13	49,64
Stream 8-4	10,02	8,28	14,54
Stream 8-5	23,00	15,41	28,34
Buffer Stream 8-5	0,00	0,00	∞
Additional Feed Plant 9	0,00	0,00	∞
Stream 9-1	11,93	5,00	23,00
Buffer Stream 9-1	0,00	0,00	∞
Stream 9-2	21,35	10,00	32,00
Buffer Stream 9-2	0,00	0,00	∞
Stream 9-3	91,41	50,00	160,00
Stream 9-4	3,17	0,01	10,00
Buffer Stream 9-4	0,00	0,00	∞
Stream 9-5	11,40	5,69	20,73
Buffer Stream 9-5	0,00	0,00	∞
Stream 9-6	6,99	1,00	22,00

Table A.4: Case 1 Winter continued

Streams	MILP Value	Min	Max
Buffer Stream 9-6	0,00	0,00	∞
Stream 9-7	17,46	7,00	36,00
Buffer Stream 9-7	0,00	0,00	∞
Stream 9-8	0,10	0,00	4,58
Stream 9-9	27,61	1,90	35,00
Stream 9-10	6,18	5,44	17,02
Stream 9-11	0,33	0,01	15,00
Stream 9-12	6,57	2,00	12,00
Buffer Stream 9-12	0,00	0,00	∞
Stream 9-13	12,54	12,00	40,00
Buffer Stream 9-13	0,00	0,00	∞
Additional Feed Plant 10	0,00	0,00	∞
Stream 10-1	67,86	5,05	80,57
Buffer Stream 10-1	0,00	0,00	∞
Stream 10-2	131,57	74,84	139,86
Stream 10-3	1,55	0,85	1,79
Stream 10-4	3,55	0,00	10,16
Stream 10-5	4,31	3,55	5,45
Stream 10-6	7,16	0,64	8,92
Stream 10-7	9,18	1,92	18,94
Buffer Stream 10-7	0,00	0,00	∞
Stream 10-8	54,53	19,60	85,44
Buffer Stream 10-8	0,00	0,00	∞
Additional Feed Plant 11	0,00	0,00	∞
Stream 11-1	110,22	110,22	261,71
Stream 11-2	1,79	0,00	8,12
Stream 11-3	0,79	0,00	4,04
Stream 11-4	0,02	0,00	1,20
Stream 11-5	4,23	0,00	10,14
Stream 11-6	1,10	0,00	3,00
Buffer Stream 11-6	0,00	0,00	∞
Stream 11-7	32,50	22,74	97,50
Buffer Stream 11-7	0,00	0,00	∞
Stream 11-8	76,62	71,44	177,96
Buffer Stream 11-8	0,00	0,00	∞

Table A.4: Case 1 Winter continued

Streams	MILP Value	Min	Max
Additional Feed Plant 12	0,00	0,00	∞
Stream 12-1	119,92	117,14	160,34
Stream 12-2	0,57	0,45	0,89
Stream 12-3	0,33	0,30	2,00
Buffer Stream 12-3	0,00	0,00	∞
Stream 12-4	0,29	0,13	0,82
Stream 12-5	116,14	116,14	157,78
Buffer Stream 12-5	0,00	0,00	∞
Stream 12-6	0,37	0,20	4,86
Stream 12-7	1,00	0,95	1,20
Stream 12-8	3,45	2,01	9,04
Buffer Stream 12-8	0,00	0,00	∞
Stream 12-9	1,47	0,00	3,00
Buffer Stream 12-9	0,00	0,00	∞
Additional Feed Plant 13	0,00	0,00	∞
Stream 13-1	6,16	0,23	10,85
Buffer Stream 13-1	0,00	0,00	∞
Stream 13-2	244,51	157,27	300,83
Stream 13-3	0,69	0,09	2,14
Stream 13-4	233,86	146,55	286,78
Buffer Stream 13-4	0,00	0,00	∞
Stream 13-5	1,94	1,01	7,02
Stream 13-6	3,37	0,07	7,99
Stream 13-7	5,45	3,94	6,90
Stream 13-8	3,04	0,20	4,00
Buffer Stream 13-8	0,00	0,00	∞
Additional Feed Plant 14	0,00	0,00	∞
Stream 14-1	2,18	0,00	10,51
Buffer Stream 14-1	0,00	0,00	∞
Stream 14-2	194,64	136,19	250,00
Stream 14-3	0,53	0,24	0,89
Stream 14-4	1,32	0,20	7,84
Buffer Stream 14-4	0,00	0,00	∞
Stream 14-5	3,40	0,00	7,10
Buffer Stream 14-5	0,00	0,00	∞

Table A.4: Case 1 Winter continued

Streams	**MILP Value**	**Min**	**Max**
Stream 14-6	0,99	0,00	5,30
Stream 14-7	2,52	0,02	4,24
Stream 14-8	3,23	0,00	7,80
Stream 14-9	0,07	0,00	3,36
Stream 14-10	0,08	0,00	3,09
Stream 14-11	5,03	0,00	11,43
Stream 15-1	11,02	10,07	30,60
Buffer Stream 15-1	0,00	0,00	∞
Stream 15-2	2,55	1,99	3,59
Stream 15-3	41,43	26,40	79,72
Buffer Stream 15-3	0,00	0,00	∞
Stream 15-4	19,33	8,81	48,68
Buffer Stream 15-4	0,00	0,00	∞
Stream 15-5	9,82	7,69	10,58
Additional Feed Plant 15-1	0,00	0,00	∞
Stream 15-6	208,82	175,27	271,31
Stream 15-7	1,62	1,45	2,23
Stream 15-8	136,07	125,83	188,75
Buffer Stream 15-8	55,24	0,00	∞
Stream 15-9	10,58	9,37	15,75
Buffer Stream 15-9	0,00	0,00	∞
Additional Feed Plant 15-2	0,00	0,00	∞
Stream 15-10	9,61	4,03	31,60
Stream 15-11	187,75	122,86	238,40
Buffer Stream 15-11	0,00	0,00	∞
Additional Feed Plant 16	0,00	0,00	∞
Stream 16-1	0,00	0,00	0,00
Stream 16-2	0,00	0,00	0,00
Stream 16-3	0,00	0,00	0,00
Stream 16-4	0,00	0,00	0,00
Buffer Stream 16-4	0,00	0,00	∞
Buffer Stream 16-3	0,00	0,00	∞
Stream 16-5	0,00	0,00	0,00
Buffer Stream 16-5	0,00	0,00	∞
Stream 16-6	0,00	0,00	0,00

Table A.4: Case 1 Winter continued

Streams	MILP Value	Min	Max
Buffer Stream 16-6	0,00	0,00	∞
Stream 16-7	0,00	0,00	0,00
Stream 16-8	0,00	0,00	0,00
Stream 16-9	0,00	0,00	0,00
Stream 16-10	0,00	0,00	0,00
Buffer Stream 16-10	0,00	0,00	∞
Stream 16-11	0,00	0,00	0,00
Buffer Stream 16-11	0,00	0,00	∞
Stream 16-12	0,00	0,00	0,00
Buffer Stream 16-12	0,00	0,00	∞
Stream 16-13	2,33	1,51	3,71
Buffer Stream 16-13	0,00	0,00	∞
Additional Feed Plant 17	0,00	0,00	∞
Stream 17-1	11,18	6,51	28,03
Buffer Stream 17-1	0,00	0,00	∞
Stream 17-2	17,07	10,25	34,33
Stream 17-3	3,56	0,28	6,56
Buffer Stream 17-3	0,00	0,00	∞
Stream 17-4	2,10	0,00	3,60
Additional Feed Plant 18	0,00	0,00	∞
Stream 18-1	11,03	0,00	∞
Buffer Stream 18-1	0,00	0,00	∞
Stream 18-2	0,53	0,00	∞
Buffer Stream 18-2	0,00	0,00	∞
Stream 18-3	40,67	0,00	∞
Buffer Stream 18-3	0,00	0,00	∞
Stream 18-4	53,30	0,00	∞
Stream 18-5	2,64	0,00	∞
Stream 18-6	1,49	0,00	∞
Stream 18-7	0,53	0,00	∞
Buffer Stream 18-7	0,00	0,00	∞
Stream 18-8	0,53	0,00	∞
Buffer Stream 18-8	0,00	0,00	∞
Switch Plant 18	1,00	0,00	1,00
Additional Feed Plant 19	0,00	0,00	∞

Table A.4: Case 1 Winter continued

Streams	MILP Value	Min	Max
Stream 19-1	0,00	0,00	∞
Buffer Stream 19-1	0,00	0,00	∞
Stream 19-2	0,00	0,00	∞
Buffer Stream 19-2	0,00	0,00	∞
Stream 19-3	0,00	0,00	∞
Buffer Stream 19-3	0,00	0,00	∞
Stream 19-4	0,00	0,00	∞
Stream 19-5	0,00	0,00	∞
Stream 19-6	0,00	0,00	∞
Stream 19-7	0,00	0,00	∞
Buffer Stream 19-7	0,00	0,00	∞
Stream 19-8	0,00	0,00	∞
Buffer Stream 19-8	0,00	0,00	∞
Switch Plant 19	0,00	0,00	1,00
Additional Feed Plant 20	0,00	0,00	∞
Stream 20-1	0,00	0,00	∞
Buffer Stream 20-1	0,00	0,00	∞
Stream 20-2	0,00	0,00	∞
Buffer Stream 20-2	0,00	0,00	∞
Stream 20-3	0,00	0,00	∞
Buffer Stream 20-3	0,00	0,00	∞
Stream 20-4	0,00	0,00	∞
Stream 20-5	0,00	0,00	∞
Stream 20-6	0,00	0,00	∞
Stream 20-7	0,00	0,00	∞
Buffer Stream 20-7	0,00	0,00	∞
Stream 20-8	0,00	0,00	∞
Buffer Stream 20-8	0,00	0,00	∞
Switch Plant 20	0,00	0,00	1,00
Additional Feed Plant 21	0,00	0,00	∞
Stream 21-1	0,65	0,00	3,65
Buffer Stream 21-1	0,00	0,00	∞
Stream 21-2	65,25	50,00	187,00
Stream 21-3	1,70	0,01	7,50
Buffer Stream 21-3	0,00	0,00	∞

Table A.4: Case 1 Winter continued

Streams	MILP Value	Min	Max
Stream 21-4	0,56	0,01	9,00
Buffer Stream 21-4	0,00	0,00	∞
Stream 21-5	13,61	13,56	79,37
Stream 21-5-16	13,61	0,00	∞
Buffer Stream 21-5	0,00	0,00	∞
Stream 21-6	48,31	40,00	125,00
Stream 21-6-16	48,31	0,00	∞
Buffer Stream 21-6	0,00	0,00	∞
Stream 21-7	0,42	0,01	6,00
Buffer Stream 21-7	0,00	0,00	∞
Additional Feed Plant 22	0,00	0,00	∞
Stream 22-1	0,00	0,00	0,00
Stream 22-2	0,00	0,00	0,00
Buffer Stream 22-2	0,00	0,00	∞
Stream 22-3	0,00	0,00	0,00
Buffer Stream 22-3	0,00	0,00	∞
Stream 22-4	0,00	0,00	0,00
Stream 22-5	0,00	0,00	0,00
Stream 22-6	0,00	0,00	0,00
Stream 22-7	0,00	0,00	0,00
Stream 22-8	0,00	0,00	0,00
Buffer Stream 22-8	0,00	0,00	∞
Stream 22-9	0,00	0,00	0,00
Buffer Stream 22-9	0,00	0,00	∞
Additional Feed Plant 23	20,71	0,00	∞
Stream 23-1	3,86	0,92	11,92
Buffer Stream 23-1	0,00	0,00	∞
Stream 23-2	75,00	36,62	81,02
Buffer Stream 23-2	0,00	0,00	∞
Stream 23-3	81,48	45,97	83,83
Stream 23-4	2,61	1,00	5,00
Buffer Stream 23-4	0,00	0,00	∞
Stream 23-5	0,00	0,00	1,00
Buffer Stream 23-5	0,00	0,00	∞
Stream 23-6	1,41	0,16	2,12

Table A.4: Case 1 Winter continued

Streams	MILP Value	Min	Max
Stream 23-7	1,94	0,95	2,70
Stream 24-1	188,25	123,46	269,58
Buffer Stream 24-1	0,00	0,00	∞
Stream 24-2	898,83	812,33	1051,74
Stream 24-3	13,36	9,92	15,96
Stream 24-4	53,92	28,68	90,56
Buffer Stream 24-4	0,00	0,00	∞
Stream 24-5	145,35	105,64	187,87
Buffer Stream 24-5	0,00	0,00	∞
Stream 24-6	228,76	139,27	297,69
Buffer Stream 24-6	0,00	0,00	∞
Stream 24-7	9,61	0,72	18,28
Buffer Stream 24-7	0,00	0,00	∞
Stream 24-8	2,20	0,00	10,03
Stream 24-9	2,03	0,00	8,01
Stream 24-10	16,48	12,98	23,87
Stream 24-11	3,78	2,04	6,48
Buffer Stream 24-11	0,00	0,00	∞
Stream 24-12	241,79	156,70	352,56
Buffer Stream 24-12	0,00	0,00	∞
Stream 24-13	27,38	19,49	39,08
Buffer Stream 24-13	0,00	0,00	∞
Additional Feed Plant 25	0,00	0,00	∞
Stream 25-1	6,57	5,26	9,18
Stream 25-2	3,48	2,38	5,26
Buffer Stream 25-2	0,00	0,00	∞
Stream 25-3	3,09	2,01	4,90
Buffer Stream 25-3	0,00	0,00	∞
Additional Feed Plant 26	0,00	0,00	∞
Stream 26-1	3,73	0,50	3,73
Stream 26-2	0,04	0,00	3,00
Buffer Stream 26-2	0,00	0,00	∞
Stream 26-3	3,69	0,01	4,00
Buffer Stream 26-3	0,00	0,00	∞
Additional Feed Plant 27	0,00	0,00	∞

Table A.4: Case 1 Winter continued

Streams	MILP Value	Min	Max
Stream 27-1	9,75	9,67	24,66
Stream 27-2	4,26	0,01	11,00
Buffer Stream 27-2	0,00	0,00	∞
Stream 27-3	5,49	0,01	15,00
Buffer Stream 27-3	0,00	0,00	∞
stream1	205,97	0,00	∞
stream10	25,42	0,00	∞
stream100	2,61	0,00	∞
stream101	0,00	0,00	∞
stream102	0,00	0,00	∞
stream103	0,00	0,00	∞
stream104	0,00	0,00	∞
stream105	0,00	0,00	∞
stream106	0,00	0,00	∞
stream107	3,86	0,00	∞
stream108	75,00	0,00	∞
stream109	14,73	0,00	∞
stream11	121,87	0,00	∞
stream110	6,71	0,00	∞
stream111	0,29	0,00	∞
stream112	0,28	0,00	∞
stream113	13,08	0,00	∞
stream114	23,00	0,00	∞
stream115	13,52	0,00	∞
stream116	7,99	0,00	∞
stream117	16,95	0,00	∞
stream118	0,00	0,00	∞
stream119	0,00	0,00	∞
stream12	66,38	0,00	∞
stream120	0,00	0,00	∞
stream121	0,00	0,00	∞
stream122	0,00	0,00	∞
stream123	0,00	0,00	∞
stream124	0,00	0,00	∞
stream125	12,54	0,00	∞

Table A.4: Case 1 Winter continued

Streams	MILP Value	Min	Max
stream126	6,99	0,00	∞
stream127	17,46	0,00	∞
stream128	0,00	0,00	∞
stream129	3,17	0,00	∞
stream13	9,61	0,00	∞
stream130	11,40	0,00	∞
stream131	6,57	0,00	∞
stream132	0,00	0,00	∞
stream133	21,35	0,00	∞
stream134	0,00	0,00	∞
stream135	11,93	0,00	∞
stream136	65,18	0,00	∞
stream137	16,98	0,00	∞
stream138	4,30	0,00	∞
stream139	22,01	0,00	∞
stream14	131,57	0,00	∞
stream140	38,46	0,00	∞
stream141	6,10	0,00	∞
stream142	4,72	0,00	∞
stream143	33,86	0,00	∞
stream144	3,33	0,00	∞
stream145	0,00	0,00	∞
stream146	85,00	0,00	∞
stream147	4,58	0,00	∞
stream148	12,73	0,00	∞
stream149	6,76	0,00	∞
stream15	110,22	0,00	∞
stream150	0,00	0,00	∞
stream151	4,87	0,00	∞
stream152	5,49	0,00	∞
stream153	3,73	0,00	∞
stream154	0,53	0,00	∞
stream155	3,48	0,00	∞
stream156	3,09	0,00	∞
stream157	0,04	0,00	∞

