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Business case analysis of energy saving in professional dishwashing sanitation

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Energiasäästön liikeanalyysi ammatillisessa astianpesussa

Tutkinto-ohjelma
Tuotantotalous

Tiivistelmä
Tämän tutkimuksen tarkoituksena oli rakentaa case-tyylinen liikeanalyysi koskien ammatillisen astianpesuprosessin energiakustannuksia ja säästöjä.

Tutkimuksen kohteena oli case-yrityksen tietokannasta löytyvät asiakkuudet, markkinat ja astianpesukoneiden toiminta. Koneen käyttöä sekä parametrejä tarkasteltiin koneen merkkistä tai iästä riippumatta, osoittaen keskimääräistä energian kulutusta noin neljänkymmenen keittiön välillä.

Tutkimus osoitti, että ei ole olemassa selkeää tapaa vertailla koneita keskenään, standardoitujen sääntöjen tai jopa puutteellisten ohjeiden vuoksi. Kuitenkin näyttöä löytyi energiahäviöstä esimerkiksi konvektion ja kuuman ilman kautta. Tämä johtuu väistämättä astianpesukoneiden puutteellisesta eristyksestä sekä seisahtaneesta tavasta suunnitella ja valmistaa tunneliastianpesukoneita. Huoneen lämpötila, jossa pestävät esineet olivat, vaikutti myös veden suhteelliseen lämmitystarpeeseen näin ollen kuluttaen enemmän energiaa.

Säästömalli ehdotettiin yhdistämällä hahmotellun astianpesukonetyypin, valmistajalta saadut tiedot sekä havainnot case-yrityksen asiakaskannasta Pirkanmaalla. Tämä ehdotti mahdollisuuden vähentää energiankulutusta suhteessa energian hintaan pääasiassa muuttamalla käyttäjien työskentelytapoja.

Avainsanat
ammatillinen astianpesu, lämpötila, hygienia, energiansäästö

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Summary
The purpose of this study was to build a case-style business analysis regarding energy cost and savings in the professional dishwashing process.

The market, dishwashing process and the behaviour of the user and manufacturers were studied, along with the details of the machine and the process. The research showed that there is no clear way to compare, for example machines with each other due to lack of standardized comparison rules or even guidelines.

However, the research concluded common result in energy loss during the dishwashing process mainly from convection and through hot air inevitably due to poor insulation and the design of the dishwasher. Also the room temperature in which the items to be washed, had clear effect on the relative need to heat the water thus consuming energy.

The savings model was built by combining the average data from outlined professional dishwasher type and the collected data from customers around Pirkanmaa. It revealed an opportunity to reduce energy consumption in relation to the energy price, by modifying the users pattern of working – for example by bringing in training and optimizing the use of the dishwasher.

Keywords
professional dishwashing, temperature, hygiene, energy saving

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1 INTRODUCTION

As the energy-price has continued to rise due to aftermath of COVID-19 and the war between Ukraine and Russia, the aim in this thesis was to argue about the possibility and benefit of lowering the temperature in the wash tank by 10-15% and what it requires from a chemical aspect in order to upkeep the required standardized thermal disinfection. The purpose was to present a profitable business case as a part of the solution area and enable the case company to make additional sales.

From the final point of view the thesis aims to show the monetary benefit as well as prove the execution of thermal sanitization of the dishes. The focus was on conveyor dishwashers sold to professional kitchens in Finland and the data gathered is from an outlined specific dishwashing type.

2 INTENTION OF THE RESEARCH

2.1 Case-company

The research topic has been formed together with the case-company in order to propose a development plan for thermal sanitization in dishwashing process due to risen energy prices.

The case company employs around 900 people in 10 countries, turning sales of 261M€ in four different business areas in 2021. One of the business areas, Professional Hygiene consists of Foodservice solutions which provide and ensures food safety and good quality through a variation on products and services for the pre-defined customer segments. As a solution, this area of business ensures high-level education and technical service alongside with safe and environmentally friendly chemical solutions for the professional kitchen. (Kiilto www-page 2022.)

2.2 Need, purpose and outlines of the thesis

Current standard of dishwashing hygiene and process has been updated in year 2013 and specifies the different requirements in order to achieve clean dishes (DIN 10510 2013). With the current rising energy prices in the Nordic countries this topic aims to propose more energy efficient methods to thermal sanitization in the dishwashing process. Reviewing activities and introducing new ways of working are needed to verify the economical productivity in the professional kitchen (Seppälä, Levo & Työppönen 2004, 24-25).

This thesis aims to analyse the current methods and standards utilized in the professional dishwashing process and compare the results to create a profitable business case. It will analyse the market and business opportunity proposal both for the end-user of the dishwasher and for the case company.

