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# Development of a Computer Health Indicator Monitoring Solution on the Example of Eesti Energia AS

Bachelor's thesis

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MBA

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TALLINNA TEHNIKAÜLIKOOL
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# Arvuti tervisenäitajate seirelahenduse väljatöötamine Eesti Energia AS–i näitel

Bakalaureusetöö

Juhendaja: Nadežda Furs
MBA

Tallinn 2021

# Author’s declaration of originality

I hereby certify that I am the sole author of this thesis. All the used materials, references to the literature and the work of others have been referred to. This thesis has not been presented for examination anywhere else.

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# Abstract

The aim of current thesis is to create a framework for replacing a computer based on the Zabbix monitoring system.

This solution was created for the Eesti Energia AS ITabi technical support team to optimize the workstation replacement process, but can also be applied in other enterprises where there is a workstation replacement process. At the moment, ITabi do every workstation replacement, but in case if it changes, this framework can be also applied to other support teams.

The developed solution was divided into 3 parts: creating a universal framework for replacing workstations, creating triggers for Zabbix to automatically notify the ITabi team about the need, and testing the framework and triggers on dedicated workstations.

Optimizing the computer replacement process should increase the efficiency of ITabi as a team and increase the speed of issuing computers, thereby making employees more satisfied.

This thesis is written in English and contains 43 pages long, including 7 chapters, 6 figures and 3 tables.

# Annotatsioon

## Arvuti tervisenäitajate seirelahenduse väljatöötmine Eesti Energia AS–i näitel

Käesoleva lõputöö eesmärk on luua raamistik Zabbixi jälgimissüsteemil põhineva arvuti asendamiseks.

See lahendus loodi Eesti Energia AS ITabi tehnilise toe meeskonnale personaalarvutite asendamise protsessi optimeerimiseks, kuid seda saab rakendada ka teistes ettevõtetes, kus on arvutite asendamise protsess.

Väljatöötatud lahendus jagunes 3 osaks: universaalse raamistiku loomine personaalarvutite asendamiseks, päästikute loomine Zabbixile, et ITabi meeskonda vajadusest automaatselt teavitada ning raamistiku ja päästikute testimine spetsiaalsetes personaalarvutites.

Arvuti asendamise protsessi optimeerimine peaks suurendama ITabi tõhusust meeskonnana ja arvutite väljaandmise kiirust, hoides seeeläbi kasutajate rahulolu teenusega.

Lõputöö on kirjutatud inglise keeles ning sisaldab teksti 43 leheküljel, 7 peatükki, 6 joonist, 3 tabelit.

# List of abbreviations and terms

| | |
|---|---|
| BIT | Business Information Technology |
| CPU | Central Processing Unit |
| CRP | Computer Replacement Program |
| HDD | Hard Drive Disk |
| ITabi | ITabi is an IT support service |
| KP | Employee Request/Kasutaja Pöördumine |
| SDD | Solid State Drive |
| S.M.A.R.T. | Self–Monitoring, Analysis and Reporting Technology System |
| SRE | Site Reliability Engineering |
| *nix | Unix–like |

# Table of contents

# List of figures

# List of tables

# 1 Introduction

« Mission – All our energy for the good of people! » [1]

Eesti Energia AS is an international energy company owned by the Estonian state. Eesti Energia AS operate in the markets for electricity and gas sales in the Baltic States, Finland and Poland, as well as on the international market for liquid fuels. Eesti Energia AS also create energy solutions from the production of electricity, heat and fuels to innovative sales, client services and energy related additional services. The main ambition of Eesti Energia AS is to offer our clients useful and convenient energy solutions and to produce energy ourselves, in an increasingly environment conserving way, as thus Eesti Energia AS will make our contribution into making the world cleaner [1].

At the time of writing, 4,435 people work for Eesti Energia AS [2].

Almost every one of the 4,435 people must work or minimally interact with a computer. People use either desktop computers or laptops to perform casual work tasks. Thus, Eesti Energia AS currently has a total of more than 10,000 devices, which is registered in the Jira Insight – Asset Management system. Out of devices – 990 stationary computers, 2746 laptops and 267 terminal clients. Based on the data above, about 57% of people working for Eesti Energia AS have their own laptop [3].

This work covers the creation of a framework and Zabbix–based triggers for replacing workstations. At this stage, the replacement of workstations is done on the basis of logic.

The main principle of Business Information Technology (BIT) at Eesti Energia AS is next "If the employee says that something is broken or does not work for him, ITabi will immediately replace his workstations."

The work itself will consider the possibilities of creating a framework for replacing a computer, analyzing possible data that can be taken from the workstation and importing it into Zabbix, analysis of the data from computer to select the most useful and necessary data on replacing a workstation for Eesti Energia AS, as well as creating triggers based

on Zabbix. Zabbix triggers created on the basis of the framework would automatically send a notification about the need to replace a workstation with a direct one to ITabi.

This topic is very relevant for Eesti Energia AS since now workstations are being replaced at the request of employees. Statistically, 1–2 replacements occur per week. It takes a lot of time for one replacement. According to the author of the thesis, optimization of the process of replacing and issuing workstations will increase overall efficiency. If something does not suit them or they want to change a workstation running Windows for macOS, the replacement will also be carried out. Therefore, ITabi needs a precise framework within which the replacement of an employee's workstations can be done.

The resulting framework and triggers for Zabbix can be universal and can be applied to any company or enterprise that would like to improve the system for replacing workstations for staff, where employees have the ability to request a replacement of workstations, as well as where in the company or enterprise as a monitoring system installed Zabbix with triggers written in this work.

## 1.1 Task Setting

The main research questions that the author will want to answer during the work will be:

1. Is it possible to create a universal framework and optimize the process of replacing employees' workstations?
2. What data should be collected and used to create triggers in Zabbix to receive an automatic notification about the need to replace employees' workstations?
3. Are there alternative monitoring tools in Eesti Energia AS to solve the problem instead of Zabbix?

After receiving answers to these questions, a conclusion will be made based on which significant changes will be made in the process of replacing employees' computers.

The creation of the framework will include analysis of three processes: from ITILv4 – 5.2.6 IT asset management [4], COBIT v4.1 – AI3 Acquire and Maintain Technology Infrastructure [5, p 81] and IT Asset Management: It's All About Process by Provance [6].

Based on the data from all three sources, a single framework will be drawn up that will optimize the process of exchanging employees' workstations based on Eesti Energia AS needs.

To create Zabbix triggers, the computer metrics from Self–Monitoring, Analysis and Reporting Technology System (S.M.A.R.T.) monitoring tools only will be taken. Later, it will be necessary to analyze all kinds of data or metrics that can be obtained using this tool. Then it will be necessary to select from this data the most important and useful ones and based on them, create triggers.

To test the performance of triggers created in the process of work, the focus group was chosen, which consists of ITabi employees who visit the office. As a result, the focus group consists of 5 people. All 5 people in the focus group have different workstations, which makes the testing more general.

For the objectivity of the tests, the load conditions will be the same regardless of the age of the computers. The test results will show if there is a difference between new and old computers. According to the results obtained, changes will be made to Zabbix triggers, if necessary.

To evaluate the effectiveness of the framework and triggers, it will also be necessary to conduct testing in a real ITabi environment.

After the trial period of the framework, reviews will be accepted both from ITabi employees, as well as from employees whose computers were replaced according to the rules of the new framework.

Results based on feedback will help to improve the framework or/and triggers.

# 2 Problem overview and formulation of the assignment

In the following chapters general overview of employee's workstation replacement process, work's scope and limitations will be analyzed. Moreover, at the end of the chapter, the author's role will describe the impact of the author in that work.

## 2.1 General overview

Throughout the existence of Eesti Energia AS, the replacement of computers from all Eesti Energia AS companies and subsidiaries has been carried out by the BIT department – ITabi.

ITabi solves any IT problems encountered by Eesti Energia AS employees, including the replacement and installation of equipment. At the time of the author's arrival in the company, there is still no clear framework for replacing the workstations of the company's employees.

Why is it important? Because for each computer the employee uses, a rental fee is charged. The rental fee is proportionally divided according to the formula: computer cost divides the warranty period into months. For a more competent distribution of finances and their management, it's important to need to know about replacing the employee's personal workstation. Facts such as how many, when and which computers were replaced are important. Knowing these facts makes it much easier to manage IT assets and finance questions.

The lack of a framework in the current situation allows the employee to trick ITabi and leave the computer to himself. For example, if the employee says that he broke the computer and needs a replacement, ITabi will provide the employee with a replacement, and if desired, the employee can buy back the "broken" computer. Thus, Eesti Energia AS loses money and the employee gets a new computer. Although, if a workstation has a residual value that was not covered during the lease, the worker is required to pay it.

Since there is no clear framework now, ITabi has 3 reasons for replacing an employee's workstations:

- The computer was broken / crashed / lost / stolen
- The computer is no longer suitable for performing work duties.

Replacing a computer is also a rather long process. It usually takes about up to 1 day to replace a computer. The author of the thesis thinks that this is fine, especially in today's times when more than 60% of Eesti Energia AS employees work from home.

Eesti Energia AS employees just cannot work without a workstation. Often, employees have to wait for their computer and because of that delay, employees cannot work and as a result, that delay affects the company and overall productivity.

## 2.2 Work's scope and limitations

Eesti Energia AS uses 3 monitoring tools: Zabbix, Jira Insight Discovery, Insight Analytics. Within the framework of this thesis, the creation of triggers only for the Zabbix monitoring system will be considered. The main focus of the work will be on creating automatic triggers in Zabbix. In combination with Zabbix triggers, the possibility of sending automatic notifications to the ITabi team will be considered.