Table A.4: Case 1 Winter continued

Streams	MILP Value	Min	Max
stream158	3,69	0,00	∞
stream16	3,78	0,00	∞
stream17	0,00	0,00	∞
stream18	21,24	0,00	∞
stream19	21,07	0,00	∞
stream2	22,79	0,00	∞
stream20	11,02	0,00	∞
stream21	10,58	0,00	∞
stream22	0,00	0,00	∞
stream23	19,33	0,00	∞
stream24	0,00	0,00	∞
stream25	41,43	0,00	∞
stream26	80,83	0,00	∞
stream27	3,45	0,00	∞
stream28	116,14	0,00	∞
stream29	0,33	0,00	∞
stream3	0,00	0,00	∞
stream30	233,86	0,00	∞
stream31	3,04	0,00	∞
stream32	1,47	0,00	∞
stream33	6,16	0,00	∞
stream34	187,75	0,00	∞
stream35	2,18	0,00	∞
stream36	1,32	0,00	∞
stream37	3,40	0,00	∞
stream38	0,00	0,00	∞
stream39	0,00	0,00	∞
stream4	0,62	0,00	∞
stream40	0,00	0,00	∞
stream41	0,00	0,00	∞
stream42	0,00	0,00	∞
stream43	0,00	0,00	∞
stream44	0,00	0,00	∞
stream45	0,00	0,00	∞
stream46	0,53	0,00	∞

Table A.4: Case 1 Winter continued

Streams	MILP Value	Min	Max
stream47	0,53	0,00	∞
stream48	11,03	0,00	∞
stream49	40,67	0,00	∞
stream5	0,00	0,00	∞
stream50	0,16	0,00	∞
stream51	0,38	0,00	∞
stream52	0,00	0,00	∞
stream53	0,00	0,00	∞
stream54	0,00	0,00	∞
stream55	0,00	0,00	∞
stream56	0,00	0,00	∞
stream57	0,00	0,00	∞
stream58	0,00	0,00	∞
stream59	0,00	0,00	∞
stream6	53,30	0,00	∞
stream60	0,00	0,00	∞
stream61	0,00	0,00	∞
stream62	2,33	0,00	∞
stream63	0,00	0,00	∞
stream64	11,18	0,00	∞
stream65	0,00	0,00	∞
stream66	3,56	0,00	∞
stream67	67,86	0,00	∞
stream68	0,00	0,00	∞
stream69	0,00	0,00	∞
stream7	27,38	0,00	∞
stream70	54,53	0,00	∞
stream71	0,00	0,00	∞
stream72	9,18	0,00	∞
stream73	1,10	0,00	∞
stream74	76,62	0,00	∞
stream75	0,00	0,00	∞
stream76	12,73	0,00	∞
stream77	19,77	0,00	∞
stream78	0,00	0,00	∞

Table A.4: Case 1 Winter continued

Streams	MILP Value	Min	Max
stream79	51,73	0,00	∞
stream8	0,00	0,00	∞
stream80	7,39	0,00	∞
stream81	19,60	0,00	∞
stream82	0,65	0,00	∞
stream83	0,42	0,00	∞
stream84	0,56	0,00	∞
stream85	0,00	0,00	∞
stream86	0,00	0,00	∞
stream87	1,70	0,00	∞
stream88	0,00	0,00	∞
stream89	0,00	0,00	∞
stream9	119,92	0,00	∞
stream90	0,00	0,00	∞
stream91	0,00	0,00	∞
stream92	0,00	0,00	∞
stream93	0,00	0,00	∞
stream94	0,00	0,00	∞
stream95	0,00	0,00	∞
stream96	0,00	0,00	∞
stream97	0,00	0,00	∞
stream98	0,00	0,00	∞
stream99	0,00	0,00	∞
Additional Feed Plant 28	0,00	0,00	∞
Stream 28-1	0,00	0,00	0,00
Stream 28-2	0,00	0,00	0,00
Buffer Stream 28-2	0,00	0,00	∞
Stream 28-3	0,00	0,00	0,00
Buffer Stream 28-3	0,00	0,00	∞
Stream 28-4	0,00	0,00	0,00
Stream 28-5	0,00	0,00	0,00
Stream 28-6	0,00	0,00	0,00
Stream 28-7	0,00	0,00	0,00
Stream 28-8	0,00	0,00	0,00
Buffer Stream 28-8	0,00	0,00	∞

Table A.4: Case 1 Winter continued

Streams	**MILP Value**	**Min**	**Max**
Stream 28-9	0,00	0,00	0,00
Buffer Stream 28-9	0,00	0,00	∞
Stream 28-10	0,00	0,00	0,00
Buffer Stream 28-10	0,00	0,00	∞
Additional Feed Plant 29	0,00	0,00	∞
Stream 29-1	16,95	7,66	19,90
Buffer Stream 29-1	0,00	0,00	∞
Stream 29-2	38,46	18,66	44,43
Stream 29-3	7,99	4,21	9,79
Buffer Stream 29-3	0,00	0,00	∞
Stream 29-4	13,52	5,09	15,60
Buffer Stream 29-4	0,00	0,00	∞
Additional Feed Plant 30	0,00	0,00	∞
Stream 30-1	121,87	121,87	236,86
Stream 30-2	19,60	15,01	41,76
Buffer Stream 30-2	0,00	0,00	∞
Stream 30-3	7,39	0,00	26,76
Buffer Stream 30-3	0,00	0,00	∞
Stream 30-4	94,88	81,12	179,30
Buffer Stream 30-4	43,15	0,00	∞

Table A.5: Case 2 Summer

Streams	MILP Value	Min	Max
Additional Feed Plant 1	12,65	0,00	∞
Stream 1-1	34,60	11,00	35,00
Buffer Stream 1-1	0,00	0,00	∞
Additional Feed Plant 2	12,18	0,00	∞
Stream 2-1	54,06	31,76	54,06
Stream 2-2	0,51	0,37	0,80
Stream 2-3	3,99	1,75	7,29
Buffer Stream 2-3	0,00	0,00	∞
Stream 2-4	50,06	28,14	51,92
Buffer Stream 2-4	0,00	0,00	∞
Stream 1-2	23,87	7,78	29,16
Buffer Stream 1-2	2,08	0,00	∞
Stream 1-3	2,97	0,00	9,56
Buffer Stream 1-3	0,00	0,00	∞
Stream 1-4	16,89	5,29	16,89
Buffer Stream 1-4	0,00	0,00	∞
Stream 1-5	67,54	20,89	67,86
Buffer Stream 1-5	0,00	0,00	∞
Stream 1-6	201,09	63,89	203,02
Stream 1-7	4,11	0,10	5,00
Buffer Stream 1-7	0,00	0,00	∞
Stream 1-8	6,89	0,00	7,36
Buffer Stream 1-8	0,00	0,00	∞
Stream 1-9	2,02	0,48	4,09
Stream 1-10	51,19	7,67	126,13
Stream 1-11	38,65	5,45	41,02
Buffer Stream 1-11	0,00	0,00	∞
Stream 1-12	62,57	0,31	73,58
Stream 1-13	0,16	0,00	2,65
Stream 1-14	7,93	0,00	62,27
Stream 1-15	8,04	0,00	89,32
Stream 1-16	5,57	0,00	9,75
Buffer Stream 1-16	0,00	0,00	∞
Stream 3-1	41,78	39,33	70,19
Stream 3-2	19,06	19,06	39,92

Table A.5: Case 2 Summer continued

Streams	MILP Value	Min	Max
Buffer Stream 3-2	0,00	0,00	∞
Stream 3-3	22,72	19,53	33,78
Buffer Stream 3-3	0,00	0,00	∞
Additional Feed Plant 4	0,00	0,00	∞
Stream 4-1	3,67	3,67	9,85
Buffer Stream 4-1	0,00	0,00	∞
Stream 4-2	3,67	3,67	9,85
Stream 4-3	0,05	0,02	0,08
Stream 4-4	0,49	0,28	0,54
Stream 4-5	0,35	0,26	0,44
Stream 5-1	0,22	0,06	0,38
Buffer Stream 5-1	0,00	0,00	∞
Stream 5-2	0,24	0,10	0,39
Buffer Stream 5-2	0,00	0,00	∞
Additional Feed Plant 5	0,00	0,00	∞
Stream 5-3	6,90	2,65	8,36
Buffer Stream 5-3	0,00	0,00	∞
Stream 5-4	21,79	9,13	21,79
Stream 5-5	0,71	0,00	1,80
Stream 5-6	14,07	7,51	15,32
Stream 5-7	14,43	5,85	16,37
Buffer Stream 5-7	0,00	0,00	∞
Additional Feed Plant 6	2,01	0,00	∞
Stream 6-1	5,19	5,19	15,57
Stream 6-2	5,19	1,00	16,00
Buffer Stream 6-2	0,00	0,00	∞
Additional Feed Plant 7	0,00	0,00	∞
Stream 7-1	4,44	3,17	15,65
Stream 7-2	4,44	4,14	14,98
Buffer Stream 7-2	0,00	0,00	∞
EL Plant 1	4,93	2,62	6,09
EL Plant 5	1,79	0,75	1,90
EL Plant 7	1,47	1,04	1,75
EL Plant 9	9,61	0,50	9,90
EL Plant 10	0,69	0,61	0,81

Table A.5: Case 2 Summer continued

Streams	MILP Value	Min	Max
EL Plant 11	0,95	0,62	1,06
EL OCM	105,00	0,00	∞
EL Plant 12	1,29	1,00	1,62
EL Plant 13	3,01	2,15	3,71
EL Plant 14	1,20	0,58	1,69
EL Plant 15	0,87	0,80	2,53
EL Plant 16	0,00	0,00	0,00
EL Plant 18	0,00	0,00	∞
EL Plant 19	2,08	0,00	∞
EL Plant 20	0,00	0,00	∞
EL Plant 21	0,58	0,28	0,94
EL P2H2	105,00	0,00	∞
EL Plant 22	0,00	0,00	0,00
EL Plant 23	0,31	0,14	0,35
EL Plant 24	4,72	4,72	420,04
EL Plant 26	0,63	0,00	0,90
EL Plant 28	0,00	0,00	0,00
EL Plant 29	0,19	0,11	0,24
Additional Feed Plant 8	0,00	0,00	∞
Stream 8-1	8,99	5,00	25,00
Buffer Stream 8-1	0,00	0,00	∞
Stream 8-2	3,90	0,00	∞
Stream 8-3	26,02	15,00	55,00
Stream 8-4	7,41	6,00	14,00
Stream 8-5	17,03	10,00	30,00
Buffer Stream 8-5	0,00	0,00	∞
Additional Feed Plant 9	0,00	0,00	∞
Stream 9-1	7,27	5,00	23,00
Buffer Stream 9-1	0,00	0,00	∞
Stream 9-2	11,59	10,00	32,00
Buffer Stream 9-2	0,00	0,00	∞
Stream 9-3	55,21	50,00	161,00
Stream 9-4	0,20	0,01	10,00
Buffer Stream 9-4	0,00	0,00	∞
Stream 9-5	1,46	0,00	18,90

Table A.5: Case 2 Summer continued

Streams	MILP Value	Min	Max
Buffer Stream 9-5	0,00	0,00	∞
Stream 9-6	1,97	1,00	24,00
Buffer Stream 9-6	0,00	0,00	∞
Stream 9-7	9,69	7,00	35,00
Buffer Stream 9-7	0,00	0,00	∞
Stream 9-8	0,16	0,00	4,73
Stream 9-9	20,46	1,90	25,00
Stream 9-10	3,76	0,43	18,72
Stream 9-11	11,66	0,01	15,00
Stream 9-12	2,71	2,00	12,00
Buffer Stream 9-12	0,00	0,00	∞
Stream 9-13	20,31	12,00	40,00
Buffer Stream 9-13	0,00	0,00	∞
Additional Feed Plant 10	0,00	0,00	∞
Stream 10-1	38,39	19,40	89,64
Buffer Stream 10-1	0,00	0,00	∞
Stream 10-2	86,87	82,77	157,30
Stream 10-3	1,08	0,75	1,93
Stream 10-4	2,40	0,00	10,16
Stream 10-5	4,74	4,26	5,00
Stream 10-6	4,34	0,11	9,10
Stream 10-7	5,63	2,01	18,95
Buffer Stream 10-7	0,00	0,00	∞
Stream 10-8	42,85	22,26	105,95
Buffer Stream 10-8	0,00	0,00	∞
Additional Feed Plant 11	0,00	0,00	∞
Stream 11-1	150,39	115,63	235,89
Stream 11-2	1,36	0,00	8,12
Stream 11-3	1,23	0,00	4,06
Stream 11-4	0,00	0,00	0,75
Stream 11-5	6,30	0,00	23,06
Stream 11-6	1,50	0,00	2,50
Buffer Stream 11-6	0,00	0,00	∞
Stream 11-7	48,47	29,65	89,35
Buffer Stream 11-7	0,00	0,00	∞

Table A.5: Case 2 Summer continued

Streams	MILP Value	Min	Max
Stream 11-8	100,42	79,11	173,34
Buffer Stream 11-8	0,00	0,00	∞
Stream OCM-1	284,95	0,00	∞
Stream OCM-2	205,00	0,00	∞
Stream OCM-3	29,93	0,00	∞
Stream OCM-4	30,96	0,00	∞
Stream OCM-5	57,40	0,00	∞
Stream OCM-6	458,96	0,00	∞
Stream OCM-7	280,85	0,00	∞
Switch OCM	1,00	0,00	1,00
Additional Feed Plant 12	0,00	0,00	∞
Stream 12-1	110,16	106,89	159,68
Stream 12-2	0,52	0,43	0,87
Stream 12-3	0,40	0,40	2,00
Buffer Stream 12-3	0,00	0,00	∞
Stream 12-4	0,32	0,12	1,46
Stream 12-5	105,93	105,39	157,00
Buffer Stream 12-5	0,00	0,00	∞
Stream 12-6	0,27	0,14	0,37
Stream 12-7	1,05	0,96	1,24
Stream 12-8	3,84	2,10	10,74
Buffer Stream 12-8	0,00	0,00	∞
Stream 12-9	1,91	0,00	3,00
Buffer Stream 12-9	0,00	0,00	∞
Additional Feed Plant 13	0,00	0,00	∞
Stream 13-1	6,96	0,28	11,01
Buffer Stream 13-1	0,00	0,00	∞
Stream 13-2	256,71	130,33	300,10
Stream 13-3	0,56	0,15	1,57
Stream 13-4	244,07	122,21	286,36
Buffer Stream 13-4	0,00	0,00	∞
Stream 13-5	2,00	0,89	8,13
Stream 13-6	3,42	0,00	7,14
Stream 13-7	5,63	4,03	6,91
Stream 13-8	3,77	0,70	5,00

Table A.5: Case 2 Summer continued

Streams	MILP Value	Min	Max
Buffer Stream 13-8	0,00	0,00	∞
Additional Feed Plant 14	0,00	0,00	∞
Stream 14-1	2,30	0,00	7,43
Buffer Stream 14-1	0,00	0,00	∞
Stream 14-2	196,85	137,65	251,76
Stream 14-3	0,48	0,22	1,03
Stream 14-4	2,10	0,06	7,79
Buffer Stream 14-4	0,00	0,00	∞
Stream 14-5	2,33	0,00	7,37
Buffer Stream 14-5	0,00	0,00	∞
Stream 14-6	1,63	0,00	5,36
Stream 14-7	2,19	0,00	4,50
Stream 14-8	3,01	0,00	5,53
Stream 14-9	0,01	0,00	3,13
Stream 14-10	0,17	0,00	3,70
Stream 14-11	3,86	0,00	9,79
Stream 15-1	10,05	8,23	35,40
Buffer Stream 15-1	0,00	0,00	∞
Stream 15-2	2,74	2,17	4,22
Stream 15-3	49,04	33,09	85,45
Buffer Stream 15-3	0,00	0,00	∞
Stream 15-4	26,20	13,29	46,76
Buffer Stream 15-4	0,00	0,00	∞
Stream 15-5	9,49	7,10	10,61
Additional Feed Plant 15-1	0,00	0,00	∞
Stream 15-6	210,79	171,22	281,17
Stream 15-7	1,91	1,40	2,21
Stream 15-8	127,38	89,95	196,60
Buffer Stream 15-8	81,09	0,00	∞
Stream 15-9	8,92	7,88	15,30
Buffer Stream 15-9	0,00	0,00	∞
Additional Feed Plant 15-2	0,00	0,00	∞
Stream 15-10	10,80	2,57	31,33
Stream 15-11	190,11	134,65	245,05
Buffer Stream 15-11	2,04	0,00	∞