The aim is to allocate and outline the machine of choice from the case company´s customer database in order to get data about the usage. The research is to be conducted with measuring equipment of both time and energy, however if not possible to get consistent data, market analysis and research will be utilised to build the case. This data is used to compose a requirements specification of needed and wished adjustments of the conveyor dishwasher, in order to achieve a more optimized energy consumption.

The focus of the thesis will be on trying to establish a business case that consider an alternative more profitable solution to thermal disinfection in professional dishwashing, focusing on conveyor dishwashers. Due to similar purposes and operations of use, the thesis will include studies made in the Nordic countries. The dishwashing process is described only for conveyor type machines as are the use of external possible detergents and rinse-aids used to ensure clean dishes. The thesis hence compares the energy needed in a standard conveyor machine versus the new proposed scenario of using either a third component to replace the standardised thermal sanitization, by optimizing the parameters of the dishwasher and/or changing the way of working.

2.3 Research problem

The professional dishwashers are different from the ones used domestically. Requirements such as capacity, program duration, size and designated area of usage are main factors that affect the decision which machine to choose for what purpose. Data on the usage behaviour of commercial dishwashers are seldom available, and if found it is usually opt-ed or affected by outer factors or the manufacturer or importer to cast a better light on the machine's abilities.

With the current energy prices there is a possibility to research the consumption by questioning the current standards and ways of working in the professional kitchen. By questioning some customers in open minded discussion forums there can be data obtained of errors in the usage behaviour and dishwashing as a process.

High water consumption and unnecessary energy use lead to high costs for the user companies – for example with pre-rinsing in the process, partially loaded baskets and so on. Educating the users would be one effective way to cut cost in the professional dishwashing process. After this task, the main idea is to introduce alternative methods, hence start questioning the different steps of the process, in order to cut cost.

Research question:
How much are we able to affect the energy consumption in a professional conveyor within the regulatory existing standards?

Sub-questions:

- How is there a profitable business case in the scenario?
- What is the best way to optimize the use of energy in a conveyor dishwasher?

2.4 Framework and abstract

In the light of the current changes in the world due to post COVID-19 dilemmas in supply chain and the current war going on between Ukraine and Russia, the prices of both energy and raw-material have risen. The theoretical framework of the thesis is built through the literature on profitability and technical data about the dishwashing process in the professional kitchen.

The theoretical part is based on the perspective of organisational profitability and success, comparing current standards and measures of dishwashing against proposals of low-energy alternative methods. As earlier discussed, the profitability is the starting point for businesses and is a function of revenue. If the revenue is higher than the costs, the business if profitable. (Eklund & Kekkonen 2011, 63.)

The goal of a chef or kitchen manager is to make the kitchen profitable, and this stresses the actors around foodservice as a business area to develop and constantly look for new more creative ways to increase the revenue. Business break-even point is calculated by taking fixed costs and dividing those with the gross profit margin. With the profit decreasing due to higher raw-material price and the fixed cost increasing due to energy crisis the best way to keep up some balance is to increase the prices of the service or product and try to lower the fixed cost. (Eklund & Kekkonen 2016, 113-116.)

Figure 1 below illustrates the key concepts of the theoretical framework and the implications of the different components in this business case about energy consumption optimisation in professional dishwashing.

Figure 1. Theoretical framework: Business case analysis

3 RESEARCH APPROACH

3.1 Qualitative research

A case study aims to produce information on a subject in order to analyse the problem in hand and present ideas and solutions. As an example, these studies have been suitable for business development and researching alternative methods to conduct problem solving. Earlier stated theory on the subject has suggested the idea of developing an alternative method to achieving energy savings in the process of dishwashing, and therefore a case study is chosen as the method of approach. The topic and research question are both multifactorial and difficult to define, therefore case study is chosen as primary strategy. (Kananen 2013, 56-59.)

By firstly gathering information about the problem in hand, based on the research questions, one can compose a task and define the target which aims to gain an in-depth understanding of the problem (Ojasalo, Moilanen & Ritalahti 2014, 51-52). By gathering the information and dividing it into qualitative and partly quantifiable methods, it is possible to investigate the topic considering the fact that this information is being questioned on base of old standards and learned ways of working.

Qualitative methods are generally used to describe the desired outcome without knowing the best way of achieving it or identifying the way to achieve the outcome. Laajalahti, Valli, Aaltola & Herkama (2018) also characterise this as a process in the sense that the different stages of the process cannot easily be structured into clear phases beforehand but rather the research, or data collecting, concerning the task may provide gradually shaping decisions.

On the other hand, quantitative way of approaching would suggest limiting a large amount of information into a composition of representative samples in order to gain understanding of the subject. Both ways are chosen in this thesis in order to generate a perfectly balanced discussion about the quite complex problem and the solutions available at this point. (Hirsijärvi, Remes & Sajavaara 2009, 161.)