The presented solution to the problem is divided into 3 parts: collecting data and sending it to the Zabbix Agent, Zabbix Agent sending data to the Zabbix Server, processing data and firing triggers.

Zabbix works via three discovery mode options: Network discovery periodically scans an IT environment and records a device's type, IP address, status, uptimes and downtimes. Low–level discovery automatically creates items, triggers and graphs based on the discovered device. In the case of this thesis, Low–level discovery will not create items and triggers, it should be done manually [7].

Collecting data and sending it to the Zabbix Agent is to find out what metrics can be taken from the workstation and sent to the Zabbix Agent.

Then Zabbix agent will send metrics to the Zabbix server where they will be processed by the server. The agent gathers operational information locally and reports data to the

Zabbix server for further processing. In case of failures (such as a hard disk running full or a crashed service process), the Zabbix server can actively alert the administrators of the particular machine that reported the failure [8].

After the data is received by the Zabbix server, the triggers will wait for the trigger conditions. After the trigger is fired, an automatic notification will be sent and KP automatically will be created.

The study does not cover the other monitoring tools such as Insight Discovery, Insight Analytics, Snow Software. Later, comparisons will be made with the listed tools, but they will not be used to solve the defined problem. Also, Unix–like (*nix) system such as macOS and Linux are out of scope since Linux mostly used for servers and MacOS has very few people at Eesti Energia. The Zabbix triggers for the *nix system will be implemented in the future.

## 2.3 Author's role

In this thesis, the author acted as a system administrator to solve the problem. The author of the thesis analyzed the existing problems in the ITabi team, including the processes of replacing employees' workstations. The author of the thesis decided to optimize the process of replacing employees' workstations since this process is crucial for the ITabi team and for the entire Eesti Energia AS. Other monitoring tools were analyzed and compared with Zabbix, and it was explained why these monitoring tools were not suitable for achieving the goals of the thesis.

The author studied various scientific sources, books, manuals and articles related to the optimization of the process of replacing employees' workstations. The author also found a few scientific sources and articles which describe a similar problem

The Zabbix test environment was prepared by the SRE team, where the author of the thesis conducted the creation and testing of triggers. Triggers were created in accordance with the data needed to replace employees’ workstations and the needs of the company. The author himself searched for all the information about creating and testing triggers. Setting up the Zabbix test environment for your needs was done by the author with the help of consultations from several engineers from the SRE team.

In collaboration with all members of ITabi team and SRE team, the solution was successfully implemented. The final framework was adjusted taking into account the opinion of everyone from the ITabi team. The author participated in the development of each part of the solution, from the creation of the framework to the implementation of the solution.

# 3 Methods and tools

The main problem of the BIT department of Eesti Energia AS is the lack of a clear process for replacing workstations, it was decided to create and optimize this process. The created solution to the problem should help speed up the process of replacing employees' workstations, save the enterprise money and the time of workers who could devote their time to solving other, more important, problems.

Since the author of the thesis is interested in automation and wants to help and improve Eesti Energia AS's company, it was decided to create a framework for the replacement of the employee's workstations. Since the work methodology at Eesti Energia AS is defined as a combination of Agile and DevOps, it was decided to use the best practice methodology in ITIL, COBIT, Provance Asset Management and other scientific sources.

Third-party views and solutions to similar problems have been fully analyzed and compared with the current situation at Eesti Energia AS. All optimal solutions that will help to better optimize this process will be taken into account, but will also be verified against information from ITIL, COBIT and other similar sources for process optimization.

## 3.1 Method overview

The main part of the work will be divided into 2 parts:

1. Theoretical analysis of collected information and data.
2. Analysis of practical results.

Although these 2 parts are basic, they have been subdivided into smaller, precise subparts. In the opinion of the author of the thesis, this approach is more rational, especially when the whole picture needs to be added to small parts.

The theoretical part will be divided into 4 parts:

1. Analysis of S.M.A.R.T. monitoring tools.

2. Analysis of the data needed to create Zabbix triggers.
3. Comparison and analysis of different monitoring systems in Eesti Energia AS.
4. Analyze data on process creation and optimization from best practices, frameworks like ITILv4, COBITv5.1 and Provance Asset Management.

The practical part will be divided into 2 parts:

1. Creation and configuration of Zabbix triggers.
2. Testing the process and Zabbix triggers.

In the theoretical part, it will be explained what kind of data, what information and how it should be processed. It is also important to separately pay attention to the part with the organization and optimization of the process.

The practical results will show how well it turned out to create and optimize the process of replacing workers' workstations.

After collecting all the necessary metrics and data, it will be concluded which metrics and data would help improve the process of replacing workstations, since you need to know that the computer really needs to be replaced, the collected metrics and data will help in the analysis and making the final decision on replacing the workstation.

## 3.2 Overview of the tools

Since different tools and approaches could be used to achieve the goal, the author of the thesis decided to focus on specific tools that fit best. In this particular case, to achieve the goal set in this thesis, the following tools were used:

- ITILv4 – The ITIL approach provides guidance to organizations and individuals on how to use IT as a tool to facilitate business change, transformation and growth. ITIL advocates that IT and digital services are aligned to the needs of the business and support its core objectives and goals [28].
- COBITv5.1 – The Control Objectives for Information and Related Technology (COBIT) is a “trusted” open standard [26] that is being used increasingly by a diverse range of organizations throughout the world. COBIT is arguably the most appropriate control framework to help an organization ensure alignment between

the use of Information Technology (IT) and its business goals, as it places emphasis on the business need that is satisfied by each control objective [27].

- Provance Asset Management – IT Service Management is the most Microsoft–centric ITSM solution on the market, letting you digitally transform both IT and your business by leveraging the Microsoft Intelligent Cloud [29].
- Zabbix – mature and effortless enterprise-class open-source monitoring solution for network monitoring and application monitoring of millions of metrics [30].
- Python – interpreted, object-oriented, high-level programming language with dynamic semantics [31].
- PowerShell – cross-platform task automation solution made up of a command–line shell, a scripting language, and a configuration management framework. PowerShell runs on Windows, Linux, and macOS [32].
- Insight Discovery – an agentless network scanner for IP-enabled hosts and devices. The collected data is imported into the Insight database for Jira Service Management [17].
- S.M.A.R.T. monitoring tools – control and monitor storage systems using the Self–Monitoring, Analysis and Reporting Technology System (S.M.A.R.T.) built into most modern ATA/SATA, SCSI/SAS and NVMe disks [34].

## 3.3 The main tool for monitoring in Eesti Energia AS – Zabbix

Zabbix is a very flexible monitoring tool that allows both polling and trapping. It can be used either through a server–agent application where the agent sends data to the server or through one or more servers that poll the results from the monitored devices. Zabbix works very well and is scalable when using its agents running on the monitored host and distributed monitoring [9].

Zabbix provides many ways of monitoring different aspects of your IT infrastructure and, indeed, almost anything you might want to hook up to it. It can be characterized as a semi-distributed monitoring system with centralized management. While many installations have a single central system, it is possible to use distributed monitoring with proxies, and most installations will use Zabbix agents [10].

The list of the features which Zabbix provides:

- A centralized, easy to use web interface
- A server that runs on most UNIX–like operating systems, including Linux, AIX, FreeBSD, OpenBSD, and SolarisNative agents for most UNIX–like operating systems and Microsoft Windows versions
- The ability to directly monitor SNMP (SNMPv1, SNMPv2c, and SNMPv3) and IPMI devices
- The ability to directly monitor Java applications using Java Management Extensions (JMX)The ability to directly monitor vCenter or vSphere instances using the VMware APIBuilt–in graphing and other visualization capabilities
- Notifications that allow easy integration with other systems
- Flexible configuration, including templating
- A lot of other features that would allow you to implement a sophisticated monitoring solution [9].

Also, Zabbix has the automatic features, such as:

- Network discovery: periodically scans network and discovers device type, IP, status, uptime/downtime, etc., and takes predefined actions.
- Low–level discovery: automatically creates items, triggers, and graphs for different elements on a device.
- Auto–registration of active agent: automatically starts monitoring new equipment with Zabbix agent [11].

However, Zabbix does have some disadvantages such as the learning curve is high and proper configuration involves a lot of "trial–and–error" approach. The structure of the official documentation is hard to follow and information chatters through different pages. But on the other hand, the flexibility and highly customizable possibilities outcome the negative sides. The employee can modify the base code and develop their own solutions to problems. There is also a strong community to provide employee support, templates and custom scripts to employees. Zabbix offers the possibility to monitor everything from server hardware, routers, printers, logs, to running services and a way to execute remote commands. The rule of thumb is that if some item has an output, it can be monitored with Zabbix [14].

The most significant part of Zabbix is items. Items are the ones that gather data from a host. Once you have configured a host, you need to add some monitoring items to start

getting actual data. An item is an individual metric. One way of quickly adding many items is to attach one of the predefined templates to a host. For optimized system performance though, you may need to fine-tune the templates to have only as many items and as frequent monitoring as is really necessary [12].

In order to create an item that gathers data host must be created first. Moving to the other end of the Zabbix spectrum an item should exist in order to create a trigger. After that existing trigger should be used for action creation. Thus, to receive an alert that the central processing unit (CPU) load it too high on Server X, firstly it is significant to create a host entry for Server X followed by an item for monitoring its CPU, then a trigger which activates if the CPU is too high, followed by an action which sends an email to specified people. While that may seem like a lot of steps, with the use of templating it really isn't. However, due to this design, it is possible to create a very flexible setup [13].

Zabbix can monitor computers and automatically notify ITabi team about next events:

1. Workstation’s blue screen of death
2. The need to replace the battery

Also, the important items and triggers have been already configured at every employee’s computer at Eesti Energia AS can be seen in Table 1 [19], [20], [35].