Table A.5: Case 2 Summer continued

Streams	MILP Value	Min	Max
Additional Feed Plant 16	0,00	0,00	∞
Stream 16-1	0,00	0,00	0,00
Stream 16-2	0,00	0,00	0,00
Stream 16-3	0,00	0,00	0,00
Stream 16-4	0,00	0,00	0,00
Buffer Stream 16-4	0,00	0,00	∞
Buffer Stream 16-3	0,00	0,00	∞
Stream 16-5	0,00	0,00	0,00
Buffer Stream 16-5	0,00	0,00	∞
Stream 16-6	0,00	0,00	0,00
Buffer Stream 16-6	0,00	0,00	∞
Stream 16-7	0,00	0,00	0,00
Stream 16-8	0,00	0,00	0,00
Stream 16-9	0,00	0,00	0,00
Stream 16-10	0,00	0,00	0,00
Buffer Stream 16-10	0,00	0,00	∞
Stream 16-11	0,00	0,00	0,00
Buffer Stream 16-11	0,00	0,00	∞
Stream 16-12	0,00	0,00	0,00
Buffer Stream 16-12	0,00	0,00	∞
Stream 16-13	1,80	0,98	3,00
Buffer Stream 16-13	0,00	0,00	∞
Additional Feed Plant 17	0,00	0,00	∞
Stream 17-1	7,11	4,80	27,03
Buffer Stream 17-1	0,00	0,00	∞
Stream 17-2	11,01	9,45	34,41
Stream 17-3	2,10	0,56	7,33
Buffer Stream 17-3	0,00	0,00	∞
Stream 17-4	1,05	0,00	3,82
Additional Feed Plant 18	0,00	0,00	∞
Stream 18-1	0,00	0,00	∞
Buffer Stream 18-1	0,00	0,00	∞
Stream 18-2	0,00	0,00	∞
Buffer Stream 18-2	0,00	0,00	∞
Stream 18-3	0,00	0,00	∞

Table A.5: Case 2 Summer continued

Streams	MILP Value	Min	Max
Buffer Stream 18-3	0,00	0,00	∞
Stream 18-4	0,00	0,00	∞
Stream 18-5	0,00	0,00	∞
Stream 18-6	0,00	0,00	∞
Stream 18-7	0,00	0,00	∞
Buffer Stream 18-7	0,00	0,00	∞
Stream 18-8	0,00	0,00	∞
Buffer Stream 18-8	0,00	0,00	∞
Switch Plant 18	0,00	0,00	1,00
Additional Feed Plant 19	0,00	0,00	∞
Stream 19-1	5,36	0,00	∞
Buffer Stream 19-1	0,00	0,00	∞
Stream 19-2	0,40	0,00	∞
Buffer Stream 19-2	0,00	0,00	∞
Stream 19-3	33,80	0,00	∞
Buffer Stream 19-3	0,00	0,00	∞
Stream 19-4	40,00	0,00	∞
Stream 19-5	2,39	0,00	∞
Stream 19-6	1,58	0,00	∞
Stream 19-7	0,04	0,00	∞
Buffer Stream 19-7	0,00	0,00	∞
Stream 19-8	0,40	0,00	∞
Buffer Stream 19-8	0,00	0,00	∞
Switch Plant 19	1,00	0,00	1,00
Additional Feed Plant 20	0,00	0,00	∞
Stream 20-1	0,00	0,00	∞
Buffer Stream 20-1	0,00	0,00	∞
Stream 20-2	0,00	0,00	∞
Buffer Stream 20-2	0,00	0,00	∞
Stream 20-3	0,00	0,00	∞
Buffer Stream 20-3	0,00	0,00	∞
Stream 20-4	0,00	0,00	∞
Stream 20-5	0,00	0,00	∞
Stream 20-6	0,00	0,00	∞
Stream 20-7	0,00	0,00	∞

Table A.5: Case 2 Summer continued

Streams	MILP Value	Min	Max
Buffer Stream 20-7	0,00	0,00	∞
Stream 20-8	0,00	0,00	∞
Buffer Stream 20-8	0,00	0,00	∞
Switch Plant 20	0,00	0,00	1,00
Additional Feed Plant 21	0,00	0,00	∞
Stream 21-1	0,69	0,00	3,34
Buffer Stream 21-1	0,00	0,00	∞
Stream 21-2	69,21	50,00	187,00
Stream 21-3	1,45	0,01	7,50
Buffer Stream 21-3	0,00	0,00	∞
Stream 21-4	0,37	0,01	9,00
Buffer Stream 21-4	0,00	0,00	∞
Stream 21-5	18,08	12,16	79,92
Stream 21-5-16	18,08	0,00	∞
Buffer Stream 21-5	0,00	0,00	∞
Stream 21-6	47,93	40,00	125,00
Stream 21-6-16	47,93	0,00	∞
Buffer Stream 21-6	0,00	0,00	∞
Stream 21-7	0,69	0,01	6,00
Buffer Stream 21-7	0,00	0,00	∞
Stream P2H2-1	23,33	0,00	∞
Stream P2H2-2	2,59	0,00	∞
Stream P2H2-3	20,74	0,00	∞
Switch P2H2	1,00	0,00	1,00
Additional Feed Plant 22	0,00	0,00	∞
Stream 22-1	0,00	0,00	0,00
Stream 22-2	0,00	0,00	0,00
Buffer Stream 22-2	0,00	0,00	∞
Stream 22-3	0,00	0,00	0,00
Buffer Stream 22-3	0,00	0,00	∞
Stream 22-4	0,00	0,00	0,00
Stream 22-5	0,00	0,00	0,00
Stream 22-6	0,00	0,00	0,00
Stream 22-7	0,00	0,00	0,00
Stream 22-8	0,00	0,00	0,00

Table A.5: Case 2 Summer continued

Streams	MILP Value	Min	Max
Buffer Stream 22-8	0,00	0,00	∞
Stream 22-9	0,00	0,00	0,00
Buffer Stream 22-9	0,00	0,00	∞
Additional Feed Plant 23	5,98	0,00	∞
Stream 23-1	3,34	0,79	9,98
Buffer Stream 23-1	0,00	0,00	∞
Stream 23-2	75,00	41,42	79,99
Buffer Stream 23-2	0,00	0,00	∞
Stream 23-3	81,22	46,31	84,97
Stream 23-4	2,80	1,00	5,00
Buffer Stream 23-4	0,00	0,00	∞
Stream 23-5	0,08	0,01	1,00
Buffer Stream 23-5	0,00	0,00	∞
Stream 23-6	1,47	0,45	2,17
Stream 23-7	1,97	1,29	2,60
Stream 24-1	192,53	127,13	285,36
Buffer Stream 24-1	0,00	0,00	∞
Stream 24-2	903,99	812,61	1045,67
Stream 24-3	12,02	8,39	15,24
Stream 24-4	44,13	0,00	93,13
Buffer Stream 24-4	0,00	0,00	∞
Stream 24-5	150,16	110,69	206,53
Buffer Stream 24-5	0,00	0,00	∞
Stream 24-6	239,80	148,22	325,95
Buffer Stream 24-6	0,00	0,00	∞
Stream 24-7	9,13	2,69	17,31
Buffer Stream 24-7	0,00	0,00	∞
Stream 24-8	5,52	0,00	11,92
Stream 24-9	1,67	0,00	8,25
Stream 24-10	16,22	8,40	22,90
Stream 24-11	3,12	2,04	6,37
Buffer Stream 24-11	0,00	0,00	∞
Stream 24-12	237,26	150,61	410,77
Buffer Stream 24-12	0,00	0,00	∞
Stream 24-13	27,86	0,00	38,97

Table A.5: Case 2 Summer continued

Streams	**MILP Value**	**Min**	**Max**
Buffer Stream 24-13	0,00	0,00	∞
Additional Feed Plant 25	1,73	0,00	∞
Stream 25-1	4,44	4,44	10,47
Stream 25-2	2,78	1,59	4,63
Buffer Stream 25-2	0,00	0,00	∞
Stream 25-3	1,66	1,11	6,40
Buffer Stream 25-3	0,00	0,00	∞
Additional Feed Plant 26	0,00	0,00	∞
Stream 26-1	3,94	0,70	3,94
Stream 26-2	0,04	0,01	3,00
Buffer Stream 26-2	0,00	0,00	∞
Stream 26-3	3,90	0,01	4,00
Buffer Stream 26-3	0,00	0,00	∞
Additional Feed Plant 27	3,15	0,00	∞
Stream 27-1	11,63	11,63	33,26
Stream 27-2	5,24	0,01	15,00
Buffer Stream 27-2	0,00	0,00	∞
Stream 27-3	6,39	0,01	20,00
Buffer Stream 27-3	0,00	0,00	∞
stream1	169,62	0,00	∞
stream10	39,99	0,00	∞
stream100	2,80	0,00	∞
stream101	0,00	0,00	∞
stream102	0,00	0,00	∞
stream103	0,00	0,00	∞
stream104	0,08	0,00	∞
stream105	0,00	0,00	∞
stream106	0,00	0,00	∞
stream107	3,34	0,00	∞
stream108	75,00	0,00	∞
stream109	14,43	0,00	∞
stream11	132,51	0,00	∞
stream110	6,90	0,00	∞
stream111	0,22	0,00	∞
stream112	0,24	0,00	∞

Table A.5: Case 2 Summer continued

Streams	MILP Value	Min	Max
stream113	8,99	0,00	∞
stream114	17,03	0,00	∞
stream115	13,82	0,00	∞
stream116	8,40	0,00	∞
stream117	16,43	0,00	∞
stream118	0,00	0,00	∞
stream119	0,00	0,00	∞
stream12	60,02	0,00	∞
stream120	0,00	0,00	∞
stream121	0,00	0,00	∞
stream122	0,00	0,00	∞
stream123	0,00	0,00	∞
stream124	0,00	0,00	∞
stream125	20,31	0,00	∞
stream126	1,97	0,00	∞
stream127	9,69	0,00	∞
stream128	0,00	0,00	∞
stream129	0,20	0,00	∞
stream13	9,13	0,00	∞
stream130	1,46	0,00	∞
stream131	2,71	0,00	∞
stream132	0,00	0,00	∞
stream133	11,59	0,00	∞
stream134	0,00	0,00	∞
stream135	7,27	0,00	∞
stream136	67,54	0,00	∞
stream137	16,89	0,00	∞
stream138	4,11	0,00	∞
stream139	21,79	0,00	∞
stream14	86,87	0,00	∞
stream140	38,65	0,00	∞
stream141	6,89	0,00	∞
stream142	5,57	0,00	∞
stream143	34,60	0,00	∞
stream144	2,97	0,00	∞

Table A.5: Case 2 Summer continued

Streams	MILP Value	Min	Max
stream145	0,00	0,00	∞
stream146	50,06	0,00	∞
stream147	3,99	0,00	∞
stream148	3,67	0,00	∞
stream149	5,19	0,00	∞
stream15	150,39	0,00	∞
stream150	0,00	0,00	∞
stream151	4,44	0,00	∞
stream152	6,39	0,00	∞
stream153	3,94	0,00	∞
stream154	1,30	0,00	∞
stream155	2,78	0,00	∞
stream156	1,66	0,00	∞
stream157	0,04	0,00	∞
stream158	3,90	0,00	∞
stream16	3,12	0,00	∞
stream17	0,00	0,00	∞
stream18	19,06	0,00	∞
stream19	22,72	0,00	∞
stream2	30,18	0,00	∞
stream20	10,05	0,00	∞
stream21	8,92	0,00	∞
stream22	0,00	0,00	∞
stream23	26,20	0,00	∞
stream24	0,00	0,00	∞
stream25	49,04	0,00	∞
stream26	46,29	0,00	∞
stream27	3,84	0,00	∞
stream28	105,93	0,00	∞
stream29	0,40	0,00	∞
stream3	40,00	0,00	∞
stream30	244,07	0,00	∞
stream31	3,77	0,00	∞
stream32	1,91	0,00	∞
stream33	6,96	0,00	∞

Table A.5: Case 2 Summer continued

Streams	MILP Value	Min	Max
stream34	188,07	0,00	∞
stream35	2,30	0,00	∞
stream36	2,10	0,00	∞
stream37	2,33	0,00	∞
stream38	0,40	0,00	∞
stream39	0,04	0,00	∞
stream4	44,13	0,00	∞
stream40	5,36	0,00	∞
stream41	33,80	0,00	∞
stream42	0,00	0,00	∞
stream43	0,40	0,00	∞
stream44	0,00	0,00	∞
stream45	0,00	0,00	∞
stream46	0,00	0,00	∞
stream47	0,00	0,00	∞
stream48	0,00	0,00	∞
stream49	0,00	0,00	∞
stream5	0,00	0,00	∞
stream50	0,00	0,00	∞
stream51	0,00	0,00	∞
stream52	0,00	0,00	∞
stream53	0,00	0,00	∞
stream54	0,00	0,00	∞
stream55	0,00	0,00	∞
stream56	0,00	0,00	∞
stream57	0,00	0,00	∞
stream58	0,00	0,00	∞
stream59	0,00	0,00	∞
stream6	0,00	0,00	∞
stream60	0,00	0,00	∞
stream61	0,00	0,00	∞
stream62	1,80	0,00	∞
stream63	0,00	0,00	∞
stream64	7,11	0,00	∞
stream65	0,00	0,00	∞

Table A.5: Case 2 Summer continued

Streams	MILP Value	Min	Max
stream66	2,10	0,00	∞
stream67	38,39	0,00	∞
stream68	0,00	0,00	∞
stream69	0,00	0,00	∞
stream7	27,86	0,00	∞
stream70	42,85	0,00	∞
stream71	0,00	0,00	∞
stream72	5,63	0,00	∞
stream73	1,50	0,00	∞
stream74	100,42	0,00	∞
stream75	0,00	0,00	∞
stream76	3,67	0,00	∞
stream77	44,80	0,00	∞
stream78	0,00	0,00	∞
stream79	55,39	0,00	∞
stream8	0,00	0,00	∞
stream80	2,43	0,00	∞
stream81	18,87	0,00	∞
stream82	0,69	0,00	∞
stream83	0,69	0,00	∞
stream84	0,37	0,00	∞
stream85	0,00	0,00	∞
stream86	0,00	0,00	∞
stream87	1,45	0,00	∞
stream88	0,00	0,00	∞
stream89	0,00	0,00	∞
stream9	110,16	0,00	∞
stream90	0,00	0,00	∞
stream91	0,00	0,00	∞
stream92	0,00	0,00	∞
stream93	0,00	0,00	∞
stream94	0,00	0,00	∞
stream95	0,00	0,00	∞
stream96	0,00	0,00	∞
stream97	0,00	0,00	∞

Table A.5: Case 2 Summer continued

Streams	MILP Value	Min	Max
stream98	0,00	0,00	∞
stream99	0,00	0,00	∞
Additional Feed Plant 28	0,00	0,00	∞
Stream 28-1	0,00	0,00	0,00
Stream 28-2	0,00	0,00	0,00
Buffer Stream 28-2	0,00	0,00	∞
Stream 28-3	0,00	0,00	0,00
Buffer Stream 28-3	0,00	0,00	∞
Stream 28-4	0,00	0,00	0,00
Stream 28-5	0,00	0,00	0,00
Stream 28-6	0,00	0,00	0,00
Stream 28-7	0,00	0,00	0,00
Stream 28-8	0,00	0,00	0,00
Buffer Stream 28-8	0,00	0,00	∞
Stream 28-9	0,00	0,00	0,00
Buffer Stream 28-9	0,00	0,00	∞
Stream 28-10	0,00	0,00	0,00
Buffer Stream 28-10	0,00	0,00	∞
Additional Feed Plant 29	0,00	0,00	∞
Stream 29-1	16,43	7,43	19,15
Buffer Stream 29-1	0,00	0,00	∞
Stream 29-2	38,65	19,34	42,16
Stream 29-3	8,40	3,06	10,47
Buffer Stream 29-3	0,00	0,00	∞
Stream 29-4	13,82	6,66	16,67
Buffer Stream 29-4	0,00	0,00	∞
Additional Feed Plant 30	0,00	0,00	∞
Stream 30-1	132,51	132,51	242,16
Stream 30-2	18,87	12,44	37,27
Buffer Stream 30-2	0,00	0,00	∞
Stream 30-3	2,43	0,00	22,70
Buffer Stream 30-3	0,00	0,00	∞
Stream 30-4	111,21	102,21	180,00
Buffer Stream 30-4	55,81	0,00	∞