**Table 1. List of Zabbix items at Eesti Energia AS**

| **Item’s name** | **Description of item** |
|---|---|
| CPU utilization | The returned value is based on single CPU core utilization percentage. |
| Disk I/O | This item corresponds to the number of disk Input/Output operations. For example, in order to read information from a file, it is needed that the process reads this file first (the same happens with writing) |
| Disk [ C:] | Disk C: memory usage |
| Disk Queue | Current average disk queue, the number of requests outstanding on the disk at the time the performance data is collected. |
| Memory | All information about RAM memory |
| Uptime | System uptime in 'N days, hh:mm:ss' format. |

Each parameter that this table contains is very helpful in monitoring the current state of computers. Triggers from this table serve as indicators, and the data that will be obtained using these triggers will be decisive when replacing employees' workstations. This table

allows you to almost immediately identify people who may need a new computer, despite the fact that their computer is not older than 36 months and don’t have any problems with doing work tasks.

## 3.4 Overview of already existing problem solution

This chapter will consider an already existing similar problem solution, which is solved within the framework of this thesis. From the overview of existing solutions, the author of the thesis will highlight the nuances of the considered solution, as well as highlight potential good solutions and moves. The author of the thesis will take them into account when solving the Eesti Energia AS problem.

### 3.4.1 Overview of the solution of the University of San Diego

Now the author of the thesis will consider a solution to the problem of replacing workstations using the example of the University of San Diego.

Equipment purchased or replaced by the replacement budget is the property of the institution, not of the department or individual. Departments must surrender alike computer for each computer installed under Computer Replacement Program (CRP). This includes any special monitors, keyboards, add–on cards, etc. that were purchased as a part of the original CRP purchase. Departments may not repurpose existing departmental computers within the department to expand the number of computers supported. If the department wishes to keep the old equipment for other uses, a request must be made in writing. Recycled equipment will not be considered as part of the 3–year replacement cycle [15]. Eesti Energia AS uses a similar system with a 3–year computer replacement cycle. If the computer is more than 3 years old and has some problems and moreover cannot be used for doing work tasks, it must be replaced and a new one given to the employee. All old computers are sold and put up for auction. In rare cases, they are issued for tests and, if necessary, they are also issued to trainees. If the computer is less than 3 years old, then it goes into the "reuse" status, similar to the redeployment inventory list of the University of San Diego.

All computers slated for replacement will be assessed by Information Technology Services to determine the feasibility of redeploying units. If units are deemed appropriate for redeployment, Information Technology Services will:

- Identify units in Information Technology Services' redeployment inventory list;
- Clean and re–image computers;
- Load appropriate anti–virus software on computer;
- Assign to next faculty or staff on the "In–line for Used/Refurbished Computers" list;
- Deliver and install computer to requesting faculty or staff – joining to USD's network;
- Transfer the asset in Computer Inventory list; [15]

This process is very similar to that used by ITabi to replace workers' computers. The only difference is that a new and clean OS is not installed on the computer immediately after the employee has returned the old computer. This is done only before handing over the computer to a new employee. According to the author of the thesis, it is more effective to reinstall the OS immediately after the employee has handed over the computer because it is not known who and when will need this computer. And if another employee needs it, it will be almost ready and ITabi just needs to configure it properly. If units are deemed inappropriate for redeployment, Information Technology will:

- Clean computer and return to lease company
- Cleans computer and breakdown (take apart) in order to identify working parts
- Recycle parts to refurbish/repair computer other units

In some cases, ITS will purchase and keep some computers off the lease so that we can utilize them in our recycled program and provide them to departments for adjunct use or special project use. These computers are available for sale to the departments at a low fair market value [15]. This case can be considered as the best practice method. The author of the thesis considers it good practice to analyze a broken computer and take working parts from it. According to the author of the thesis, this would allow the company to save money. Now at Eesti Energia AS, broken computers that have no warranty and which are difficult to fix or cost more than buying a new computer will be scrapped. No parts are removed from broken computers. The author of the thesis will propose to introduce this

practice and, based on the conclusions of colleagues from the ITabi team, a decision will be made regarding this practice.

### 3.4.2 Overview of the solution of the University of Washington Bothell

In this chapter will be watched another point of view to process of replacement of the computers. The author of the thesis will consider a solution to the problem of replacing workstations using the example of the University of Washington Bothell. The United States of America universities more or less have the same system of computer replacement. The crucial point here is that The University of Washington Bothell suggests another point of view for the workstation replacement process.

Scope of the University of Washington Bothell is next: this policy applies to the computing equipment provided to the faculty members (including full–time lecturers) and permanent staff of the University of Washington, Bothell purchased using Information Technologies funds other than department or startup funding. This policy covers ONE machine per 4–year lifecycle. A lifecycle is the 4–year period after which a primary workstation will be considered for replacement [16]. Unlike Eesti Energia AS, they use a 4–year replacement cycle for workstations of employees. This cycle can take 3–5 years. This directly depends on the financial capabilities of the enterprise, although this cycle helps to reduce costs and make asset management more efficient and reasonable, they will still be large.

Computing workstations used by student workers are not covered under the equipment replacement process. Computers that are recovered during this process will be evaluated for usefulness and made available for upgrades if newer than the current student workers computer. Departments may also purchase computers for student workers if the computers available do not fit their needs [16]. Although at Eesti Energia AS, any employee has the option of replacing the computer, the replacement must be justified. Unlike the University of Washington process, Eesti Energia AS employees cannot get a new workstation until the old computer is at least 36 months old or 3 years old.

The University of San Diego has the next rationale for such politics. UWB is committed to ensuring that each faculty and staff member has access to a modern computing platform to support the mission of the university. In the fulfillment of this commitment, this policy is designed to guide the regular replacement of computing equipment [16]. The author of

the thesis and Eesti Energia AS are in solidarity with the University of Washington on streamlining the workstation replacement process. Eesti Energia AS also strives to provide all employees with modern and advanced computers to get the job done most efficiently. Since some employees do not need computers to perform their direct work duties, they are assigned shared workplaces, which also fall under the 3–year equipment replacement cycle. Unfortunately, some workplaces are not often used, so replacing such shared computers can be problematic.

Now, the author of the thesis would like to overview the summary about the University of Washington Bothell. When the standard 4–year lifecycle on an existing system ends, the options for replacement are as follows:

1. Pick from one of the standard configurations in the table below. At the end of the 4–year cycle, the system will be replaced per this policy and the old system re-deployed within UWB or disposed of in accordance with UW Bothell policies.
2. Propose a custom configuration. UWB IT will provide up to the amount for a standard configuration (based on yearly economic and budget factors) toward a single system. School/Department budgets are responsible for covering additional costs for custom configurations. (Custom configurations require consultation with IT staff to ensure that the purchase is compliant with all UWB and IT purchasing policies) [16].

University policy dictates that no refurbished equipment may be purchased. All equipment is newly manufactured and distributed to UW Bothell by contracted vendors [16]. At Eesti Energia AS the employees also cannot buy out a repaired computer or just a computer that has been issued for use. The only exception is that employees can buy a computer only by replacing it at the end of its life cycle. The author of the thesis and Eesti Energia AS fully agree with this policy of the University of Washington, since the asset still has economic value and can be profitable from it.

University of Washington Bothell has the next policy statements: life–cycle replacement of faculty and staff computing equipment is intended to ensure that their primary computing resource is sufficiently modern and powerful. To this end, UW Bothell will replace a faculty or staff member's primary workstation at a regular interval. This interval will typically be 4 years. A standard and custom configuration machines will be redeployed to a secondary location within UW Bothell beyond the lifecycle period. The

additional use beyond the end of the lifecycle period provides UW Bothell students, faculty, and staff with additional computing resources and as a result, extends funding available for the standard configuration options [16]. The small conclusion about that process: this process is very similar to the current process currently used by BIT at Eesti Energia AS. The only difference is that Eesti Energia AS uses a 3–year equipment change cycle. Also, at Eesti Energia AS, employees cannot choose the computer they receive, because the basic principles of BIT are to recycle all possible equipment, including employees' workstations. The only exception is a custom–made computer for performing special work duties, which were previously justified and scheduled in writing. The University of Washington Bothell counts the addition of RAM or similar components as the custom configuration, while Eesti Energia AS only offers standard assemblies. It is also important to note that all replaced vehicles at the University of Washington Bothell must be returned only if they have not been stolen or lost. Eesti Energia AS is not obliged to return the equipment if, when replacing the equipment with a new one, it wishes to buy out the old workstation. In general, the processes are similar. It was possible to try to implement in Eesti Energia AS a system for the return of any employee's workstation. An exception would be the loss or theft of your computer. This will save money on repairing non–warranty computers.

## 3.5 Comparing Zabbix with other monitoring tools in Eesti Energia AS

Zabbix is not the only tool monitoring used by Eesti Energia AS. Besides it, Insight discovery and Insight Analytics are also used. All monitoring tools are useful and share common features at Eesti Energia AS.

Insight Discovery is an enterprise network scanning with automated asset discovery and dependency mapping [17]. Insight is used for asset and configuration management. It’s like a database that stores everything you own – from hardware and software to offices, keyboards and licenses, Insight can store whatever information or data need it to store:

- Business services (billing, email, payroll)
- Hardware and software (servers, computers, mobile phones, software licenses)
- Employees (John, Mary, Mathias)
- Offices (Sydney, Melbourne, Stockholm)

- Server components (RAM, network adapters, hard drives) [18].

Both Zabbix and Insight Discovery are asset management tools, but approach this in different ways. Zabbix is more used for hardware monitoring and control of hardware metrics and data. Insight Discovery approaches this issue from a different angle. Insight Discovery helps to better organize the IT asset management and monitoring of the devices themselves, rather than their metrics and indicators. Thanks to Insight Discovery, the administrator or analytics can easily find out the history of any device, see the list of owners, see any changes associated with this device. And the biggest advantage is efficient asset management. Anyone with access to Insight Discovery can always find out the most important information about any registered IT asset in the system.

Although Zabbix, of course, can also monitor assets and act as an asset register, it doesn't have the same functionality and flexibility as Insight Discovery. The data that Zabbix can take for information is the internal data of the asset itself, for instance, Zabbix can maintain host inventory information (e.g., serial number, MAC address, OS, software) [21]. If desired, anyone who has the access or rights can get any metrics from Zabbix that are related to any IT asset. This is an undoubted advantage since over time Eesti Energia AS needs to track a particular metric that may change whereas Zabbix is a flexible and universal tool that is constantly evolving, which, according to the author of the thesis, is its greatest advantage.

# 4 Data analysis based on Zabbix

This section will consider the S.M.A.R.T. technology, which will be used to extract data and metrics from a computer. After that, the collected data will be delivered to the Zabbix item. Triggers will be created based on these Zabbix items, which will be monitored at a configured frequency.

## 4.1 Zabbix S.M.A.R.T. Monitoring tools

S.M.A.R.T. montools (S.M.A.R.T. Monitoring Tools) is a set of utility programs (S.M.A.R.T. ctl and S.M.A.R.T. d) to control and monitor computer storage systems using the Self–Monitoring, Analysis and Reporting Technology (S.M.A.R.T.) system built into most modern (P) ATA, Serial ATA, SCSI / SAS and NVMe hard drives. S.M.A.R.T. montools displays early warning signs of hard drive problems detected by S.M.A.R.T., often giving notice of impending failure while it is still possible to back data up [34].

According to the author of the thesis, the templates prepared in advance already contain a fairly good number of functions that can later be improved or changed. To improve the performance of the template, it will be possible to rewrite it in another programming language that works faster than the original programming language in which the template was written. Also, if the capabilities of any template are not enough, then it is possible, if necessary, to add the output of the necessary attributes that would facilitate monitoring of the hardware.

At the time of writing thesis, the following templates were available on the Zabbix official website [22]:

- S.M.A.R.T. monitoring with S.M.A.R.T. montools (LLD, DI)
- zbx–S.M.A.R.T. monitor
- S.M.A.R.T. monitoring with S.M.A.R.T. montools (LLD, Trapper)
- Storage Device Monitoring via S.M.A.R.T. montools

- S.M.A.R.T. monitoring with S.M.A.R.T. montools
- smregex
- Cross–platform S.M.A.R.T. monitoring (LLD, Trapper)

Each of these templates has its own sets of items and triggers, but often the general purpose of templates is the same and they all contain duplicate elements. Also, the difference is that all these templates are written in different programming languages, and therefore, we can conclude that the speed of their work is also different. The speed of the triggers depends on the programming language and it is also a very important factor since the speed of our team's response to the problem depends on the speed of receiving data. The sooner the ITabi team receives information about a breakdown or potential breakdown, the better because the team will be able to prepare the computer in advance for replacement.

Unfortunately, templates with good functionality «zbx–S.M.A.R.T. monitor» and «S.M.A.R.T. monitoring with S.M.A.R.T. montools » will not be considered in this thesis, since the version of Zabbix used in Eesti Energia AS is not suitable for using these templates, and to use these templates, versions 4.4.x and 3.4.x are required, respectively. The author of the thesis suggests that some of the functions of these templates could still work on the current version of Zabbix in Eesti Energia AS, but there is no guarantee that they will work completely and correctly.

Although smregex and Storage Device Monitoring via S.M.A.R.T. montools were the good candidates for implementation, their greatest drawback is that they work only on *nix system. And since almost everyone in Eesti Energia AS uses Windows, these options are out of the scope of the work and they are not efficient from the point of view of the enterprise.

Thus, out of 7 candidates, only 3 remained: S.M.A.R.T. monitoring with S.M.A.R.T. montools (LLD, DI), S.M.A.R.T. monitoring with S.M.A.R.T. montools (LLD, Trapper), Cross–platform S.M.A.R.T. monitoring (LLD, Trapper). All candidates can and are able to work with most versions of Zabbix, and also work without a problem on almost all operating systems, including Windows. Now the author of the thesis will consider them in more detail and the main features of every template will be described and analyzed carefully.

### 4.1.1 S.M.A.R.T. monitoring with S.M.A.R.T. montools (LLD, DI)

The S.M.A.R.T. monitoring with S.M.A.R.T. montools (LLD, DI) is described as template with discovery scripts for monitoring disks S.M.A.R.T. attributes using S.M.A.R.T. montools in Zabbix. Zabbix server 3.4+ is recommended with dependence items support but there are also older templates for 3.2, 3.0, 2.4, 2.2 provided as is. Discovery scripts should work with them too [23]. This template is the most popular and frequently downloaded in the S.M.A.R.T. montools section, so the author of the thesis immediately drew attention to it. The selected template has good functionality, is written in 4 programming languages and can work perfectly with almost any OS. The only drawback, according to the author of the thesis, is that the recommended version of Zabbix required for work is 3.4+. The conclusion made by the author of the thesis was disappointing. Most likely, this template will not work on the version, but this should be verified by testing. the author of the thesis believes that in the event of a problem or some kind of malfunction of the program, it cannot be corrected by writing additional code. The main features of S.M.A.R.T. monitoring with S.M.A.R.T. montools are:

- Supports SATA, SAS and NVMe devices
- Two discovery scripts – for Linux/BSD/MacOS and Windows
- Simple discovery in MacOS by scanning /dev/disk/* (macOS)
- Discover with S.M.A.R.T. ctl —scan–open (nix, windows)
- Discover NVMe devices with S.M.A.R.T. ctl —scan–open –dnvme
- Discover Hardware RAID with sg_scan (nix only)
- Discover NVMe devices with nvme–cli (nix only)
- Handling usbjmicron (nix only)
- Handling Areca SATA RAID (nix only)
- Try to enable S.M.A.R.T. if it is disabled (nix, macOS, windows) [23]

The author of the thesis believes that the functions of this Template are useful for solving the problem, the detection of disks that are connected to the NVMe port, which are mainly used by SSDs in desktop workstations. Since ITabi is also involved in the maintenance and replacement of desktop workstations, this is also an important point. Unfortunately, the rest of the useful functions work mainly on *nix systems. Since there are employees in Eesti Energia AS who use macOS, this is usually an exception to the rule and will therefore receive less attention.

### 4.1.2 S.M.A.R.T. monitoring with S.M.A.R.T. montools (LLD, Trapper)

Description of the S.M.A.R.T. monitoring with S.M.A.R.T. montools (LLD, Trapper) contains the following text: This is the template for Zabbix providing S.M.A.R.T. monitoring for HDD using S.M.A.R.T. ctl utility. LLD is used for disks discovery. Only devices with S.M.A.R.T. enabled will be discovered. Get all S.M.A.R.T. attributes from S.M.A.R.T. ctl and some other attributes of device. Required: *nix OS, S.M.A.R.T. montools, sg kernel module and sg_map utils [24]. Unfortunately, the author of this template did not describe a single function or trigger, and therefore, to find out what this template is, it remains to be learned only in practice. But based on the original article, where the author of the template describes the principles of this template, the author of the thesis is not sure that this template is suitable for use on Windows operating systems.

### 4.1.3 Cross–platform S.M.A.R.T. monitoring (LDD, Trapper)

The author of the template describes Cross–platform S.M.A.R.T. monitoring (LLD, Trapper) as Cross–platform S.M.A.R.T. monitoring scripts with two display modes: device and serial. LLD discovers and sends data in one pass, using a minimal number of utilities. Supports any S.M.A.R.T. name and displays it as is [25]. This S.M.A.R.T. template is a pretty good candidate for use by Eesti Energia AS. Good functionality, there is a small FAQ where is possible to find answers to the common questions. Unfortunately, the author of the template is no longer involved in the development, so there is no talk of any support from the creator. Next, the author of the thesis will consider the functionality of this template in more detail. The template has the next functions:

- Utilises S.M.A.R.T. ctl error return codes
- Low–Level Discovery
- SAS support
- SSD wear monitoring (SAS only)
- csmi support
- Efficient: no unnecessary processes are spawned
- Bulk items upload with zabbix–sender
- Error–proof configuration: various safeguard triggers
- Automatic RAID passthrough (when S.M.A.R.T. ctl detects the drives)

This particular template is quite unique compared to all other templates. Only this template works for everyone, it works with most operating systems, there are already pre-created triggers that will only have to be configured after installation. Also unique is the data on the temperature of physical disks, which is very important to monitor and check regularly. According to the author of the template, the only programming language he used was a python. Although python is not the fastest programming language, it is quite good for templates. If the speed of python is not enough, theoretically, it will be possible to rewrite it in another faster programming language. This is possible since this template is under the "The Unlicensed" category.