Table A.6: Case 2 Winter

Streams	MILP Value	Min	Max
Additional Feed Plant 1	0,00	0,00	∞
Stream 1-1	33,86	11,00	35,00
Buffer Stream 1-1	0,00	0,00	∞
Additional Feed Plant 2	8,98	0,00	∞
Stream 2-1	54,78	31,87	54,78
Stream 2-2	0,64	0,40	0,77
Stream 2-3	4,23	2,58	7,48
Buffer Stream 2-3	0,00	0,00	∞
Stream 2-4	50,54	27,78	51,30
Buffer Stream 2-4	0,00	0,00	∞
Stream 1-2	23,80	7,60	28,21
Buffer Stream 1-2	1,79	0,00	∞
Stream 1-3	3,33	0,00	9,42
Buffer Stream 1-3	0,00	0,00	∞
Stream 1-4	16,98	5,23	16,98
Buffer Stream 1-4	0,00	0,00	∞
Stream 1-5	65,18	22,86	66,97
Buffer Stream 1-5	0,00	0,00	∞
Stream 1-6	196,73	68,46	201,16
Stream 1-7	4,30	0,10	5,00
Buffer Stream 1-7	0,00	0,00	∞
Stream 1-8	6,10	0,00	8,32
Buffer Stream 1-8	0,00	0,00	∞
Stream 1-9	1,97	0,38	3,59
Stream 1-10	52,65	0,00	149,52
Stream 1-11	38,46	1,35	42,79
Buffer Stream 1-11	0,00	0,00	∞
Stream 1-12	55,16	17,53	68,89
Stream 1-13	0,00	0,00	1,00
Stream 1-14	14,68	0,00	54,99
Stream 1-15	10,24	0,00	91,18
Stream 1-16	4,72	0,00	8,60
Buffer Stream 1-16	0,00	0,00	∞
Stream 3-1	42,31	41,99	64,16
Stream 3-2	21,24	18,50	32,56

Table A.6: Case 2 Winter continued

Streams	MILP Value	Min	Max
Buffer Stream 3-2	0,00	0,00	∞
Stream 3-3	21,07	21,07	33,20
Buffer Stream 3-3	0,00	0,00	∞
Additional Feed Plant 4	0,00	0,00	∞
Stream 4-1	12,73	0,14	12,73
Buffer Stream 4-1	0,00	0,00	∞
Stream 4-2	12,73	0,14	12,73
Stream 4-3	0,05	0,00	0,07
Stream 4-4	0,41	0,10	0,63
Stream 4-5	0,46	0,10	0,51
Stream 5-1	0,29	0,07	0,33
Buffer Stream 5-1	0,00	0,00	∞
Stream 5-2	0,28	0,00	0,37
Buffer Stream 5-2	0,00	0,00	∞
Additional Feed Plant 5	0,00	0,00	∞
Stream 5-3	6,71	2,08	7,44
Buffer Stream 5-3	0,00	0,00	∞
Stream 5-4	22,01	9,26	22,01
Stream 5-5	0,48	0,00	1,80
Stream 5-6	14,35	7,21	16,01
Stream 5-7	14,73	5,16	16,37
Buffer Stream 5-7	0,00	0,00	∞
Additional Feed Plant 6	3,28	0,00	∞
Stream 6-1	6,76	6,76	15,45
Stream 6-2	6,76	1,42	9,79
Buffer Stream 6-2	0,00	0,00	∞
Additional Feed Plant 7	0,00	0,00	∞
Stream 7-1	4,96	3,16	13,80
Stream 7-2	4,96	4,87	14,95
Buffer Stream 7-2	0,00	0,00	∞
EL Plant 1	4,85	0,67	6,18
EL Plant 5	1,76	0,00	2,01
EL Plant 7	1,30	0,33	2,04
EL Plant 9	8,36	8,20	11,09
EL Plant 10	0,81	0,00	0,98

Table A.6: Case 2 Winter continued

Streams	MILP Value	Min	Max
EL Plant 11	0,95	0,00	1,20
EL OCM	105,00	0,00	∞
EL Plant 12	1,42	0,88	47,79
EL Plant 13	2,91	2,15	4,15
EL Plant 14	1,10	0,79	1,82
EL Plant 15	0,85	0,76	2,52
EL Plant 16	0,00	0,00	0,00
EL Plant 18	2,05	0,00	∞
EL Plant 19	0,00	0,00	∞
EL Plant 20	0,00	0,00	∞
EL Plant 21	0,66	0,56	0,76
EL P2H2	105,00	0,00	∞
EL Plant 22	0,00	0,00	0,00
EL Plant 23	0,30	0,00	0,40
EL Plant 24	4,93	4,58	5,39
EL Plant 26	0,80	0,62	1,03
EL Plant 28	0,00	0,00	0,00
EL Plant 29	0,18	0,11	0,24
Additional Feed Plant 8	0,00	0,00	∞
Stream 8-1	9,09	1,45	19,41
Buffer Stream 8-1	0,00	0,00	∞
Stream 8-2	4,07	0,00	∞
Stream 8-3	27,13	27,13	49,64
Stream 8-4	9,47	8,28	14,54
Stream 8-5	18,04	15,41	28,34
Buffer Stream 8-5	0,00	0,00	∞
Additional Feed Plant 9	0,00	0,00	∞
Stream 9-1	11,93	5,00	23,00
Buffer Stream 9-1	0,00	0,00	∞
Stream 9-2	21,35	10,00	32,00
Buffer Stream 9-2	0,00	0,00	∞
Stream 9-3	91,41	50,00	160,00
Stream 9-4	3,17	0,01	10,00
Buffer Stream 9-4	0,00	0,00	∞
Stream 9-5	11,40	5,69	20,73

Table A.6: Case 2 Winter continued

Streams	MILP Value	Min	Max
Buffer Stream 9-5	0,00	0,00	∞
Stream 9-6	6,99	1,00	22,00
Buffer Stream 9-6	0,00	0,00	∞
Stream 9-7	17,46	7,00	36,00
Buffer Stream 9-7	0,00	0,00	∞
Stream 9-8	0,10	0,00	4,58
Stream 9-9	27,61	1,90	35,00
Stream 9-10	6,18	5,44	17,02
Stream 9-11	0,33	0,01	15,00
Stream 9-12	6,57	2,00	12,00
Buffer Stream 9-12	0,00	0,00	∞
Stream 9-13	12,54	12,00	40,00
Buffer Stream 9-13	0,00	0,00	∞
Additional Feed Plant 10	0,00	0,00	∞
Stream 10-1	66,98	5,05	80,57
Buffer Stream 10-1	0,00	0,00	∞
Stream 10-2	129,60	74,84	139,86
Stream 10-3	1,53	0,85	1,79
Stream 10-4	3,49	0,00	10,16
Stream 10-5	4,33	3,55	5,45
Stream 10-6	7,05	0,64	8,92
Stream 10-7	9,05	1,92	18,94
Buffer Stream 10-7	0,00	0,00	∞
Stream 10-8	53,57	19,60	85,44
Buffer Stream 10-8	0,00	0,00	∞
Additional Feed Plant 11	0,00	0,00	∞
Stream 11-1	110,22	110,22	261,71
Stream 11-2	1,79	0,00	8,12
Stream 11-3	0,79	0,00	4,04
Stream 11-4	0,02	0,00	1,20
Stream 11-5	4,23	0,00	10,14
Stream 11-6	1,10	0,00	3,00
Buffer Stream 11-6	0,00	0,00	∞
Stream 11-7	32,50	22,74	97,50
Buffer Stream 11-7	0,00	0,00	∞

Table A.6: Case 2 Winter continued

Streams	MILP Value	Min	Max
Stream 11-8	76,62	71,44	177,96
Buffer Stream 11-8	0,00	0,00	∞
Stream OCM-1	284,95	0,00	∞
Stream OCM-2	205,00	0,00	∞
Stream OCM-3	29,93	0,00	∞
Stream OCM-4	30,96	0,00	∞
Stream OCM-5	57,40	0,00	∞
Stream OCM-6	458,96	0,00	∞
Stream OCM-7	280,85	0,00	∞
Switch OCM	1,00	0,00	1,00
Additional Feed Plant 12	0,00	0,00	∞
Stream 12-1	119,92	117,14	160,34
Stream 12-2	0,57	0,45	0,89
Stream 12-3	0,33	0,30	2,00
Buffer Stream 12-3	0,00	0,00	∞
Stream 12-4	0,29	0,13	0,82
Stream 12-5	116,14	116,14	157,78
Buffer Stream 12-5	0,00	0,00	∞
Stream 12-6	0,37	0,20	4,86
Stream 12-7	1,00	0,95	1,20
Stream 12-8	3,45	2,01	9,04
Buffer Stream 12-8	0,00	0,00	∞
Stream 12-9	1,43	0,00	3,00
Buffer Stream 12-9	0,00	0,00	∞
Additional Feed Plant 13	0,00	0,00	∞
Stream 13-1	6,02	0,23	10,85
Buffer Stream 13-1	0,00	0,00	∞
Stream 13-2	239,26	157,27	300,83
Stream 13-3	0,68	0,09	2,14
Stream 13-4	228,86	146,55	286,78
Buffer Stream 13-4	0,00	0,00	∞
Stream 13-5	1,94	1,01	7,02
Stream 13-6	3,29	0,07	7,99
Stream 13-7	5,37	3,94	6,90
Stream 13-8	2,95	0,20	4,00

Table A.6: Case 2 Winter continued

Streams	MILP Value	Min	Max
Buffer Stream 13-8	0,00	0,00	∞
Additional Feed Plant 14	0,00	0,00	∞
Stream 14-1	2,18	0,00	10,51
Buffer Stream 14-1	0,00	0,00	∞
Stream 14-2	194,78	136,19	250,00
Stream 14-3	0,53	0,24	0,89
Stream 14-4	1,32	0,20	7,84
Buffer Stream 14-4	0,00	0,00	∞
Stream 14-5	3,40	0,00	7,10
Buffer Stream 14-5	0,00	0,00	∞
Stream 14-6	0,99	0,00	5,30
Stream 14-7	2,52	0,02	4,24
Stream 14-8	3,23	0,00	7,80
Stream 14-9	0,07	0,00	3,36
Stream 14-10	0,08	0,00	3,09
Stream 14-11	5,03	0,00	11,43
Stream 15-1	10,98	10,07	30,60
Buffer Stream 15-1	0,00	0,00	∞
Stream 15-2	2,55	1,99	3,59
Stream 15-3	41,47	26,40	79,72
Buffer Stream 15-3	0,00	0,00	∞
Stream 15-4	19,33	8,81	48,68
Buffer Stream 15-4	0,00	0,00	∞
Stream 15-5	9,81	7,69	10,58
Additional Feed Plant 15-1	0,00	0,00	∞
Stream 15-6	208,94	175,27	271,31
Stream 15-7	1,62	1,45	2,23
Stream 15-8	136,03	125,83	188,75
Buffer Stream 15-8	55,23	0,00	∞
Stream 15-9	10,61	9,37	15,75
Buffer Stream 15-9	0,00	0,00	∞
Additional Feed Plant 15-2	0,00	0,00	∞
Stream 15-10	9,47	4,03	31,60
Stream 15-11	187,88	122,86	238,40
Buffer Stream 15-11	0,00	0,00	∞

Table A.6: Case 2 Winter continued

Streams	**MILP Value**	**Min**	**Max**
Additional Feed Plant 16	0,00	0,00	∞
Stream 16-1	0,00	0,00	0,00
Stream 16-2	0,00	0,00	0,00
Stream 16-3	0,00	0,00	0,00
Stream 16-4	0,00	0,00	0,00
Buffer Stream 16-4	0,00	0,00	∞
Buffer Stream 16-3	0,00	0,00	∞
Stream 16-5	0,00	0,00	0,00
Buffer Stream 16-5	0,00	0,00	∞
Stream 16-6	0,00	0,00	0,00
Buffer Stream 16-6	0,00	0,00	∞
Stream 16-7	0,00	0,00	0,00
Stream 16-8	0,00	0,00	0,00
Stream 16-9	0,00	0,00	0,00
Stream 16-10	0,00	0,00	0,00
Buffer Stream 16-10	0,00	0,00	∞
Stream 16-11	0,00	0,00	0,00
Buffer Stream 16-11	0,00	0,00	∞
Stream 16-12	0,00	0,00	0,00
Buffer Stream 16-12	0,00	0,00	∞
Stream 16-13	2,33	1,51	3,71
Buffer Stream 16-13	0,00	0,00	∞
Additional Feed Plant 17	0,00	0,00	∞
Stream 17-1	11,18	6,51	28,03
Buffer Stream 17-1	0,00	0,00	∞
Stream 17-2	17,07	10,25	34,33
Stream 17-3	3,56	0,28	6,56
Buffer Stream 17-3	0,00	0,00	∞
Stream 17-4	2,10	0,00	3,60
Additional Feed Plant 18	0,00	0,00	∞
Stream 18-1	11,03	0,00	∞
Buffer Stream 18-1	0,00	0,00	∞
Stream 18-2	0,53	0,00	∞
Buffer Stream 18-2	0,00	0,00	∞
Stream 18-3	40,67	0,00	∞

Table A.6: Case 2 Winter continued

Streams	MILP Value	Min	Max
Buffer Stream 18-3	0,00	0,00	∞
Stream 18-4	53,30	0,00	∞
Stream 18-5	2,64	0,00	∞
Stream 18-6	1,49	0,00	∞
Stream 18-7	0,53	0,00	∞
Buffer Stream 18-7	0,00	0,00	∞
Stream 18-8	0,53	0,00	∞
Buffer Stream 18-8	0,00	0,00	∞
Switch Plant 18	1,00	0,00	1,00
Additional Feed Plant 19	0,00	0,00	∞
Stream 19-1	0,00	0,00	∞
Buffer Stream 19-1	0,00	0,00	∞
Stream 19-2	0,00	0,00	∞
Buffer Stream 19-2	0,00	0,00	∞
Stream 19-3	0,00	0,00	∞
Buffer Stream 19-3	0,00	0,00	∞
Stream 19-4	0,00	0,00	∞
Stream 19-5	0,00	0,00	∞
Stream 19-6	0,00	0,00	∞
Stream 19-7	0,00	0,00	∞
Buffer Stream 19-7	0,00	0,00	∞
Stream 19-8	0,00	0,00	∞
Buffer Stream 19-8	0,00	0,00	∞
Switch Plant 19	0,00	0,00	1,00
Additional Feed Plant 20	0,00	0,00	∞
Stream 20-1	0,00	0,00	∞
Buffer Stream 20-1	0,00	0,00	∞
Stream 20-2	0,00	0,00	∞
Buffer Stream 20-2	0,00	0,00	∞
Stream 20-3	0,00	0,00	∞
Buffer Stream 20-3	0,00	0,00	∞
Stream 20-4	0,00	0,00	∞
Stream 20-5	0,00	0,00	∞
Stream 20-6	0,00	0,00	∞
Stream 20-7	0,00	0,00	∞

Table A.6: Case 2 Winter continued

Streams	MILP Value	Min	Max
Buffer Stream 20-7	0,00	0,00	∞
Stream 20-8	0,00	0,00	∞
Buffer Stream 20-8	0,00	0,00	∞
Switch Plant 20	0,00	0,00	1,00
Additional Feed Plant 21	0,00	0,00	∞
Stream 21-1	0,69	0,00	3,65
Buffer Stream 21-1	0,00	0,00	∞
Stream 21-2	69,45	50,00	187,00
Stream 21-3	1,78	0,01	7,50
Buffer Stream 21-3	0,00	0,00	∞
Stream 21-4	0,60	0,01	9,00
Buffer Stream 21-4	0,00	0,00	∞
Stream 21-5	15,14	13,56	79,37
Stream 21-5-16	15,14	0,00	∞
Buffer Stream 21-5	0,00	0,00	∞
Stream 21-6	50,77	40,00	125,00
Stream 21-6-16	50,77	0,00	∞
Buffer Stream 21-6	0,00	0,00	∞
Stream 21-7	0,46	0,01	6,00
Buffer Stream 21-7	0,00	0,00	∞
Stream P2H2-1	23,33	0,00	∞
Stream P2H2-2	2,59	0,00	∞
Stream P2H2-3	20,74	0,00	∞
Switch P2H2	1,00	0,00	1,00
Additional Feed Plant 22	0,00	0,00	∞
Stream 22-1	0,00	0,00	0,00
Stream 22-2	0,00	0,00	0,00
Buffer Stream 22-2	0,00	0,00	∞
Stream 22-3	0,00	0,00	0,00
Buffer Stream 22-3	0,00	0,00	∞
Stream 22-4	0,00	0,00	0,00
Stream 22-5	0,00	0,00	0,00
Stream 22-6	0,00	0,00	0,00
Stream 22-7	0,00	0,00	0,00
Stream 22-8	0,00	0,00	0,00