| | |
|---|---|
| Information | {#DISKID}: Device name had changed on {HOST.NAME} |
| Information | {#DISKID}: Firmware version had changed on {HOST.NAME} |
| Information | {#DISKID}: No SMART values were discovered |
| Information | {#DISKID}: Serial number had changed on {HOST.NAME} |
| Warning | {#DISKID}: SMART is available but disabled |
| Information | {#DISKID}: SMART is unavailable - device lacks SMART capability |
| Disaster | {#DISKID}: SMART self-test had FAILED on {HOST.NAME} |
| Disaster | {#DVALUE5}: [5]{#SMARTNAME} has changed within past 5 days on {HOST.NAME} |
| Problem | {#DVALUE5}: [5]{#SMARTNAME} is more than 0 on {HOST.NAME} |
| Warning | {#DVALUE10}: [10]{#SMARTNAME} has changed within past 5 days on {HOST.NAME} |
| Warning | {#DVALUE11}: [11]{#SMARTNAME} has changed within past 5 days on {HOST.NAME} |
| Problem | {#DVALUE184}: [184]{#SMARTNAME} has changed within past 5 days on {HOST.NAME} |
| Disaster | {#DVALUE187}: [187]{#SMARTNAME} has changed within past 5 days on {HOST.NAME} |
| Problem | {#DVALUE187}: [187]{#SMARTNAME} is more than 0 on {HOST.NAME} |
| Problem | {#DVALUE188}: [188]{#SMARTNAME} has changed within past 5 days on {HOST.NAME} |
| Warning | {#DVALUE188}: [188]{#SMARTNAME} is more than 0 on {HOST.NAME} |
| Problem | {#DVALUE197}: [197]{#SMARTNAME} is more than 0 on {HOST.NAME} |
| Problem | {#DVALUE198}: [198]{#SMARTNAME} is more than 0 on {HOST.NAME} |
| Warning | {#DVALUE199}: [199]{#SMARTNAME} has changed within past 5 days on {HOST.NAME} |
| Problem | {#DVALUE200}: [200]{#SMARTNAME} is more than 0 on {HOST.NAME} |

Figure 1. List of triggers from Cross–platform S.M.A.R.T monitoring (LLD, Trapper)

Cross–platform S.M.A.R.T. monitoring has pre-prepared items and triggers, which makes it as easy as possible to work with this template. Also, all the functionality of this template can work perfectly with the Zabbix version in Eesti Energia AS. Moreover, this is only a

small list of available triggers, since there are many more of them than shown in the picture. But, unfortunately, most of these triggers are for informational purposes only and the information obtained from them cannot be used to create automatic notifications for replacing a computer. For example, information that the hard drive has been replaced could be used to detect tampering with the laptop case and replace the hard drive there. With such an attempt to open the warranty, the warranty is automatically cancelled and, accordingly, in the future, in case of any breakdown, this can cause serious problems and economic damage. Although this information is not key as a signal for replacing the computer, it can also be included in the list of used and enabled triggers.

## 4.2 Data analysis conclusion

After analyzing all possible options for creating triggers that will help with tracking faults and other hard disk metrics, the author of the thesis came to the conclusion that, judging by the general description of these templates, they perform similar functions, but again, they do it in their own way. Each template is written in its own programming language, some templates are from a mixture of different programming languages. Some of the templates were made for general use by other people, while others templates were written by people for their own specific purposes and only made available to the public. According to the author, it is better to use a general-purpose template with the most frequently used function and sets of already made triggers and the rest. It is also important to note that some of the templates may not support Windows, and since about 95% of computers in Eesti Energia AS use Windows as their main operating system, this indicator is critically important for deciding whether to use this template. It is also important to note that a huge plus is that, if necessary, it is possible to rewrite or add a template depending on company needs. This option can be considered if the built-in functionality is not sufficient to meet the needs of Eesti Energia AS.

It is also important to note that based on the data obtained as a result of the implementation of template S.M.A.R.T. in the Zabbix monitoring system, it will be possible to create a more complete picture of the state of workstations and the need to replace them. Based on this data, a list of general criteria will be generated to analyses the potential replacement of worker workstations. More details about the criteria and the metrics and data used in them will be written in the next chapter.

# 5 Solution realization

The process of the replacements of employee's workstations is not as simple as "take an old computer and give a new one". This process is complex and much more complicated than it looks like. It is always important to know what to do with a returned old computer and how to monitor a new one to ensure maximum control and value over the asset.

In some organizations, there is a centralized team responsible for IT asset management. This team may also be responsible for configuration management. In other organizations, each technical team may be responsible for the management of the IT assets they support [4]. In the case of Eesti Energia AS, the part of BIT – ITabi team, in which the author of the thesis works, is in charge of all possible support, configuration and monitoring of the asset. Thus, the author of the thesis is himself a part of all ongoing processes in ITabi and is often the executor of many replacements of employee's workstations.

## 5.1 Process description and optimization

Before starting, to create a framework for replacing workstations, it is necessary to define what an IT asset is. Referring to ITILv4 IT asset is any financially valuable component that can contribute to the delivery of an IT [4]. Thus, almost all computer technology used by Eesti Energia AS falls within this definition. Moreover, it is also very important to define what IT asset management takes and what concepts it includes. To do this, the author of the thesis decided to look again at ITIL, where there was a suitable definition for this. According to ITIL, the purpose of the IT asset management practice is to plan and manage the full lifecycle of all IT assets, to help the organization [4]:

- Maximize value
- Control costs
- Manage risks
- Support decision–making about purchase, re–use and retirement of assets
- Meet regulatory and contractual requirements.

Understanding the cost and value of assets is essential to also comprehend the cost and value of products and services, and is, therefore, an important underpinning factor in everything the service provider does [4]. It becomes clear that the value and cost of the asset itself are directly related to the value of the product and service with which the asset is associated. Therefore, it is crucial to carefully consider the meaning and need for each asset in order to get the maximum value.

The next step in creating a framework is the need to use an asset register. Since Eesti Energia AS employs 4,435 people and many of them have at least a workstation, monitor and docking station, the need to monitor these assets is enormous. According to ITIL, IT asset management requires accurate inventory information, which it keeps in an asset register [4]. Fortunately, Eesti Energia AS already uses the IT asset register and this is Jira Insight Discovery. As mentioned earlier, about 4 thousand different IT assets have already been recorded in Jira Insight Discovery. The thesis author will take a closer look at Jira Insight Discovery. Parameters in Jira Insight Discovery, which are required for each asset [33]:

- Asset type (monitor, dock, laptop and so on)
- Asset unique ID (One letter (depend on asset type) and 5 numbers)
- Jira Insight Discovery unique object ID
- Owner of the asset/responsible person
- Inventory date
- Physical location of the asset
- Model of the asset (depends on type)
- Serial number of the asset
- Price of the asset

About that case, ITIL says that it is important to know where they are and to help protect them from theft, damage, and data leakage. They may need special handling when they are re-used or decommissioned [4]:

IT asset management helps to optimize the use of valuable resources [ITIL book, p 168]. Accordingly, having all of the above data, IT asset management becomes much easier and more efficient. Any BIT employee can check the history of any asset added to the asset register at any time. This history will show all changes in any parameters in the asset

register. Mentioning ITIL, provide current and historical data, reports about IT assets is an important part of asset management [4].

In the case of replacing workstations, it is obvious that there is a need to change the owner of both the old and the new workstations, as well as change the date of inventory for the old computer, will be regarded as the date of delivery of the computer back to the ITabi, and for the new workstation, this date will indicate the date of issue of this workstation to the employee. That's a crucial aspect of the computer replacement framework.

In order to control assets, the company should do an audit of every asset it has. Quoting ITIL, audits are still needed, but these can be less frequent and are easier to do when there is already an accurate asset register [4]. As it can be seen, the timing and frequency of the audit is not specified, which means that the company itself can set them. The last audit at Eesti Energia AS takes place a few years ago. According to the author of the thesis, the last audit before that was about 2 years ago. Thus, it is possible to conclude that an audit at Eesti Energia AS takes place approximately every 2–3 years, depending on the need.

Further, according to ITIL – Hardware assets must be labelled for clear identification [4]. Eesti Energia AS uses such a system, that is, each asset has its own unique asset ID, which is applied to every asset. For a more comfortable use of the label, each asset type has its own definitions.

At Eesti Energia AS, every workstation has its own unique label and can be identified by it. In the case of accepting an old computer, it is very important to check not only the asset tag, but also its serial number, because if the employee wants, he can easily replace the tag with any other, but this will not work with the serial number.

Now let's take a closer look at the reasons for replacing workstations. at the moment, the following reasons are the main ones for replacing or giving a new workstation:

- The computer was broken / crashed / lost / stolen
- The computer is no longer suitable for performing work duties.

These reasons only partially fit the definitions of effective ITIL and COBIT asset management. The reasons for replacing any asset must be well–reasoned. An employee cannot just ask for a replacement computer at any time. This is not efficient for the company, nor from the point of view of logic and ITIL/COBIT of course. The author of

the thesis adds and combine the following reasons for replacing the employee's workstations:

- The computer is defective
- The computer is outdated and cannot perform work duties
- The computer has software trouble which cannot be fixed

After all this, a reasonable question arises: what to do with returned assets that are older than 3 years? The author of the thesis found the answer to this question in COBIT.

According to data from COBIT, such kind of assets should be marked as “Outdated IT Assets”. According to the author, this label can more effectively manage assets that have already left or are on the verge of exiting their life cycle. After the introduction of this concept, it will be necessary to determine what criteria the assets must meet in order to get into the "Outdated" category. The answer was found to the authors of the thesis.

Dividing assets into categories will help define their future more accurately and thereby help improve overall control over assets. IT assets can be categorized as Outdated Assets if they meet one of the following categories:

Lost or Stolen

- Relevant staff whose assets were stolen must report, using the form of lost or stolen assets supported by chronology and security reports (if necessary) to the ITabi, Finance and acknowledged by the employee’s manager. This issue will be noted in the asset register by the ITabi.
- The standard treatment for assets that are lost, stolen, or physically damaged (total loss of function), is decided after a case–by–case investigation. ITabi will investigate the case and follow up with an action approved by the IT head. After considering all facts, a decision will be made.
- After the investigation, if it is the employee's fault, the employee will have to pay a fine amount to the Eesti Energia AS. [5]

The employees will now be penalized for damage or loss of any of the assets. The very fact of the presence of fines will make employees more attentive to the issued assets. Since, once an employee asset has been issued by the ITabi team, employees have further responsibility for the issued asset and return it in the same state in which it was issued.

If the computer falls under the "Outdated" category due to Damage or Worn, is it possible to benefit even from such a device? The author of the thesis believes that yes, it is possible. Referring the best practice experience from the solution the University of San Diego such things as:

- Cleans computer and breakdown in order to identify working parts [15].
- Recycle parts to refurbish/repair computer other units [15].

Referring to ITIL, a significant part of IT asset management is controlling the asset lifecycle in collaboration with other practices. In case of that work, taking parts from the old computer is considered as the best practice which will help BIT to control costs, support decision-making about the purchase, re-use, retirement, and disposal of assets [4]. This raises the question: which parts can be collected and how to find out which ones are workable?

To determine the still normally functioning parts of the computer, hardware diagnostics will be made. Through this analysis, it will be possible to clearly say which parts from the computer can be used to repair other computers. Such practice will help to reduce the economic costs of computer repairs and as well as on the purchase of new workstations. In case an ITabi specialist cannot repair it and the warranty has expired, a new computer should be bought and given to the employee.

And after all, it is significant to simulate a situation when the computer was returned and did not fall under the "Outdated" status. What should be done in such a situation? There are only 3 options for the development of events:

- The computer is being reused
- The computer is added to the wholesale list and prepared for it.
- The computer is sent for utilization.

In most cases, the computer is being reused, which means that the hard drive is formatted and Windows is reinstalled. This gives the new employee a clean computer without any old information. Citing the ITIL, erasure or shredding of disk drives depends on information security requirements [4]. Eesti Energia AS has such requirements from information security. This is a mandatory condition for issuing any computer. After that, all the necessary data is entered into the asset register, which is the Jira Insight Discovery.

One of the most significant points is the visual assessment of the asset. If an employee brings an old workstation for replacement and after replacement, it falls under the category of "reuse", ITabi employee need to very clearly assess the appearance of this asset and conclude whether it is suitable for reuse. The workstation can work, but it looks like it is about to fall apart. Is this workstation suitable for issuing to another employee? The author of the thesis and colleagues from ITabi believe no. According to the author of the thesis and the ITabi team, the main principle in this matter should be the following: would I like such a computer for myself? This principle allows you to make the right decision about the appearance of the asset quite clearly and consciously.

In the case of selling assets, everything happens in much the same way as when giving out workstations to the employee. All data is deleted from the disk so that it cannot be recovered. After that, the assets are put up for sale with all the details, ITabi does not remove any parts and leaves the computer as it is.

Another important point is hardware assets may also be subject to regulatory requirements, such as the EU Waste Electrical and Electronic Equipment Directive [4]. Since Eesti Energia AS is located in European Union, at this point, it is important to pay attention, since there are huge fines for companies that improperly dispose of hardware assets. As far as Eesti Energia AS itself does not deal with recycling, a company specialized in recycling was found and a contract was concluded with it.

## 5.2 Framework creation

To create a framework for determining the current state of a workstation and making a decision on its replacement, it is necessary to take into account both the data received from the employee, that is, his opinion about the health of the workstation and the data received from the monitoring systems at the computer.

The presence of this framework will help the ITabi team make clearer and more thoughtful decisions about replacing or not replacing employee’s workstations. Also, thanks to this framework, it will be possible to receive more information and dates from the workstation, since to create this framework, special triggers have also been developed in Zabbix, which help to increase the level of control over assets.

Moreover, since the framework uses Zabbix as the main tool for assessing the state of workstations, the already existing process will go to another level, it will become more efficient, faster and more controllable. This is how Zabbix will become an integral part of the framework and a global part of the whole process.

As a part of the creation of the framework, the general data of all computers from the Zabbix monitoring system will be used. Based on the total date, it will be possible to make a clear idea of the minimum, average and maximum resource consumption of the computers.

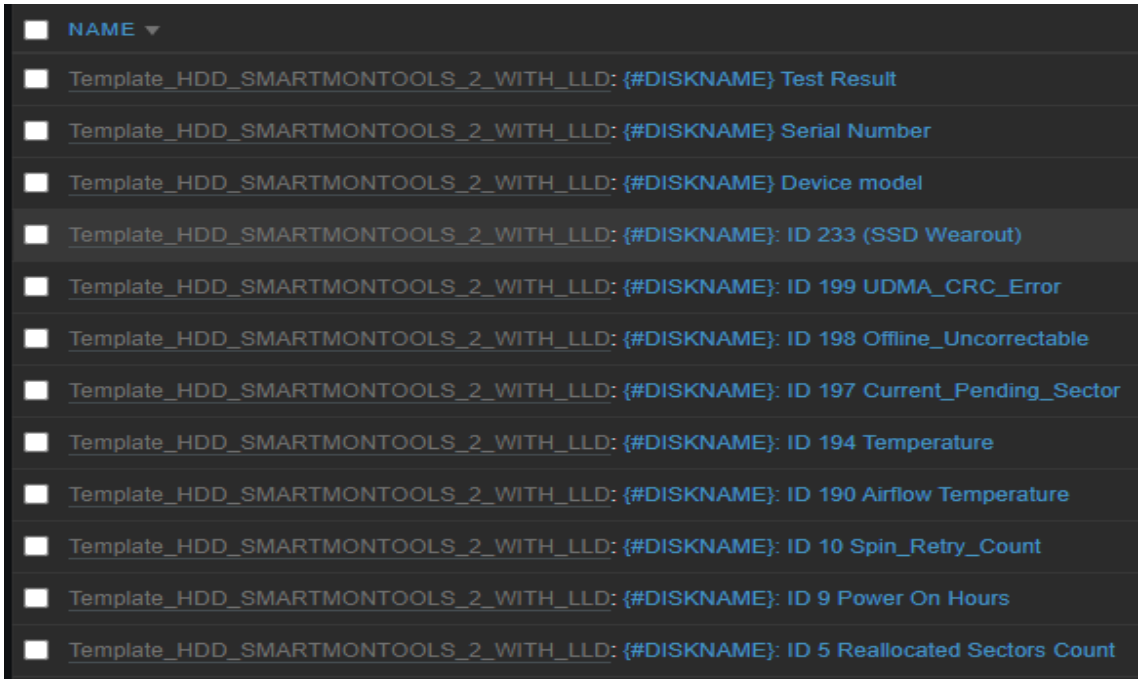


Figure 2. List of the Zabbix Items

Based on Zabbix items from the template as shown in Figure 2 and working together with the ITabi team and SRE team, the following workstation replacement framework has been developed. The framework is based on a scoring system, where each value of metrics in the framework has its own number of points. ITabi specialist needs to choose the number of points that corresponds to the performance of the workstation. On the basis of the number of collected points, it will be defined if the workstation needs to be replaced.

**Table 2. Framework for workstation replacement**

| Metrics\Definition | Minimum | Average | Maximum (+1 p) |
|---|---|---|---|
| CPU utilization | 0% – 10% | 11% – 70% | 71% – 100% |

| | | | |
|---|---|---|---|
| RAM usage | ~1.5gb / 8gb<br>~2.5gb / 16gb | ~3gb / 8gb<br>~7gb / 16gb | ~6.5gb / 8gb<br>~14gb / 16gb |
| Disk space used | <50gb / 512gb | >50<400gb / 512gb | >400gb / 512gb |
| S.M.A.R.T. HHD/SDD health status check | Should be: OK | Should be: OK | “Bad,”, “Caution,” or “Unknown” |
| SSD wear out | ~7% – 10% | ~20% | >80% |
| Disk temperature | 0C – 24C | 25C – 45C | >46C |
| Uncorrectable sectors | 0 | 1 – 10 | >10 (100 max) |
| Reallocated Sectors Count | 0 | < 5 | 100 |
| Spin Retry Count | 0 | <10 | 100 |

The selected metrics were selected after discussing the workstation metrics with ITabi and the SRE Team. The result of the discussion was a general conclusion about what metrics and data need to be collected in order to more accurately determine the state of the computer and the need to replace it. In order to more accurately understand how the framework works, the following metrics from the framework will be analyzed and explained:

- CPU Utilization – shows the level of processor utilization. If the level of processor utilization is always about 90%, then the computer will not be able to execute new assigned commands or operations until it completes the previous work/commands.
- RAM usage – The amount of time that it takes RAM to receive a request from the processor and then read or write data. Generally, the faster the RAM, the faster the processing speed [36]. If the memory load is at a high level, then the computer's performance will noticeably decrease.
- Disk space used – If employee have a disk full of different information, it’s logical to assume that employee may experience performance issues because over time, the HDD free sectors get smaller and smaller, so fresh data gets spread across different parts of each platter, that happens due time for the heads to move between each section [37].

- S.M.A.R.T. HDD/SDD health status check – shows overall disk health and his status.
- In case of SSD: SSD wear out – A flash memory device is read and written in pages. A read is relatively straightforward as a read command with the address is issued and the respective data is returned. A write can only occur to those pages that are erased; therefore, host write commands invoke flash erase cycles prior to writing to the flash. This write/erase cycling causes cell wear which imposes the limited write–life [38].
- Disk temperature – shows the temperature of the disk at the time of taking metrics.
- Offline uncorrectable sectors – Uncorrectable Pending Sector Count is a critical S.M.A.R.T. parameter that indicates a number of uncorrectable errors while reading/writing a sector on the hard drive. The error can cause drive corruption and permanent disk failure leading to data loss [40].
- Reallocated Sectors Count – Reallocation Event Count S.M.A.R.T. parameter indicates a count of remap operations (transferring data from a bad sector to a special reserved disk area – spare area) [41].
- Spin Retry Count – This S.M.A.R.T. parameter indicates the count of retry of spin start attempts. This attribute stores a total count of the spin start attempts to reach the fully operational speed (under the condition that the first attempt was unsuccessful). Spin attempts are counted for the entire hard drive's lifetime so far. What this means is that physical parts of the hard disk could start degrading and malfunctioning [42].