Table A.6: Case 2 Winter continued

Streams	MILP Value	Min	Max
Buffer Stream 22-8	0,00	0,00	∞
Stream 22-9	0,00	0,00	0,00
Buffer Stream 22-9	0,00	0,00	∞
Additional Feed Plant 23	20,68	0,00	∞
Stream 23-1	3,86	0,92	11,92
Buffer Stream 23-1	0,00	0,00	∞
Stream 23-2	75,00	36,62	81,02
Buffer Stream 23-2	0,00	0,00	∞
Stream 23-3	81,48	45,97	83,83
Stream 23-4	2,61	1,00	5,00
Buffer Stream 23-4	0,00	0,00	∞
Stream 23-5	0,00	0,00	1,00
Buffer Stream 23-5	0,00	0,00	∞
Stream 23-6	1,41	0,16	2,12
Stream 23-7	1,94	0,95	2,70
Stream 24-1	186,26	123,46	269,58
Buffer Stream 24-1	0,00	0,00	∞
Stream 24-2	890,48	812,33	1051,74
Stream 24-3	13,28	9,92	15,96
Stream 24-4	53,65	28,68	90,56
Buffer Stream 24-4	0,00	0,00	∞
Stream 24-5	143,91	105,64	187,87
Buffer Stream 24-5	0,00	0,00	∞
Stream 24-6	226,46	139,27	297,69
Buffer Stream 24-6	0,00	0,00	∞
Stream 24-7	9,49	0,72	18,28
Buffer Stream 24-7	0,00	0,00	∞
Stream 24-8	2,20	0,00	10,03
Stream 24-9	2,03	0,00	8,01
Stream 24-10	16,28	12,98	23,87
Stream 24-11	3,74	2,04	6,48
Buffer Stream 24-11	0,00	0,00	∞
Stream 24-12	239,82	156,70	352,56
Buffer Stream 24-12	0,00	0,00	∞
Stream 24-13	27,14	19,49	39,08

Table A.6: Case 2 Winter continued

Streams	MILP Value	Min	Max
Buffer Stream 24-13	0,00	0,00	∞
Additional Feed Plant 25	0,00	0,00	∞
Stream 25-1	6,57	5,26	9,18
Stream 25-2	3,48	2,38	5,26
Buffer Stream 25-2	0,00	0,00	∞
Stream 25-3	3,09	2,01	4,90
Buffer Stream 25-3	0,00	0,00	∞
Additional Feed Plant 26	0,00	0,00	∞
Stream 26-1	3,73	0,50	3,73
Stream 26-2	0,04	0,00	3,00
Buffer Stream 26-2	0,00	0,00	∞
Stream 26-3	3,69	0,01	4,00
Buffer Stream 26-3	0,00	0,00	∞
Additional Feed Plant 27	0,00	0,00	∞
Stream 27-1	9,67	9,67	24,66
Stream 27-2	4,22	0,01	11,00
Buffer Stream 27-2	0,00	0,00	∞
Stream 27-3	5,44	0,01	15,00
Buffer Stream 27-3	0,00	0,00	∞
stream1	202,43	0,00	∞
stream10	23,98	0,00	∞
stream100	2,61	0,00	∞
stream101	0,00	0,00	∞
stream102	0,00	0,00	∞
stream103	0,00	0,00	∞
stream104	0,00	0,00	∞
stream105	0,00	0,00	∞
stream106	0,00	0,00	∞
stream107	3,86	0,00	∞
stream108	75,00	0,00	∞
stream109	14,73	0,00	∞
stream11	121,87	0,00	∞
stream110	6,71	0,00	∞
stream111	0,29	0,00	∞
stream112	0,28	0,00	∞

Table A.6: Case 2 Winter continued

Streams	MILP Value	Min	Max
stream113	9,09	0,00	∞
stream114	18,04	0,00	∞
stream115	13,52	0,00	∞
stream116	7,99	0,00	∞
stream117	16,95	0,00	∞
stream118	0,00	0,00	∞
stream119	0,00	0,00	∞
stream12	64,40	0,00	∞
stream120	0,00	0,00	∞
stream121	0,00	0,00	∞
stream122	0,00	0,00	∞
stream123	0,00	0,00	∞
stream124	0,00	0,00	∞
stream125	12,54	0,00	∞
stream126	6,99	0,00	∞
stream127	17,46	0,00	∞
stream128	0,00	0,00	∞
stream129	3,17	0,00	∞
stream13	9,49	0,00	∞
stream130	11,40	0,00	∞
stream131	6,57	0,00	∞
stream132	0,00	0,00	∞
stream133	12,40	0,00	∞
stream134	8,95	0,00	∞
stream135	11,93	0,00	∞
stream136	65,18	0,00	∞
stream137	16,98	0,00	∞
stream138	4,30	0,00	∞
stream139	22,01	0,00	∞
stream14	129,60	0,00	∞
stream140	38,46	0,00	∞
stream141	6,10	0,00	∞
stream142	4,72	0,00	∞
stream143	33,86	0,00	∞
stream144	3,33	0,00	∞

Table A.6: Case 2 Winter continued

Streams	MILP Value	Min	Max
stream145	0,00	0,00	∞
stream146	50,54	0,00	∞
stream147	4,23	0,00	∞
stream148	12,73	0,00	∞
stream149	6,76	0,00	∞
stream15	110,22	0,00	∞
stream150	0,00	0,00	∞
stream151	4,96	0,00	∞
stream152	5,44	0,00	∞
stream153	3,73	0,00	∞
stream154	0,50	0,00	∞
stream155	3,48	0,00	∞
stream156	3,09	0,00	∞
stream157	0,04	0,00	∞
stream158	3,69	0,00	∞
stream16	3,74	0,00	∞
stream17	0,00	0,00	∞
stream18	21,24	0,00	∞
stream19	21,07	0,00	∞
stream2	24,03	0,00	∞
stream20	10,98	0,00	∞
stream21	10,61	0,00	∞
stream22	0,00	0,00	∞
stream23	19,33	0,00	∞
stream24	0,00	0,00	∞
stream25	41,47	0,00	∞
stream26	80,80	0,00	∞
stream27	3,45	0,00	∞
stream28	116,14	0,00	∞
stream29	0,33	0,00	∞
stream3	0,00	0,00	∞
stream30	228,86	0,00	∞
stream31	2,95	0,00	∞
stream32	1,43	0,00	∞
stream33	6,02	0,00	∞

Table A.6: Case 2 Winter continued

Streams	MILP Value	Min	Max
stream34	187,88	0,00	∞
stream35	2,18	0,00	∞
stream36	1,32	0,00	∞
stream37	3,40	0,00	∞
stream38	0,00	0,00	∞
stream39	0,00	0,00	∞
stream4	0,35	0,00	∞
stream40	0,00	0,00	∞
stream41	0,00	0,00	∞
stream42	0,00	0,00	∞
stream43	0,00	0,00	∞
stream44	0,00	0,00	∞
stream45	0,00	0,00	∞
stream46	0,53	0,00	∞
stream47	0,53	0,00	∞
stream48	11,03	0,00	∞
stream49	40,67	0,00	∞
stream5	0,00	0,00	∞
stream50	0,24	0,00	∞
stream51	0,29	0,00	∞
stream52	0,00	0,00	∞
stream53	0,00	0,00	∞
stream54	0,00	0,00	∞
stream55	0,00	0,00	∞
stream56	0,00	0,00	∞
stream57	0,00	0,00	∞
stream58	0,00	0,00	∞
stream59	0,00	0,00	∞
stream6	53,30	0,00	∞
stream60	0,00	0,00	∞
stream61	0,00	0,00	∞
stream62	2,33	0,00	∞
stream63	0,00	0,00	∞
stream64	1,89	0,00	∞
stream65	9,29	0,00	∞

Table A.6: Case 2 Winter continued

Streams	MILP Value	Min	Max
stream66	3,56	0,00	∞
stream67	66,98	0,00	∞
stream68	0,00	0,00	∞
stream69	0,00	0,00	∞
stream7	27,14	0,00	∞
stream70	53,57	0,00	∞
stream71	0,00	0,00	∞
stream72	9,05	0,00	∞
stream73	1,10	0,00	∞
stream74	76,62	0,00	∞
stream75	0,00	0,00	∞
stream76	12,73	0,00	∞
stream77	19,77	0,00	∞
stream78	0,00	0,00	∞
stream79	55,94	0,00	∞
stream8	0,00	0,00	∞
stream80	7,39	0,00	∞
stream81	19,60	0,00	∞
stream82	0,69	0,00	∞
stream83	0,46	0,00	∞
stream84	0,60	0,00	∞
stream85	0,00	0,00	∞
stream86	0,00	0,00	∞
stream87	1,78	0,00	∞
stream88	0,00	0,00	∞
stream89	0,00	0,00	∞
stream9	119,92	0,00	∞
stream90	0,00	0,00	∞
stream91	0,00	0,00	∞
stream92	0,00	0,00	∞
stream93	0,00	0,00	∞
stream94	0,00	0,00	∞
stream95	0,00	0,00	∞
stream96	0,00	0,00	∞
stream97	0,00	0,00	∞

Table A.6: Case 2 Winter continued

Streams	MILP Value	Min	Max
stream98	0,00	0,00	∞
stream99	0,00	0,00	∞
Additional Feed Plant 28	0,00	0,00	∞
Stream 28-1	0,00	0,00	0,00
Stream 28-2	0,00	0,00	0,00
Buffer Stream 28-2	0,00	0,00	∞
Stream 28-3	0,00	0,00	0,00
Buffer Stream 28-3	0,00	0,00	∞
Stream 28-4	0,00	0,00	0,00
Stream 28-5	0,00	0,00	0,00
Stream 28-6	0,00	0,00	0,00
Stream 28-7	0,00	0,00	0,00
Stream 28-8	0,00	0,00	0,00
Buffer Stream 28-8	0,00	0,00	∞
Stream 28-9	0,00	0,00	0,00
Buffer Stream 28-9	0,00	0,00	∞
Stream 28-10	0,00	0,00	0,00
Buffer Stream 28-10	0,00	0,00	∞
Additional Feed Plant 29	0,00	0,00	∞
Stream 29-1	16,95	7,66	19,90
Buffer Stream 29-1	0,00	0,00	∞
Stream 29-2	38,46	18,66	44,43
Stream 29-3	7,99	4,21	9,79
Buffer Stream 29-3	0,00	0,00	∞
Stream 29-4	13,52	5,09	15,60
Buffer Stream 29-4	0,00	0,00	∞
Additional Feed Plant 30	0,00	0,00	∞
Stream 30-1	121,87	121,87	236,86
Stream 30-2	19,60	15,01	41,76
Buffer Stream 30-2	0,00	0,00	∞
Stream 30-3	7,39	0,00	26,76
Buffer Stream 30-3	0,00	0,00	∞
Stream 30-4	94,88	81,12	179,30
Buffer Stream 30-4	38,95	0,00	∞

Table A.7: Case 3 Summer

Streams	MILP Value	Min	Max
Additional Feed Plant 1	0,00	0,00	∞
Stream 1-1	24,17	11,00	35,00
Buffer Stream 1-1	0,00	0,00	∞
Additional Feed Plant 2	45,47	0,00	∞
Stream 2-1	89,35	31,00	100,00
Stream 2-2	0,25	0,10	5,00
Stream 2-3	4,35	1,50	20,00
Buffer Stream 2-3	0,00	0,00	∞
Stream 2-4	85,00	25,00	85,00
Buffer Stream 2-4	0,00	0,00	∞
Stream 1-2	17,71	7,78	29,16
Buffer Stream 1-2	0,00	0,00	∞
Stream 1-3	1,23	0,00	9,56
Buffer Stream 1-3	0,00	0,00	∞
Stream 1-4	11,37	5,29	16,89
Buffer Stream 1-4	0,00	0,00	∞
Stream 1-5	47,60	20,89	67,86
Buffer Stream 1-5	0,00	0,00	∞
Stream 1-6	138,65	63,89	203,02
Stream 1-7	2,84	0,10	5,00
Buffer Stream 1-7	0,00	0,00	∞
Stream 1-8	3,28	0,00	7,36
Buffer Stream 1-8	0,00	0,00	∞
Stream 1-9	1,80	0,48	4,09
Stream 1-10	62,36	7,67	126,13
Stream 1-11	26,61	5,45	41,02
Buffer Stream 1-11	0,00	0,00	∞
Stream 1-12	53,29	0,31	73,58
Stream 1-13	0,04	0,00	2,65
Stream 1-14	5,15	0,00	62,27
Stream 1-15	24,02	0,00	89,32
Stream 1-16	3,84	0,00	9,75
Buffer Stream 1-16	0,00	0,00	∞
Stream 3-1	41,78	39,33	70,19
Stream 3-2	19,06	19,06	39,92

Table A.7: Case 3 Summer continued

Streams	MILP Value	Min	Max
Buffer Stream 3-2	0,00	0,00	∞
Stream 3-3	22,72	19,53	33,78
Buffer Stream 3-3	0,00	0,00	∞
Additional Feed Plant 4	0,00	0,00	∞
Stream 4-1	9,85	3,67	9,85
Buffer Stream 4-1	0,00	0,00	∞
Stream 4-2	9,85	3,67	9,85
Stream 4-3	0,06	0,02	0,08
Stream 4-4	0,43	0,28	0,54
Stream 4-5	0,36	0,26	0,44
Stream 5-1	0,18	0,06	0,38
Buffer Stream 5-1	0,00	0,00	∞
Stream 5-2	0,20	0,10	0,39
Buffer Stream 5-2	0,00	0,00	∞
Additional Feed Plant 5	0,00	0,00	∞
Stream 5-3	5,92	2,65	8,36
Buffer Stream 5-3	0,00	0,00	∞
Stream 5-4	17,71	9,13	21,79
Stream 5-5	0,68	0,00	1,80
Stream 5-6	12,72	7,51	15,32
Stream 5-7	11,42	5,85	16,37
Buffer Stream 5-7	0,00	0,00	∞
Additional Feed Plant 6	1,97	0,00	∞
Stream 6-1	5,19	5,19	15,57
Stream 6-2	5,19	1,00	16,00
Buffer Stream 6-2	0,00	0,00	∞
Additional Feed Plant 7	0,00	0,00	∞
Stream 7-1	5,20	3,17	15,65
Stream 7-2	5,20	4,14	14,98
Buffer Stream 7-2	0,00	0,00	∞
EL Plant 1	4,59	2,62	6,09
EL Plant 5	1,66	0,75	1,90
EL Plant 7	1,49	1,04	1,75
EL Plant 9	7,89	0,50	9,90
EL Plant 10	0,69	0,61	0,81

Table A.7: Case 3 Summer continued

Streams	MILP Value	Min	Max
EL Plant 11	0,95	0,62	1,06
EL OCM	40,98	0,00	∞
EL Plant 12	1,29	1,00	1,62
EL Plant 13	3,01	2,15	3,71
EL Plant 14	1,21	0,58	1,69
EL Plant 15	0,80	0,80	2,53
EL Plant 16	0,00	0,00	0,00
EL Plant 18	0,00	0,00	∞
EL Plant 19	2,08	0,00	∞
EL Plant 20	0,00	0,00	∞
EL Plant 21	0,58	0,28	0,94
EL P2H2	40,98	0,00	∞
EL Plant 22	0,00	0,00	0,00
EL Plant 23	0,31	0,14	0,35
EL Plant 24	4,72	4,72	420,04
EL Plant 26	0,80	0,00	0,90
EL Plant 28	0,00	0,00	0,00
EL Plant 29	0,17	0,11	0,24
Additional Feed Plant 8	0,00	0,00	∞
Stream 8-1	8,00	8,00	25,00
Buffer Stream 8-1	0,00	0,00	∞
Stream 8-2	3,59	0,00	∞
Stream 8-3	23,93	15,00	55,00
Stream 8-4	7,14	6,00	14,00
Stream 8-5	15,93	10,00	30,00
Buffer Stream 8-5	0,00	0,00	∞
Additional Feed Plant 9	0,00	0,00	∞
Stream 9-1	19,70	5,00	23,00
Buffer Stream 9-1	0,00	0,00	∞
Stream 9-2	27,02	10,00	32,00
Buffer Stream 9-2	0,00	0,00	∞
Stream 9-3	139,70	50,00	161,00
Stream 9-4	6,12	0,01	10,00
Buffer Stream 9-4	0,00	0,00	∞
Stream 9-5	11,35	0,00	18,90