Summing up, the sum of points for replacing a workstation should be at least 6 points out of 8. The workstation that scored this number of points must be replaced since there will soon be obvious system freezes, and thus, it is better to replace such a workstation in advance, rather than waiting for the user to call. while if the total of the points scored is 5 or less, it would be more reasonable to wait for a KP from the employee himself, in order to examine his workstation individually. It is also important to clarify the reasons for such high loads from the employee himself and then check the employee’s computer personally. Such verification will help to verify the authenticity of the results. For instance, a high RAM load may be due to the fact that the employee has opened 10 browser windows and 20 tabs are open in each browser window. That kind of verification will help ITabi employee to more clearly determine the state of the workstation.

Moreover, it is important to clarify that the loads on the metrics specified in the framework should be constant, stable, or frequently–periodic. The one–time load is not the reason for replacing the workstation. In the event of such a high load, an ITabi employee can remotely view the metrics of the employee's workstation and, depending on the reasons for the system load, issue recommendations to increase the speed of the workstation. It is also always important to remember that errors and malfunctions are not always contained in the equipment. Both firmware and general software can be the culprit for high performance. Thus, this fact must also be taken into account. After all, updating the firmware or drivers can be a potential reduction in the workload that arose due to software bugs.

## 5.3 Trigger's creation

According to the information received by the author of the thesis from an engineer from the SRE team the process can be seen in figure 3.

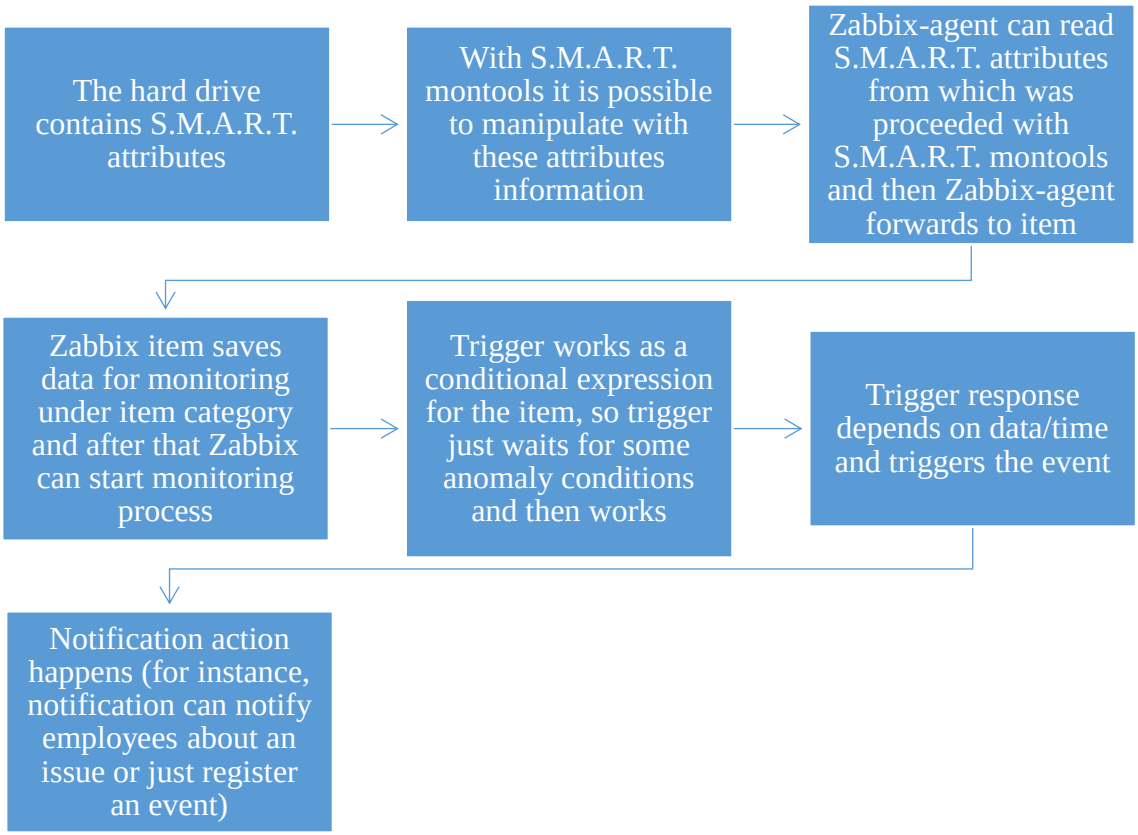


Figure 3. Zabbix scheme: from HDD/SSD data to administrator notification

In order to ensure the security of hard drives, it was decided to create triggers in the Zabbix Agent–server to ensure constant control and monitoring. To receive information

from the hard drive, the S.M.A.R.T. attributes, which are built into every hard drive, will be used. With an eye to use the S.M.A.R.T. metrics and data of almost any hard drive, it is necessary to use a set of S.M.A.R.T. montools utilities that can capture and process S.M.A.R.T. data and metrics.

In order to check the security of hard drives regularly, it was decided to use triggers in the Zabbix Agent–server to ensure constant control and monitoring.

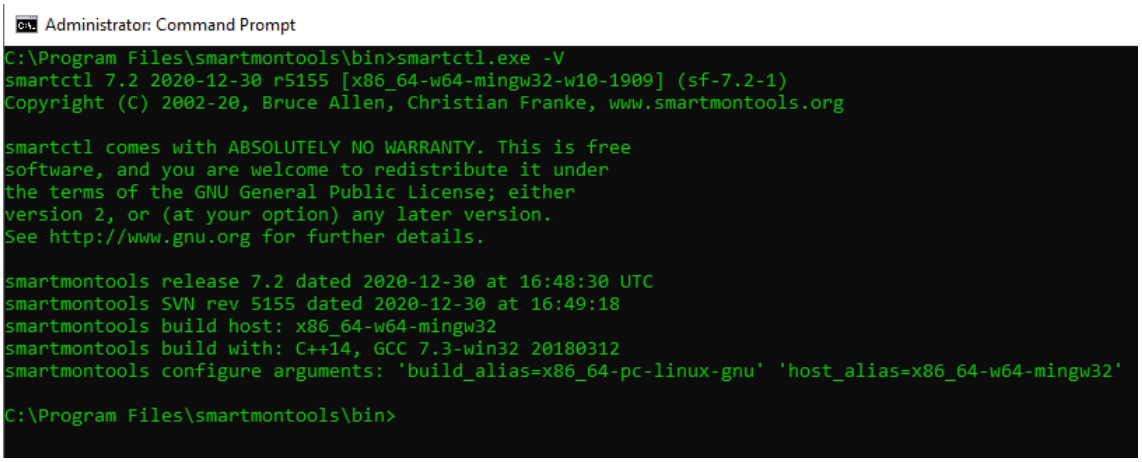


Figure 4. S.M.A.R.T. ctl version control

Unfortunately, at the templates testing stage, it turned out that the use of two out of three templates, which were also considered in the thesis, turned out to be impossible to implement for the following reasons:

- Potential cybersecurity threats
- Lack of intelligible documentation
- Partial support for the version of Zabbix used by Eesti Energia AS

In this way, the only working and valid for use is the template "S.M.A.R.T. monitoring with S.M.A.R.T. montools (LLD, DI)".

The testing starts with the first and only remaining template: “S.M.A.R.T. monitoring with S.M.A.R.T. montools (LLD, DI)”. To check the performance of the template, a test command was used to display general information about the disk used (figure 6).

```
C:\Program Files\Zabbix>.\zabbix_agentd.exe -c zabbix_smartctl.win.conf -t uHDD.discovery
uHDD.discovery                                  [t|{
 "data":[
        {
                "{#DISKSN}":"18451F413E10",
                "{#DISKMODEL}":"Micron 1100 SATA 512GB",
                "{#DISKNAME}":"/dev/sda",
                "{#DISKCMD}":"/dev/sda -data",
                "{#SMART_ENABLED}":"1",
                "{#DISKTYPE}":"1"
        }
 ]
}]
```

Figure 5. S.M.A.R.T. test command

After making sure that this template is working and ready to use, the author of the thesis began to implement triggers on his own workstation for testing. The creation of a trigger itself turned out to be not a difficult process, because triggers are a kind of limits for workstation data metrics, breaking which a notification will come to the system. The final list of triggers from the chosen template is shown in figure 5.

| SEVERITY | NAME ▲ |
|---|---|
| Warning | Template: {#DISKNAME}: Disk airflow temperature: {ITEM.LASTVALUE} |
| Average | Template: {#DISKNAME}: Disk airflow temperature: {ITEM.LASTVALUE} |
| Information | Template: {#DISKNAME}: Disk has been replaced (new serial number received) |
| Warning | Template: {#DISKNAME}: Disk temperature: {ITEM.LASTVALUE} |
| Average | Template: {#DISKNAME}: Disk temperature: {ITEM.LASTVALUE} |
| Average | Template: {#DISKNAME}: One or more SMART attributes are FAILING_NOW |
| Average | Template: {#DISKNAME}: SMART (Offline) Uncorrectable Sector Count has been registered |
| Warning | Template: {#DISKNAME}: SMART Current Pending Sector counter incremented |
| Average | Template: {#DISKNAME}: SMART Reallocated Sectors Count has been registered |
| Average | Template: {#DISKNAME}: SMART Spin Retry Count has been registered |
| Average | Template: {#DISKNAME}: SMART test status: FAILED! |
| Average | Template: {#DISKNAME}: SMART UltraDMA CRC Error Count too high: {ITEM.LASTVALUE}. Check cable! |
| Average | Template: {#DISKNAME}: SSD wearout (<5% left) |
| Warning | Template: {#DISKNAME}: SSD wearout (<10% left) |

Figure 6. List of the Zabbix triggers

These triggers allow you to very closely monitor the state of the hard disk of a workstation. But not all of the triggers from this list will be used. At the moment, the triggers that fit the needs of Eesti Energia are:

- Information
- Average
- Warning
- Disaster

It is also important to note the different trigger levels. There are 6 different severity levels in Table 3 [39], but there is little need to use them all. For example, trigger “Disk has been replaced” will have severity level “Information” because they are less important than “Average” or “Warning”, but they still should be noticed, while more important triggers like “Disk Temperature” or “SSD wearout” will have severity level “Warning” or “Disaster” because if trigger works, then something bad will happen.