Table A.7: Case 3 Summer continued

Streams	**MILP Value**	**Min**	**Max**
Buffer Stream 9-5	0,00	0,00	∞
Stream 9-6	14,34	1,00	24,00
Buffer Stream 9-6	0,00	0,00	∞
Stream 9-7	23,77	7,00	35,00
Stream 9-7-1	16,94	0,00	∞
Buffer Stream 9-7	0,00	0,00	∞
Stream 9-8	0,41	0,00	4,73
Stream 9-9	13,67	1,90	25,00
Stream 9-10	9,50	0,43	18,72
Stream 9-11	1,76	0,01	15,00
Stream 9-12	9,16	2,00	12,00
Buffer Stream 9-12	0,00	0,00	∞
Stream 9-13	28,24	12,00	40,00
Stream 9-13-1	14,57	0,00	∞
Buffer Stream 9-13	0,00	0,00	∞
Additional Feed Plant 10	0,00	0,00	∞
Stream 10-1	38,39	19,40	89,64
Buffer Stream 10-1	0,00	0,00	∞
Stream 10-2	86,87	82,77	157,30
Stream 10-3	1,08	0,75	1,93
Stream 10-4	2,40	0,00	10,16
Stream 10-5	4,74	4,26	5,00
Stream 10-6	4,34	0,11	9,10
Stream 10-7	5,63	2,01	18,95
Buffer Stream 10-7	0,00	0,00	∞
Stream 10-8	42,85	22,26	105,95
Buffer Stream 10-8	0,00	0,00	∞
Additional Feed Plant 11	0,00	0,00	∞
Stream 11-1	150,39	115,63	235,89
Stream 11-2	1,36	0,00	8,12
Stream 11-3	1,23	0,00	4,06
Stream 11-4	0,00	0,00	0,75
Stream 11-5	6,30	0,00	23,06
Stream 11-6	1,50	0,00	2,50
Buffer Stream 11-6	0,00	0,00	∞

Table A.7: Case 3 Summer continued

Streams	MILP Value	Min	Max
Stream 11-7	48,47	29,65	89,35
Buffer Stream 11-7	0,00	0,00	∞
Stream 11-8	100,42	79,11	173,34
Buffer Stream 11-8	0,00	0,00	∞
Stream OCM-1	111,20	0,00	∞
Stream OCM-2	80,00	0,00	∞
Stream OCM-3	11,68	0,00	∞
Stream OCM-4	12,08	0,00	∞
Stream OCM-5	22,40	0,00	∞
Stream OCM-6	179,10	0,00	∞
Stream OCM-7	109,60	0,00	∞
Switch OCM	1,00	0,00	1,00
Additional Feed Plant 12	0,00	0,00	∞
Stream 12-1	110,16	106,89	159,68
Stream 12-2	0,52	0,43	0,87
Stream 12-3	0,40	0,40	2,00
Buffer Stream 12-3	0,00	0,00	∞
Stream 12-4	0,32	0,12	1,46
Stream 12-5	105,93	105,39	157,00
Buffer Stream 12-5	0,00	0,00	∞
Stream 12-6	0,27	0,14	0,37
Stream 12-7	1,05	0,96	1,24
Stream 12-8	3,84	2,10	10,74
Buffer Stream 12-8	0,00	0,00	∞
Stream 12-9	1,91	0,00	3,00
Buffer Stream 12-9	0,00	0,00	∞
Additional Feed Plant 13	0,00	0,00	∞
Stream 13-1	6,96	0,28	11,01
Buffer Stream 13-1	2,23	0,00	∞
Stream 13-2	256,71	130,33	300,10
Stream 13-3	0,56	0,15	1,57
Stream 13-4	244,07	122,21	286,36
Buffer Stream 13-4	0,00	0,00	∞
Stream 13-5	2,00	0,89	8,13
Stream 13-6	3,42	0,00	7,14

Table A.7: Case 3 Summer continued

Streams	**MILP Value**	**Min**	**Max**
Stream 13-7	5,63	4,03	6,91
Stream 13-8	3,77	0,70	5,00
Buffer Stream 13-8	0,00	0,00	∞
Additional Feed Plant 14	0,00	0,00	∞
Stream 14-1	2,67	0,00	7,43
Buffer Stream 14-1	0,00	0,00	∞
Stream 14-2	206,74	137,65	251,76
Stream 14-3	0,50	0,22	1,03
Stream 14-4	2,36	0,06	7,79
Buffer Stream 14-4	0,00	0,00	∞
Stream 14-5	2,84	0,00	7,37
Buffer Stream 14-5	0,00	0,00	∞
Stream 14-6	1,40	0,00	5,36
Stream 14-7	2,44	0,00	4,50
Stream 14-8	3,30	0,00	5,53
Stream 14-9	0,01	0,00	3,13
Stream 14-10	0,18	0,00	3,70
Stream 14-11	3,83	0,00	9,79
Stream 15-1	8,67	8,23	35,40
Buffer Stream 15-1	0,00	0,00	∞
Stream 15-2	2,78	2,17	4,22
Stream 15-3	49,66	33,09	85,45
Buffer Stream 15-3	0,00	0,00	∞
Stream 15-4	26,20	13,29	46,76
Buffer Stream 15-4	0,00	0,00	∞
Stream 15-5	9,46	7,10	10,61
Additional Feed Plant 15-1	0,00	0,00	∞
Stream 15-6	215,67	171,22	281,17
Stream 15-7	1,90	1,40	2,21
Stream 15-8	130,59	89,95	196,60
Buffer Stream 15-8	0,00	0,00	∞
Stream 15-9	9,11	7,88	15,30
Buffer Stream 15-9	0,00	0,00	∞
Additional Feed Plant 15-2	0,00	0,00	∞
Stream 15-10	8,57	2,57	31,33

Table A.7: Case 3 Summer continued

Streams	MILP Value	Min	Max
Stream 15-11	198,88	134,65	245,05
Buffer Stream 15-11	5,93	0,00	∞
Additional Feed Plant 16	0,00	0,00	∞
Stream 16-1	0,00	0,00	0,00
Stream 16-2	0,00	0,00	0,00
Stream 16-3	0,00	0,00	0,00
Stream 16-4	0,00	0,00	0,00
Buffer Stream 16-4	0,00	0,00	∞
Buffer Stream 16-3	0,00	0,00	∞
Stream 16-5	0,00	0,00	0,00
Buffer Stream 16-5	0,00	0,00	∞
Stream 16-6	0,00	0,00	0,00
Buffer Stream 16-6	0,00	0,00	∞
Stream 16-7	0,00	0,00	0,00
Stream 16-8	0,00	0,00	0,00
Stream 16-9	0,00	0,00	0,00
Stream 16-10	0,00	0,00	0,00
Buffer Stream 16-10	0,00	0,00	∞
Stream 16-11	0,00	0,00	0,00
Buffer Stream 16-11	0,00	0,00	∞
Stream 16-12	0,00	0,00	0,00
Buffer Stream 16-12	0,00	0,00	∞
Stream 16-13	1,82	0,98	3,00
Buffer Stream 16-13	0,00	0,00	∞
Additional Feed Plant 17	0,00	0,00	∞
Stream 17-1	7,41	4,80	27,03
Buffer Stream 17-1	0,00	0,00	∞
Stream 17-2	11,38	9,45	34,41
Stream 17-3	2,15	0,56	7,33
Buffer Stream 17-3	0,00	0,00	∞
Stream 17-4	1,08	0,00	3,82
Additional Feed Plant 18	0,00	0,00	∞
Stream 18-1	0,00	0,00	∞
Buffer Stream 18-1	0,00	0,00	∞
Stream 18-2	0,00	0,00	∞

Table A.7: Case 3 Summer continued

Streams	MILP Value	Min	Max
Buffer Stream 18-2	0,00	0,00	∞
Stream 18-3	0,00	0,00	∞
Buffer Stream 18-3	0,00	0,00	∞
Stream 18-4	0,00	0,00	∞
Stream 18-5	0,00	0,00	∞
Stream 18-6	0,00	0,00	∞
Stream 18-7	0,00	0,00	∞
Buffer Stream 18-7	0,00	0,00	∞
Stream 18-8	0,00	0,00	∞
Buffer Stream 18-8	0,00	0,00	∞
Switch Plant 18	0,00	0,00	1,00
Additional Feed Plant 19	0,00	0,00	∞
Stream 19-1	5,36	0,00	∞
Buffer Stream 19-1	0,00	0,00	∞
Stream 19-2	0,40	0,00	∞
Buffer Stream 19-2	0,00	0,00	∞
Stream 19-3	33,80	0,00	∞
Buffer Stream 19-3	0,00	0,00	∞
Stream 19-4	40,00	0,00	∞
Stream 19-5	2,39	0,00	∞
Stream 19-6	1,58	0,00	∞
Stream 19-7	0,04	0,00	∞
Buffer Stream 19-7	0,00	0,00	∞
Stream 19-8	0,40	0,00	∞
Buffer Stream 19-8	0,00	0,00	∞
Switch Plant 19	1,00	0,00	1,00
Additional Feed Plant 20	0,00	0,00	∞
Stream 20-1	0,00	0,00	∞
Buffer Stream 20-1	0,00	0,00	∞
Stream 20-2	0,00	0,00	∞
Buffer Stream 20-2	0,00	0,00	∞
Stream 20-3	0,00	0,00	∞
Buffer Stream 20-3	0,00	0,00	∞
Stream 20-4	0,00	0,00	∞
Stream 20-5	0,00	0,00	∞

Table A.7: Case 3 Summer continued

Streams	MILP Value	Min	Max
Stream 20-6	0,00	0,00	∞
Stream 20-7	0,00	0,00	∞
Buffer Stream 20-7	0,00	0,00	∞
Stream 20-8	0,00	0,00	∞
Buffer Stream 20-8	0,00	0,00	∞
Switch Plant 20	0,00	0,00	1,00
Additional Feed Plant 21	0,00	0,00	∞
Stream 21-1	0,70	0,00	3,34
Buffer Stream 21-1	0,00	0,00	∞
Stream 21-2	70,25	50,00	187,00
Stream 21-3	1,47	0,01	7,50
Buffer Stream 21-3	0,00	0,00	∞
Stream 21-4	0,37	0,01	9,00
Buffer Stream 21-4	0,00	0,00	∞
Stream 21-5	18,42	12,16	79,92
Stream 21-5-16	18,42	0,00	∞
Buffer Stream 21-5	0,00	0,00	∞
Stream 21-6	48,58	40,00	125,00
Stream 21-6-16	48,58	0,00	∞
Buffer Stream 21-6	0,00	0,00	∞
Stream 21-7	0,70	0,01	6,00
Buffer Stream 21-7	0,00	0,00	∞
Stream P2H2-1	9,11	0,00	∞
Stream P2H2-2	1,01	0,00	∞
Stream P2H2-3	8,10	0,00	∞
Switch P2H2	1,00	0,00	1,00
Additional Feed Plant 22	0,00	0,00	∞
Stream 22-1	0,00	0,00	0,00
Stream 22-2	0,00	0,00	0,00
Buffer Stream 22-2	0,00	0,00	∞
Stream 22-3	0,00	0,00	0,00
Buffer Stream 22-3	0,00	0,00	∞
Stream 22-4	0,00	0,00	0,00
Stream 22-5	0,00	0,00	0,00
Stream 22-6	0,00	0,00	0,00

Table A.7: Case 3 Summer continued

Streams	MILP Value	Min	Max
Stream 22-7	0,00	0,00	0,00
Stream 22-8	0,00	0,00	0,00
Buffer Stream 22-8	0,00	0,00	∞
Stream 22-9	0,00	0,00	0,00
Buffer Stream 22-9	0,00	0,00	∞
Additional Feed Plant 23	5,35	0,00	∞
Stream 23-1	3,34	0,79	9,98
Buffer Stream 23-1	0,00	0,00	∞
Stream 23-2	75,00	41,42	79,99
Buffer Stream 23-2	0,00	0,00	∞
Stream 23-3	81,22	46,31	84,97
Stream 23-4	2,80	1,00	5,00
Buffer Stream 23-4	0,00	0,00	∞
Stream 23-5	0,08	0,01	1,00
Buffer Stream 23-5	0,00	0,00	∞
Stream 23-6	1,47	0,45	2,17
Stream 23-7	1,97	1,29	2,60
Stream 24-1	192,53	127,13	285,36
Buffer Stream 24-1	0,00	0,00	∞
Stream 24-2	903,99	812,61	1045,67
Stream 24-3	12,02	8,39	15,24
Stream 24-4	44,13	0,00	93,13
Buffer Stream 24-4	0,00	0,00	∞
Stream 24-5	150,16	110,69	206,53
Buffer Stream 24-5	0,00	0,00	∞
Stream 24-6	239,80	148,22	325,95
Buffer Stream 24-6	0,00	0,00	∞
Stream 24-7	9,13	2,69	17,31
Buffer Stream 24-7	0,00	0,00	∞
Stream 24-8	5,52	0,00	11,92
Stream 24-9	1,67	0,00	8,25
Stream 24-10	16,22	8,40	22,90
Stream 24-11	3,12	2,04	6,37
Buffer Stream 24-11	0,00	0,00	∞
Stream 24-12	237,26	150,61	410,77

Table A.7: Case 3 Summer continued

Streams	MILP Value	Min	Max
Buffer Stream 24-12	0,00	0,00	∞
Stream 24-13	27,86	0,00	38,97
Buffer Stream 24-13	0,00	0,00	∞
Additional Feed Plant 25	0,00	0,00	∞
Stream 25-1	4,44	4,44	10,47
Stream 25-2	2,78	1,59	4,63
Buffer Stream 25-2	0,00	0,00	∞
Stream 25-3	1,66	1,11	6,40
Buffer Stream 25-3	1,66	0,00	∞
Additional Feed Plant 26	0,00	0,00	∞
Stream 26-1	1,00	0,70	3,94
Stream 26-2	0,01	0,01	3,00
Buffer Stream 26-2	0,00	0,00	∞
Stream 26-3	0,99	0,01	4,00
Buffer Stream 26-3	0,99	0,00	∞
Additional Feed Plant 27	3,15	0,00	∞
Stream 27-1	11,63	11,63	33,26
Stream 27-2	5,24	0,01	15,00
Buffer Stream 27-2	0,00	0,00	∞
Stream 27-3	6,39	0,01	20,00
Buffer Stream 27-3	5,67	0,00	∞
stream1	159,73	0,00	∞
stream10	39,99	0,00	∞
stream100	2,80	0,00	∞
stream101	0,00	0,00	∞
stream102	0,00	0,00	∞
stream103	0,00	0,00	∞
stream104	0,08	0,00	∞
stream105	0,00	0,00	∞
stream106	0,00	0,00	∞
stream107	3,34	0,00	∞
stream108	75,00	0,00	∞
stream109	11,42	0,00	∞
stream11	132,51	0,00	∞
stream110	5,92	0,00	∞

Table A.7: Case 3 Summer continued

Streams	MILP Value	Min	Max
stream111	0,18	0,00	∞
stream112	0,20	0,00	∞
stream113	8,00	0,00	∞
stream114	15,93	0,00	∞
stream115	9,41	0,00	∞
stream116	5,39	0,00	∞
stream117	11,81	0,00	∞
stream118	0,00	0,00	∞
stream119	0,00	0,00	∞
stream12	60,02	0,00	∞
stream120	0,00	0,00	∞
stream121	0,00	0,00	∞
stream122	0,00	0,00	∞
stream123	0,00	0,00	∞
stream124	0,00	0,00	∞
stream125	13,67	0,00	∞
stream126	14,34	0,00	∞
stream127	6,83	0,00	∞
stream128	0,00	0,00	∞
stream129	6,12	0,00	∞
stream13	9,13	0,00	∞
stream130	11,35	0,00	∞
stream131	4,44	0,00	∞
stream132	4,73	0,00	∞
stream133	11,28	0,00	∞
stream134	15,74	0,00	∞
stream135	19,70	0,00	∞
stream136	47,60	0,00	∞
stream137	11,37	0,00	∞
stream138	2,84	0,00	∞
stream139	17,71	0,00	∞
stream14	86,87	0,00	∞
stream140	26,61	0,00	∞
stream141	3,28	0,00	∞
stream142	3,84	0,00	∞