**Table 3. Severity of the Zabbix triggers**

| SEVERITY | DEFINITION | COLOUR |
|---|---|---|
| Not classified | Unknown severity. | Grey |
| Information | For information purposes. | Light green |
| Warning | Be warned. | Yellow |
| Average | Average problem. | Orange |
| High | Something important has happened. | Red |
| Disaster | Disaster. Financial losses, etc. | Bright red |

With such configured settings, the chance of false positives results for triggers is less; also, with the help of severity, specialists and SRE will be able to more accurately determine the situation and, accordingly, react to it more rationally. For example, information about replacing a hard drive or SSD workstation is extremely important in order to avoid economic losses or any manipulation of the asset. But this information is not critical, since the asset, even after the replacement of the disk, will work and function normally, while the proceedings will be carried out by another department of Eesti Energia.

## 5.4 Solution realization results and their analysis

In this part, the main results of the work and its analysis will be highlighted. After processing and analyzing the results, it will be possible to conclude whether the main, previously set goal of the work has been achieved. Also, based on the conclusion, it will be possible to determine further steps for development.

### 5.4.1 Results

In the course of the work, the author of the thesis achieved certain results, namely:

1. The most important workstation metrics were selected, verified, tested, analyzed and filtered. Based on the filtered information received, a final list of metrics was compiled that are necessary for monitoring a workstation and which can be added to Zabbix.
2. Based on the collected information and on the opinion of colleagues from SRE and ITabi, who are experienced, a Framework was created with the most important computer metrics. Framework can be seen in table 2.
3. Based on the received metrics and framework, items and triggers were created in Zabbix and that can be seen in figure 6, which will help to replace the workstation more efficiently.
4. The process has been completely overhauled and improved with ITILv4, COBIT 5.1, Provance asset management and best practice experience from other companies with similar problem. Also, the created framework was implemented in the replacement process, which greatly simplified the process of replacing workstations.

The obtained results fully met the expectations of the author and the company. To obtain more accurate information, the results obtained should be analyzed.

### 5.4.2 Results analysis

As a result of the analysis of the information required to replace a workstation, the following components were derived:

- CPU
- RAM

- HDD / SSD [43]

These components were taken since they are the components of absolutely all workstations, so it was reasonable to take them as a basis. As a result, the analysis showed the most important metrics that could be taken from these components and added to Zabbix. Thus, it was possible to cover the most vulnerable metrics of the component data and improve overall control.

The framework turned out to be universal and the author of the thesis is sure that it can be implemented in other companies, if necessary. But there are a number of conditions for this, without which the implementation of the framework is impossible:

- Company should have an existing workstation replacement process with all additional stuff such as IT asset register, for instance.
- Company should have Zabbix as a monitoring tool. It is highly desirable to have the most recent version of Zabbix

The triggers are based on data that can be taken from components and added to the Zabbix. The triggers that were created were tuned more carefully to suit the company's conditions. Thus, the presence of triggers will make it possible to timely find out about the malfunctions of the workstation. At the moment, the number of triggers that have been added to Zabbix is limited by the scope of work, but in the future, other triggers will definitely be added and tested.

Significant results have been achieved in terms of process optimization. We managed to fully optimize the process, make it faster and, in addition, link it with the created framework and Zabbix triggers. After analyzing the final version of the replacement process, the author of the thesis came to the conclusion that actions for optimization managed to speed up this process by 15–20%. Also, with the help of a clearer structure, the process became clearer and more understandable for new employees and also helped the company save money for the company because the fewer workstations issued for replacement, the less they need to be purchased and their use becomes more rational.

The author of the thesis has analyzed the application of this framework on real examples of Eesti Energia workstations. One of the examples where it turned out to be possible to use the framework turned out to be very indicative. The person made an appeal, where he

indicated that the computer had become very buggy and it was impossible to work on it. After checking the computer metrics using Zabbix and evaluating them using the framework created by the author of the thesis, the ITabi employee concluded that the computer would not be replaced, but only actions would be taken to improve performance. The ITabi employee found it very strange that at some moments the processor utilization turned out to be abnormally high. Having learned from the user what type of work he is engaged in, the ITabi employee decided to study in more detail what processes cause such a high load. In the end, it turned out that there was a virus on the computer and it was decided to reinstall the OS for maximum safety. Thus, with the help of the framework, the economic value of the asset was preserved, the computer became better after reinstallation and the user was satisfied.

Another example of using the framework was interesting too. This time, one of the workstations had a trigger about too much RAM usage. Having decided to check the user's workstation through Zabbix, the ITabi employee discovered that there were other problems on the workstation, such as a sufficiently large number of errors on the hard disk and the constant workstation load. After assessing the situation with the framework, an ITabi employee decided to replace the workstation due to the heavy load of the system and the presence of errors. During the replacement process, an ITabi employee also learned that the workstation had a battery problem. Replacing it, the old workstation went to the utilization having previously passed the workstation utilization procedure, since, with the current problems, it was not economically profitable to install a new battery and repair the disk. Also, such workstation cannot be added for sale since it does not meet the requirements for this.

# 6 Further steps

The solution that was created during the work is still far from ideal. The author of the thesis is sure that this framework can be further improved by adding some functions. For example, an excellent solution would be to combine all monitoring tools to achieve the most effective result and the fastest replacement of employees' workstations.

Since Zabbix is a constantly evolving monitoring system, its potential for development is also endless. Thanks to this, it is possible to develop the process and display the necessary metrics if necessary. For example, a CPU temperature metric is crucial for some system, so the nearest future goal is to add this metric to Zabbix. The more metrics it will be possible to take into account, the better, faster and more efficiently the replacement of workers' workstations will take place. In the case of Eesti Energia AS, the author of the thesis is sure that the company, which is constantly developing, will soon begin to expand, and then it will be possible to apply this process in other offices of the company, which is undoubtedly the fact that this solution is very flexible and universal. Also, the idea of introducing new systems, for example, Netdata, sounds very promising. Zabbix and Netdata will be able to perfectly complement each other and together they will be able to easily solve the assigned tasks.

Moreover, since the created framework helps to make decisions about workstations, in the future it is also possible to create a manual for employee, which will describe possible steps, methods and tips to reduce workstation workload and increase productivity.

Furthermore, it is planned to create an automation system for Zabbix, which would itself monitor the state of the workstation, determine their state based on the created framework and itself would notify ITabi employees about the need to replace the workstation and would show the general state of the workstation, which could easily determine the condition immediately. The plans include the creation of a colour scheme: green–yellow–red, where good working stations would be marked in green, stations with errors that could be corrected without a replacement would be marked in yellow, and workstations that need to be replaced as soon as possible would be marked in red.

Also in the future, it is possible to parse the computer into smaller parts, for example, parse the keyboard or its buttons. Moreover, since according to the Eesti Energia AS contract all computers of the same model are identical, it will also be possible to remove the case or cooler to be replaced if damaged. This can save money and is also a great opportunity for employees to gain experience in computer repair.

As the author of the thesis plans to continue working for Eesti Energia AS after graduation this process will be finalized to the most efficient end with the help of the SRE team and ITabi.

# 7 Summary

The main problem that was addressed in the thesis was the lack of a framework for replacing workers' workstations. The author of the thesis developed and optimized the framework, created and configured triggers in Zabbix and thereby helped improve the existing process and bring it to a new level thus fulfilling the goals and aims that were set in the thesis and solving the enterprise problem. Also, the author of the thesis supported the IT goals set by the enterprise, thereby ensuring the required level of process and framework.

The main goal of this thesis was to create and optimize the framework, as well as create triggers for Zabbix. To do this, the author of the thesis used well–known techniques for creating and optimizing processes, in the form of ITIL and COBIT, as well as analyzing best practices from other companies. Also, in the course of writing the thesis, the following research questions were posed, to which the author received answers to the approach of writing the work.

1) Is it possible to create a universal framework and optimize the process of replacing employees' workstations? Yes, it is possible to create a universal framework that can be used in other companies as well. Of course, to enter such a framework, certain initial conditions are needed, in the form of a registered asset, for example.

2) What data should be collected and used to create triggers in Zabbix to receive an automatic notification about the need to replace employees' workstations? The most important data is the data which can show critically important metrics, such as hard drive health, number of critical errors on the hard drive.

3) Are there alternative monitoring tools in Eesti Energia AS to solve this problem instead of Zabbix? Unfortunately, no, there is no other alternative for Zabbix at Eesti Energia AS currently. Although Zabbix is not a perfect monitoring tool, it is very close to it.

As part of the analysis, the author described the current position of the company on the issue of replacing workstations, compared Zabbix with other monitoring tools used by Eesti Energia AS and described why Zabbix is best suited to solve the problem.

In conclusion, the desired results have been achieved. The author of the thesis will continue to improve this process and help optimize the work of ITabi. Thus, all possible and potential works and projects of the author will be associated mainly with ITabi.

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