Table A.7: Case 3 Summer continued

Streams	MILP Value	Min	Max
stream143	24,17	0,00	∞
stream144	0,00	0,00	∞
stream145	1,23	0,00	∞
stream146	85,00	0,00	∞
stream147	4,35	0,00	∞
stream148	9,85	0,00	∞
stream149	5,19	0,00	∞
stream15	150,39	0,00	∞
stream150	0,00	0,00	∞
stream151	5,20	0,00	∞
stream152	0,71	0,00	∞
stream153	1,00	0,00	∞
stream154	4,24	0,00	∞
stream155	2,78	0,00	∞
stream156	0,00	0,00	∞
stream157	0,01	0,00	∞
stream158	0,00	0,00	∞
stream16	3,12	0,00	∞
stream17	0,00	0,00	∞
stream18	19,06	0,00	∞
stream19	22,72	0,00	∞
stream2	40,07	0,00	∞
stream20	8,67	0,00	∞
stream21	9,11	0,00	∞
stream22	0,00	0,00	∞
stream23	26,20	0,00	∞
stream24	0,00	0,00	∞
stream25	49,66	0,00	∞
stream26	130,59	0,00	∞
stream27	3,84	0,00	∞
stream28	105,93	0,00	∞
stream29	0,40	0,00	∞
stream3	40,00	0,00	∞
stream30	244,07	0,00	∞
stream31	3,77	0,00	∞

Table A.7: Case 3 Summer continued

Streams	MILP Value	Min	Max
stream32	1,91	0,00	∞
stream33	4,73	0,00	∞
stream34	192,95	0,00	∞
stream35	2,67	0,00	∞
stream36	2,36	0,00	∞
stream37	2,84	0,00	∞
stream38	0,40	0,00	∞
stream39	0,04	0,00	∞
stream4	44,13	0,00	∞
stream40	5,36	0,00	∞
stream41	33,80	0,00	∞
stream42	0,00	0,00	∞
stream43	0,40	0,00	∞
stream44	0,00	0,00	∞
stream45	0,00	0,00	∞
stream46	0,00	0,00	∞
stream47	0,00	0,00	∞
stream48	0,00	0,00	∞
stream49	0,00	0,00	∞
stream5	0,00	0,00	∞
stream50	0,00	0,00	∞
stream51	0,00	0,00	∞
stream52	0,00	0,00	∞
stream53	0,00	0,00	∞
stream54	0,00	0,00	∞
stream55	0,00	0,00	∞
stream56	0,00	0,00	∞
stream57	0,00	0,00	∞
stream58	0,00	0,00	∞
stream59	0,00	0,00	∞
stream6	0,00	0,00	∞
stream60	0,00	0,00	∞
stream61	0,00	0,00	∞
stream62	1,82	0,00	∞
stream63	0,00	0,00	∞

Table A.7: Case 3 Summer continued

Streams	MILP Value	Min	Max
stream64	0,00	0,00	∞
stream65	7,41	0,00	∞
stream66	2,15	0,00	∞
stream67	38,39	0,00	∞
stream68	0,00	0,00	∞
stream69	0,00	0,00	∞
stream7	27,86	0,00	∞
stream70	42,85	0,00	∞
stream71	0,00	0,00	∞
stream72	5,63	0,00	∞
stream73	1,50	0,00	∞
stream74	100,42	0,00	∞
stream75	0,00	0,00	∞
stream76	9,85	0,00	∞
stream77	38,62	0,00	∞
stream78	0,00	0,00	∞
stream79	60,84	0,00	∞
stream8	0,00	0,00	∞
stream80	2,43	0,00	∞
stream81	18,87	0,00	∞
stream82	0,70	0,00	∞
stream83	0,70	0,00	∞
stream84	0,37	0,00	∞
stream85	0,00	0,00	∞
stream86	0,00	0,00	∞
stream87	1,47	0,00	∞
stream88	0,00	0,00	∞
stream89	0,00	0,00	∞
stream9	110,16	0,00	∞
stream90	0,00	0,00	∞
stream91	0,00	0,00	∞
stream92	0,00	0,00	∞
stream93	0,00	0,00	∞
stream94	0,00	0,00	∞
stream95	0,00	0,00	∞

Table A.7: Case 3 Summer continued

Streams	MILP Value	Min	Max
stream96	0,00	0,00	∞
stream97	0,00	0,00	∞
stream98	0,00	0,00	∞
stream99	0,00	0,00	∞
Additional Feed Plant 28	0,00	0,00	∞
Stream 28-1	0,00	0,00	0,00
Stream 28-2	0,00	0,00	0,00
Buffer Stream 28-2	0,00	0,00	∞
Stream 28-3	0,00	0,00	0,00
Buffer Stream 28-3	0,00	0,00	∞
Stream 28-4	0,00	0,00	0,00
Stream 28-5	0,00	0,00	0,00
Stream 28-6	0,00	0,00	0,00
Stream 28-7	0,00	0,00	0,00
Stream 28-8	0,00	0,00	0,00
Buffer Stream 28-8	0,00	0,00	∞
Stream 28-9	0,00	0,00	0,00
Buffer Stream 28-9	0,00	0,00	∞
Stream 28-10	0,00	0,00	0,00
Buffer Stream 28-10	0,00	0,00	∞
Additional Feed Plant 29	0,00	0,00	∞
Stream 29-1	11,81	7,43	19,15
Buffer Stream 29-1	0,00	0,00	∞
Stream 29-2	26,61	19,34	42,16
Stream 29-3	5,39	3,06	10,47
Buffer Stream 29-3	0,00	0,00	∞
Stream 29-4	9,41	6,66	16,67
Buffer Stream 29-4	0,00	0,00	∞
Additional Feed Plant 30	0,00	0,00	∞
Stream 30-1	132,51	132,51	242,16
Stream 30-2	18,87	12,44	37,27
Buffer Stream 30-2	0,00	0,00	∞
Stream 30-3	2,43	0,00	22,70
Buffer Stream 30-3	0,00	0,00	∞
Stream 30-4	111,21	102,21	180,00

Table A.7: Case 3 Summer continued

Streams	MILP Value	Min	Max
Buffer Stream 30-4	50,37	0,00	∞

Table A.8: Case 3 Winter

Streams	MILP Value	Min	Max
Additional Feed Plant 1	0,00	0,00	∞
Stream 1-1	24,82	11,00	35,00
Buffer Stream 1-1	0,00	0,00	∞
Additional Feed Plant 2	52,83	0,00	∞
Stream 2-1	89,58	31,00	100,00
Stream 2-2	0,99	0,10	5,00
Stream 2-3	4,58	1,50	20,00
Buffer Stream 2-3	0,00	0,00	∞
Stream 2-4	85,00	25,00	85,00
Buffer Stream 2-4	0,00	0,00	∞
Stream 1-2	16,93	7,60	28,21
Buffer Stream 1-2	0,00	0,00	∞
Stream 1-3	2,39	0,00	9,42
Buffer Stream 1-3	0,00	0,00	∞
Stream 1-4	12,38	5,23	16,98
Buffer Stream 1-4	0,00	0,00	∞
Stream 1-5	47,60	22,86	66,97
Buffer Stream 1-5	0,00	0,00	∞
Stream 1-6	141,20	68,46	201,16
Stream 1-7	3,08	0,10	5,00
Buffer Stream 1-7	0,00	0,00	∞
Stream 1-8	3,97	0,00	8,32
Buffer Stream 1-8	0,00	0,00	∞
Stream 1-9	1,91	0,38	3,59
Stream 1-10	66,82	0,00	149,52
Stream 1-11	26,64	1,35	42,79
Buffer Stream 1-11	0,00	0,00	∞
Stream 1-12	52,81	17,53	68,89
Stream 1-13	0,00	0,00	1,00

Table A.8: Case 3 Winter continued

Streams	MILP Value	Min	Max
Stream 1-14	10,54	0,00	54,99
Stream 1-15	10,24	0,00	91,18
Stream 1-16	3,39	0,00	8,60
Buffer Stream 1-16	0,00	0,00	∞
Stream 3-1	64,16	41,99	64,16
Stream 3-2	31,84	18,50	32,56
Buffer Stream 3-2	0,00	0,00	∞
Stream 3-3	32,32	21,07	33,20
Buffer Stream 3-3	0,00	0,00	∞
Additional Feed Plant 4	0,00	0,00	∞
Stream 4-1	12,73	0,14	12,73
Buffer Stream 4-1	0,00	0,00	∞
Stream 4-2	12,73	0,14	12,73
Stream 4-3	0,05	0,00	0,07
Stream 4-4	0,41	0,10	0,63
Stream 4-5	0,46	0,10	0,51
Stream 5-1	0,24	0,07	0,33
Buffer Stream 5-1	0,00	0,00	∞
Stream 5-2	0,23	0,00	0,37
Buffer Stream 5-2	0,00	0,00	∞
Additional Feed Plant 5	0,00	0,00	∞
Stream 5-3	5,73	2,08	7,44
Buffer Stream 5-3	0,00	0,00	∞
Stream 5-4	16,93	9,26	22,01
Stream 5-5	0,67	0,00	1,80
Stream 5-6	12,98	7,21	16,01
Stream 5-7	10,72	5,16	16,37
Buffer Stream 5-7	0,00	0,00	∞
Additional Feed Plant 6	3,61	0,00	∞
Stream 6-1	6,76	6,76	15,45
Stream 6-2	6,76	1,42	9,79
Buffer Stream 6-2	0,00	0,00	∞
Additional Feed Plant 7	0,50	0,00	∞
Stream 7-1	4,87	3,16	13,80
Stream 7-2	4,87	4,87	14,95

Table A.8: Case 3 Winter continued

Streams	MILP Value	Min	Max
Buffer Stream 7-2	0,00	0,00	∞
EL Plant 1	4,59	0,67	6,18
EL Plant 5	1,60	0,00	2,01
EL Plant 7	1,29	0,33	2,04
EL Plant 9	8,36	8,20	11,09
EL Plant 10	0,76	0,00	0,98
EL Plant 11	0,99	0,00	1,20
EL OCM	40,98	0,00	∞
EL Plant 12	1,46	0,88	47,79
EL Plant 13	2,81	2,15	4,15
EL Plant 14	0,97	0,79	1,82
EL Plant 15	0,82	0,76	2,52
EL Plant 16	0,00	0,00	0,00
EL Plant 18	0,00	0,00	∞
EL Plant 19	2,10	0,00	∞
EL Plant 20	0,00	0,00	∞
EL Plant 21	0,66	0,56	0,76
EL P2H2	40,98	0,00	∞
EL Plant 22	0,00	0,00	0,00
EL Plant 23	0,30	0,00	0,40
EL Plant 24	4,83	4,58	5,39
EL Plant 26	0,83	0,62	1,03
EL Plant 28	0,00	0,00	0,00
EL Plant 29	0,17	0,11	0,24
Additional Feed Plant 8	0,00	0,00	∞
Stream 8-1	9,09	1,45	19,41
Buffer Stream 8-1	0,00	0,00	∞
Stream 8-2	4,07	0,00	∞
Stream 8-3	27,13	27,13	49,64
Stream 8-4	9,47	8,28	14,54
Stream 8-5	18,04	15,41	28,34
Buffer Stream 8-5	0,00	0,00	∞
Additional Feed Plant 9	0,00	0,00	∞
Stream 9-1	11,93	5,00	23,00
Buffer Stream 9-1	0,00	0,00	∞

Table A.8: Case 3 Winter continued

Streams	MILP Value	Min	Max
Stream 9-2	21,35	10,00	32,00
Buffer Stream 9-2	0,00	0,00	∞
Stream 9-3	91,41	50,00	160,00
Stream 9-4	3,17	0,01	10,00
Buffer Stream 9-4	0,00	0,00	∞
Stream 9-5	11,40	5,69	20,73
Buffer Stream 9-5	0,00	0,00	∞
Stream 9-6	6,99	1,00	22,00
Buffer Stream 9-6	0,00	0,00	∞
Stream 9-7	17,46	7,00	36,00
Stream 9-7-1	5,79	0,00	∞
Buffer Stream 9-7	0,00	0,00	∞
Stream 9-8	0,10	0,00	4,58
Stream 9-9	27,61	1,90	35,00
Stream 9-10	6,18	5,44	17,02
Stream 9-11	0,33	0,01	15,00
Stream 9-12	6,57	2,00	12,00
Buffer Stream 9-12	0,00	0,00	∞
Stream 9-13	12,54	12,00	40,00
Stream 9-13-1	4,21	0,00	∞
Buffer Stream 9-13	0,00	0,00	∞
Additional Feed Plant 10	0,00	0,00	∞
Stream 10-1	42,57	5,05	80,57
Buffer Stream 10-1	0,00	0,00	∞
Stream 10-2	74,84	74,84	139,86
Stream 10-3	1,06	0,85	1,79
Stream 10-4	1,87	0,00	10,16
Stream 10-5	4,73	3,55	5,45
Stream 10-6	3,92	0,64	8,92
Stream 10-7	5,56	1,92	18,94
Buffer Stream 10-7	0,00	0,00	∞
Stream 10-8	26,71	19,60	85,44
Buffer Stream 10-8	0,00	0,00	∞
Additional Feed Plant 11	0,00	0,00	∞
Stream 11-1	151,10	110,22	261,71

Table A.8: Case 3 Winter continued

Streams	MILP Value	Min	Max
Stream 11-2	2,45	0,00	8,12
Stream 11-3	0,79	0,00	4,04
Stream 11-4	0,02	0,00	1,20
Stream 11-5	4,23	0,00	10,14
Stream 11-6	1,51	0,00	3,00
Buffer Stream 11-6	0,00	0,00	∞
Stream 11-7	45,71	22,74	97,50
Buffer Stream 11-7	0,00	0,00	∞
Stream 11-8	103,88	71,44	177,96
Buffer Stream 11-8	0,00	0,00	∞
Stream OCM-1	111,20	0,00	∞
Stream OCM-2	80,00	0,00	∞
Stream OCM-3	11,68	0,00	∞
Stream OCM-4	12,08	0,00	∞
Stream OCM-5	22,40	0,00	∞
Stream OCM-6	179,10	0,00	∞
Stream OCM-7	109,60	0,00	∞
Switch OCM	1,00	0,00	1,00
Additional Feed Plant 12	0,00	0,00	∞
Stream 12-1	133,74	117,14	160,34
Stream 12-2	0,61	0,45	0,89
Stream 12-3	0,37	0,30	2,00
Buffer Stream 12-3	0,00	0,00	∞
Stream 12-4	0,29	0,13	0,82
Stream 12-5	129,41	116,14	157,78
Buffer Stream 12-5	0,00	0,00	∞
Stream 12-6	0,37	0,20	4,86
Stream 12-7	1,02	0,95	1,20
Stream 12-8	3,97	2,01	9,04
Buffer Stream 12-8	0,00	0,00	∞
Stream 12-9	1,35	0,00	3,00
Buffer Stream 12-9	0,00	0,00	∞
Additional Feed Plant 13	0,00	0,00	∞
Stream 13-1	5,65	0,23	10,85
Buffer Stream 13-1	0,00	0,00	∞

Table A.8: Case 3 Winter continued

Streams	MILP Value	Min	Max
Stream 13-2	225,33	157,27	300,83
Stream 13-3	0,64	0,09	2,14
Stream 13-4	215,59	146,55	286,78
Buffer Stream 13-4	0,00	0,00	∞
Stream 13-5	1,94	1,01	7,02
Stream 13-6	3,09	0,07	7,99
Stream 13-7	5,17	3,94	6,90
Stream 13-8	2,74	0,20	4,00
Buffer Stream 13-8	0,00	0,00	∞
Additional Feed Plant 14	0,00	0,00	∞
Stream 14-1	1,92	0,00	10,51
Buffer Stream 14-1	0,00	0,00	∞
Stream 14-2	171,94	136,19	250,00
Stream 14-3	0,47	0,24	0,89
Stream 14-4	1,16	0,20	7,84
Buffer Stream 14-4	0,00	0,00	∞
Stream 14-5	3,00	0,00	7,10
Buffer Stream 14-5	0,00	0,00	∞
Stream 14-6	0,99	0,00	5,30
Stream 14-7	2,17	0,02	4,24
Stream 14-8	2,73	0,00	7,80
Stream 14-9	0,07	0,00	3,36
Stream 14-10	0,08	0,00	3,09
Stream 14-11	4,72	0,00	11,43
Stream 15-1	10,07	10,07	30,60
Buffer Stream 15-1	0,00	0,00	∞
Stream 15-2	2,41	1,99	3,59
Stream 15-3	39,06	26,40	79,72
Buffer Stream 15-3	0,00	0,00	∞
Stream 15-4	16,61	8,81	48,68
Buffer Stream 15-4	0,00	0,00	∞
Stream 15-5	9,88	7,69	10,58
Additional Feed Plant 15-1	0,00	0,00	∞
Stream 15-6	198,17	175,27	271,31
Stream 15-7	1,58	1,45	2,23

Table A.8: Case 3 Winter continued

Streams	**MILP Value**	**Min**	**Max**
Stream 15-8	133,54	125,83	188,75
Buffer Stream 15-8	51,71	0,00	∞
Stream 15-9	9,58	9,37	15,75
Buffer Stream 15-9	0,00	0,00	∞
Additional Feed Plant 15-2	0,00	0,00	∞
Stream 15-10	10,69	4,03	31,60
Stream 15-11	165,85	122,86	238,40
Buffer Stream 15-11	0,00	0,00	∞
Additional Feed Plant 16	0,00	0,00	∞
Stream 16-1	0,00	0,00	0,00
Stream 16-2	0,00	0,00	0,00
Stream 16-3	0,00	0,00	0,00
Stream 16-4	0,00	0,00	0,00
Buffer Stream 16-4	0,00	0,00	∞
Buffer Stream 16-3	0,00	0,00	∞
Stream 16-5	0,00	0,00	0,00
Buffer Stream 16-5	0,00	0,00	∞
Stream 16-6	0,00	0,00	0,00
Buffer Stream 16-6	0,00	0,00	∞
Stream 16-7	0,00	0,00	0,00
Stream 16-8	0,00	0,00	0,00
Stream 16-9	0,00	0,00	0,00
Stream 16-10	0,00	0,00	0,00
Buffer Stream 16-10	0,00	0,00	∞
Stream 16-11	0,00	0,00	0,00
Buffer Stream 16-11	0,00	0,00	∞
Stream 16-12	0,00	0,00	0,00
Buffer Stream 16-12	0,00	0,00	∞
Stream 16-13	1,99	1,51	3,71
Buffer Stream 16-13	0,00	0,00	∞
Additional Feed Plant 17	0,00	0,00	∞
Stream 17-1	7,59	6,51	28,03
Buffer Stream 17-1	0,00	0,00	∞
Stream 17-2	13,00	10,25	34,33
Stream 17-3	3,41	0,28	6,56

Table A.8: Case 3 Winter continued

Streams	MILP Value	Min	Max
Buffer Stream 17-3	0,00	0,00	∞
Stream 17-4	2,19	0,00	3,60
Additional Feed Plant 18	0,00	0,00	∞
Stream 18-1	0,00	0,00	∞
Buffer Stream 18-1	0,00	0,00	∞
Stream 18-2	0,00	0,00	∞
Buffer Stream 18-2	0,00	0,00	∞
Stream 18-3	0,00	0,00	∞
Buffer Stream 18-3	0,00	0,00	∞
Stream 18-4	0,00	0,00	∞
Stream 18-5	0,00	0,00	∞
Stream 18-6	0,00	0,00	∞
Stream 18-7	0,00	0,00	∞
Buffer Stream 18-7	0,00	0,00	∞
Stream 18-8	0,00	0,00	∞
Buffer Stream 18-8	0,00	0,00	∞
Switch Plant 18	0,00	0,00	1,00
Additional Feed Plant 19	0,00	0,00	∞
Stream 19-1	7,21	0,00	∞
Buffer Stream 19-1	0,00	0,00	∞
Stream 19-2	0,50	0,00	∞
Buffer Stream 19-2	0,00	0,00	∞
Stream 19-3	40,85	0,00	∞
Buffer Stream 19-3	0,00	0,00	∞
Stream 19-4	49,55	0,00	∞
Stream 19-5	2,57	0,00	∞
Stream 19-6	1,50	0,00	∞
Stream 19-7	0,50	0,00	∞
Buffer Stream 19-7	0,00	0,00	∞
Stream 19-8	0,50	0,00	∞
Buffer Stream 19-8	0,00	0,00	∞
Switch Plant 19	1,00	0,00	1,00
Additional Feed Plant 20	0,00	0,00	∞
Stream 20-1	0,00	0,00	∞
Buffer Stream 20-1	0,00	0,00	∞

Table A.8: Case 3 Winter continued

Streams	**MILP Value**	**Min**	**Max**
Stream 20-2	0,00	0,00	∞
Buffer Stream 20-2	0,00	0,00	∞
Stream 20-3	0,00	0,00	∞
Buffer Stream 20-3	0,00	0,00	∞
Stream 20-4	0,00	0,00	∞
Stream 20-5	0,00	0,00	∞
Stream 20-6	0,00	0,00	∞
Stream 20-7	0,00	0,00	∞
Buffer Stream 20-7	0,00	0,00	∞
Stream 20-8	0,00	0,00	∞
Buffer Stream 20-8	0,00	0,00	∞
Switch Plant 20	0,00	0,00	1,00
Additional Feed Plant 21	0,00	0,00	∞
Stream 21-1	0,69	0,00	3,65
Buffer Stream 21-1	0,00	0,00	∞
Stream 21-2	69,45	50,00	187,00
Stream 21-3	1,78	0,01	7,50
Buffer Stream 21-3	0,00	0,00	∞
Stream 21-4	0,60	0,01	9,00
Buffer Stream 21-4	0,00	0,00	∞
Stream 21-5	15,14	13,56	79,37
Stream 21-5-16	15,14	0,00	∞
Buffer Stream 21-5	0,00	0,00	∞
Stream 21-6	50,77	40,00	125,00
Stream 21-6-16	50,77	0,00	∞
Buffer Stream 21-6	0,00	0,00	∞
Stream 21-7	0,46	0,01	6,00
Buffer Stream 21-7	0,00	0,00	∞
Stream P2H2-1	9,11	0,00	∞
Stream P2H2-2	1,01	0,00	∞
Stream P2H2-3	8,10	0,00	∞
Switch P2H2	1,00	0,00	1,00
Additional Feed Plant 22	0,00	0,00	∞
Stream 22-1	0,00	0,00	0,00
Stream 22-2	0,00	0,00	0,00

Table A.8: Case 3 Winter continued

Streams	MILP Value	Min	Max
Buffer Stream 22-2	0,00	0,00	∞
Stream 22-3	0,00	0,00	0,00
Buffer Stream 22-3	0,00	0,00	∞
Stream 22-4	0,00	0,00	0,00
Stream 22-5	0,00	0,00	0,00
Stream 22-6	0,00	0,00	0,00
Stream 22-7	0,00	0,00	0,00
Stream 22-8	0,00	0,00	0,00
Buffer Stream 22-8	0,00	0,00	∞
Stream 22-9	0,00	0,00	0,00
Buffer Stream 22-9	0,00	0,00	∞
Additional Feed Plant 23	25,81	0,00	∞
Stream 23-1	3,86	0,92	11,92
Buffer Stream 23-1	0,00	0,00	∞
Stream 23-2	75,00	36,62	81,02
Buffer Stream 23-2	0,00	0,00	∞
Stream 23-3	81,48	45,97	83,83
Stream 23-4	2,61	1,00	5,00
Buffer Stream 23-4	0,00	0,00	∞
Stream 23-5	0,00	0,00	1,00
Buffer Stream 23-5	0,00	0,00	∞
Stream 23-6	1,41	0,16	2,12
Stream 23-7	1,94	0,95	2,70
Stream 24-1	172,28	123,46	269,58
Buffer Stream 24-1	0,00	0,00	∞
Stream 24-2	831,55	812,33	1051,74
Stream 24-3	12,74	9,92	15,96
Stream 24-4	51,75	28,68	90,56
Buffer Stream 24-4	0,00	0,00	∞
Stream 24-5	133,74	105,64	187,87
Buffer Stream 24-5	0,00	0,00	∞
Stream 24-6	210,22	139,27	297,69
Buffer Stream 24-6	0,00	0,00	∞
Stream 24-7	8,67	0,72	18,28
Buffer Stream 24-7	0,00	0,00	∞

Table A.8: Case 3 Winter continued

Streams	**MILP Value**	**Min**	**Max**
Stream 24-8	2,20	0,00	10,03
Stream 24-9	2,03	0,00	8,01
Stream 24-10	14,86	12,98	23,87
Stream 24-11	3,46	2,04	6,48
Buffer Stream 24-11	0,00	0,00	∞
Stream 24-12	225,94	156,70	352,56
Buffer Stream 24-12	0,00	0,00	∞
Stream 24-13	25,49	19,49	39,08
Buffer Stream 24-13	0,00	0,00	∞
Additional Feed Plant 25	0,00	0,00	∞
Stream 25-1	5,26	5,26	9,18
Stream 25-2	2,80	2,38	5,26
Buffer Stream 25-2	0,00	0,00	∞
Stream 25-3	2,47	2,01	4,90
Buffer Stream 25-3	0,00	0,00	∞
Additional Feed Plant 26	0,00	0,00	∞
Stream 26-1	0,50	0,50	3,73
Stream 26-2	0,00	0,00	3,00
Buffer Stream 26-2	0,00	0,00	∞
Stream 26-3	0,49	0,01	4,00
Buffer Stream 26-3	0,00	0,00	∞
Additional Feed Plant 27	0,00	0,00	∞
Stream 27-1	9,67	9,67	24,66
Stream 27-2	4,22	0,01	11,00
Buffer Stream 27-2	0,00	0,00	∞
Stream 27-3	5,44	0,01	15,00
Buffer Stream 27-3	0,00	0,00	∞
stream1	160,67	0,00	∞
stream10	0,00	0,00	∞
stream100	2,61	0,00	∞
stream101	0,00	0,00	∞
stream102	0,00	0,00	∞
stream103	0,00	0,00	∞
stream104	0,00	0,00	∞
stream105	0,00	0,00	∞

Table A.8: Case 3 Winter continued

Streams	MILP Value	Min	Max
stream106	0,00	0,00	∞
stream107	3,86	0,00	∞
stream108	75,00	0,00	∞
stream109	10,72	0,00	∞
stream11	129,38	0,00	∞
stream110	5,73	0,00	∞
stream111	0,24	0,00	∞
stream112	0,23	0,00	∞
stream113	9,09	0,00	∞
stream114	18,04	0,00	∞
stream115	9,26	0,00	∞
stream116	5,65	0,00	∞
stream117	11,73	0,00	∞
stream118	0,00	0,00	∞
stream119	0,00	0,00	∞
stream12	42,90	0,00	∞
stream120	0,00	0,00	∞
stream121	0,00	0,00	∞
stream122	0,00	0,00	∞
stream123	0,00	0,00	∞
stream124	0,00	0,00	∞
stream125	8,33	0,00	∞
stream126	6,99	0,00	∞
stream127	11,67	0,00	∞
stream128	0,00	0,00	∞
stream129	3,17	0,00	∞
stream13	8,67	0,00	∞
stream130	11,40	0,00	∞
stream131	5,26	0,00	∞
stream132	1,31	0,00	∞
stream133	14,01	0,00	∞
stream134	7,34	0,00	∞
stream135	11,93	0,00	∞
stream136	47,60	0,00	∞
stream137	12,38	0,00	∞

Table A.8: Case 3 Winter continued

Streams	MILP Value	Min	Max
stream138	3,08	0,00	∞
stream139	16,93	0,00	∞
stream14	74,84	0,00	∞
stream140	26,64	0,00	∞
stream141	3,97	0,00	∞
stream142	3,39	0,00	∞
stream143	24,82	0,00	∞
stream144	0,00	0,00	∞
stream145	2,39	0,00	∞
stream146	85,00	0,00	∞
stream147	4,58	0,00	∞
stream148	12,73	0,00	∞
stream149	6,76	0,00	∞
stream15	151,10	0,00	∞
stream150	0,00	0,00	∞
stream151	4,87	0,00	∞
stream152	5,44	0,00	∞
stream153	0,50	0,00	∞
stream154	3,73	0,00	∞
stream155	2,80	0,00	∞
stream156	2,47	0,00	∞
stream157	0,00	0,00	∞
stream158	0,49	0,00	∞
stream16	3,46	0,00	∞
stream17	0,00	0,00	∞
stream18	31,84	0,00	∞
stream19	32,32	0,00	∞
stream2	0,00	0,00	∞
stream20	10,07	0,00	∞
stream21	9,58	0,00	∞
stream22	0,00	0,00	∞
stream23	16,61	0,00	∞
stream24	0,00	0,00	∞
stream25	39,06	0,00	∞
stream26	81,83	0,00	∞

Table A.8: Case 3 Winter continued

Streams	MILP Value	Min	Max
stream27	3,97	0,00	∞
stream28	129,41	0,00	∞
stream29	0,37	0,00	∞
stream3	49,55	0,00	∞
stream30	215,59	0,00	∞
stream31	2,74	0,00	∞
stream32	1,35	0,00	∞
stream33	5,65	0,00	∞
stream34	165,85	0,00	∞
stream35	1,92	0,00	∞
stream36	1,16	0,00	∞
stream37	3,00	0,00	∞
stream38	0,50	0,00	∞
stream39	0,50	0,00	∞
stream4	51,75	0,00	∞
stream40	7,21	0,00	∞
stream41	40,85	0,00	∞
stream42	0,20	0,00	∞
stream43	0,29	0,00	∞
stream44	0,00	0,00	∞
stream45	0,00	0,00	∞
stream46	0,00	0,00	∞
stream47	0,00	0,00	∞
stream48	0,00	0,00	∞
stream49	0,00	0,00	∞
stream5	0,00	0,00	∞
stream50	0,00	0,00	∞
stream51	0,00	0,00	∞
stream52	0,00	0,00	∞
stream53	0,00	0,00	∞
stream54	0,00	0,00	∞
stream55	0,00	0,00	∞
stream56	0,00	0,00	∞
stream57	0,00	0,00	∞
stream58	0,00	0,00	∞

Table A.8: Case 3 Winter continued

Streams	MILP Value	Min	Max
stream59	0,00	0,00	∞
stream6	0,00	0,00	∞
stream60	0,00	0,00	∞
stream61	0,00	0,00	∞
stream62	1,99	0,00	∞
stream63	1,08	0,00	∞
stream64	0,00	0,00	∞
stream65	6,52	0,00	∞
stream66	3,41	0,00	∞
stream67	42,57	0,00	∞
stream68	0,00	0,00	∞
stream69	0,00	0,00	∞
stream7	25,49	0,00	∞
stream70	26,71	0,00	∞
stream71	0,00	0,00	∞
stream72	5,56	0,00	∞
stream73	1,51	0,00	∞
stream74	103,88	0,00	∞
stream75	0,00	0,00	∞
stream76	12,73	0,00	∞
stream77	32,98	0,00	∞
stream78	0,00	0,00	∞
stream79	60,20	0,00	∞
stream8	0,00	0,00	∞
stream80	7,84	0,00	∞
stream81	20,99	0,00	∞
stream82	0,69	0,00	∞
stream83	0,46	0,00	∞
stream84	0,60	0,00	∞
stream85	0,00	0,00	∞
stream86	0,00	0,00	∞
stream87	1,78	0,00	∞
stream88	0,00	0,00	∞
stream89	0,00	0,00	∞
stream9	133,74	0,00	∞

Table A.8: Case 3 Winter continued

Streams	MILP Value	Min	Max
stream90	0,00	0,00	∞
stream91	0,00	0,00	∞
stream92	0,00	0,00	∞
stream93	0,00	0,00	∞
stream94	0,00	0,00	∞
stream95	0,00	0,00	∞
stream96	0,00	0,00	∞
stream97	0,00	0,00	∞
stream98	0,00	0,00	∞
stream99	0,00	0,00	∞
Additional Feed Plant 28	0,00	0,00	∞
Stream 28-1	0,00	0,00	0,00
Stream 28-2	0,00	0,00	0,00
Buffer Stream 28-2	0,00	0,00	∞
Stream 28-3	0,00	0,00	0,00
Buffer Stream 28-3	0,00	0,00	∞
Stream 28-4	0,00	0,00	0,00
Stream 28-5	0,00	0,00	0,00
Stream 28-6	0,00	0,00	0,00
Stream 28-7	0,00	0,00	0,00
Stream 28-8	0,00	0,00	0,00
Buffer Stream 28-8	0,00	0,00	∞
Stream 28-9	0,00	0,00	0,00
Buffer Stream 28-9	0,00	0,00	∞
Stream 28-10	0,00	0,00	0,00
Buffer Stream 28-10	0,00	0,00	∞
Additional Feed Plant 29	0,00	0,00	∞
Stream 29-1	11,73	7,66	19,90
Buffer Stream 29-1	0,00	0,00	∞
Stream 29-2	26,64	18,66	44,43
Stream 29-3	5,65	4,21	9,79
Buffer Stream 29-3	0,00	0,00	∞
Stream 29-4	9,26	5,09	15,60
Buffer Stream 29-4	0,00	0,00	∞
Additional Feed Plant 30	0,00	0,00	∞

Table A.8: Case 3 Winter continued

Streams	**MILP Value**	**Min**	**Max**
Stream 30-1	129,38	121,87	236,86
Stream 30-2	20,99	15,01	41,76
Buffer Stream 30-2	0,00	0,00	∞
Stream 30-3	7,84	0,00	26,76
Buffer Stream 30-3	0,00	0,00	∞
Stream 30-4	100,55	81,12	179,30
Buffer Stream 30-4	40,36	0,00	∞