3.2 Constructive research

Case oriented methods have had the goal of investigating or interpreting casually analytical topics, with the attempts to achieve an alternative set of outcomes in order to pursue development (Ragin, C. C. 2014). However, this development must be based on information and theory about the problem. For this task, constructive research about the energy consumption in the outlined dishwasher will be conducted.

A constructive research aims to produce a concrete output to a problem. This method requires that the processes are described and followed in order for the output to be reliable. The outcome (energy savings) must also be contexed with the theoretical knowledge and the possible alternative solutions grounded in theory, as well as take the hygiene on the surface into account. Constructive research is hence based on the theory and data collected, finds out what the process is, how it is developed and what kind of reformed process is created (Figure 2). (Ojasalo et al., 2014, 37.)

In this case, constructive research method is used when identifying and measuring the energy consumption in the dishwasher – the outcome will be a list of demands to secure a lower energy level merely by upsetting or rather tweaking the parameters and mainly used (standard) settings of the machine. The aspect of clean items, or sanitation, also need to be taken into account according to current hygiene standards and way of working. Thus, the comparable setting will probably be shown through the ratio between lowering the tank temperature and the sanitation of the surface.

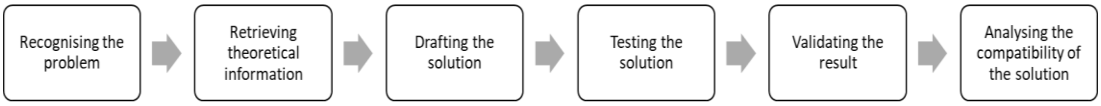

Figure 2. The process of constructive research (Ojasalo et al., 2014, 67)

3.3 Data collection methods

In order for this thesis to be able to fairly research the subject, both qualitative and quantitative methods are needed as they do not compete against each other – rather complement one another to be able to enhance the quality of the discussion (Ojasalo et al., 2014, 121-122). The dishwashing process is quite identical, but the similarities divide opinions and the way of working split professionals into different casts. This inevitable fact of different work culture invites us to gather both empirical and theoretical data around the professional dishwashing as a process, in order to suggest improvements.

Open discussion and brainstorming around the subject are suitable as collection method and this requires open-heartedness and reflection around the topic rather than the old worn-down way of thinking (Ojasalo et al., 2014, 158). The case-company´s database of machines at customers will be the subject of this data collection as well as the end-users themselves, including observation. This data will be used as guidance when discussing the alternative methods of sanitization in the dishwashing process.

In order to build a good business case, the market analysis will have a big role, hence this qualitative data will be gathered from the case-company´s database and through open discussion about the different aspects related to this topic. The data from a market analysis will serve as base for the discussion about further developing the dishwashing process and what alternatives de facto are possible from end-user perspective.

Quantitative data is considered to provide relatively superficial but reliable information about the subject, whilst qualitative data provide in-depth but poorly generalisable information (Ojasalo et al., 2014, 122). Therefore, both methods have been chosen – to achieve good balanced discussion around the topic.

The business case is also consisting of a theoretical, measurable amount of data, for example energy-level, usage, run-time, process steps both in time and quantity (dishwashing baskets / hour) and so on. To validate different theoretical outcomes in the discussion the quantitative data is used and allows to target the results and examine the problem in detail. (Ojasalo et al., 2014, 105.)

According to Kananen (2014, 52) quantitative research aims to generalise findings and to, through the data collected, generate qualitative data which improves the accuracy and validity of supposed conclusions. In this thesis the quantitative data is used to build a strong foundation around the outlined dishwashers energy consumption and usage – and furthermore connect different end-users' data into a composable and usable average.

The profitable outcome can also be measured in quantity, which is demonstrated in the framework of this thesis. Therefore, data will also be measured on basis of collected energy data of the dishwasher and compared with the different outcome alternative suggestions to thermal sanitization from a monetary aspect. The data is collected from two different locations that use the same model of machine.

Data collected includes parameters that possibly affect the sanitation of dishes, comparing the energy consumption to other modifications. The report also includes some common information about the machine, ambient temperature in the kitchen, boiler and tank water temperature, dosage of rinse-aid and detergent and what kind of programs in use. In the report is also specified used equipment (see Attachment 1-2). The testing after collected data included, per se altering temperature in the wash tank in order to see what effect it has on the energy consumption, keeping hygienic standards in mind. Specific instruments and equipment used in the research, is documented in Attachment 1.

4 CONVEYOR DISHWASHING

4.1 Introduction

Dishwashing is a necessary process in order to remove residue and foodstuff, or soil, from the dishes. In the case-company´s customer base there is municipal professional users, commercial enterprises, hotels, private chains and smaller private foodservice companies that all use professional dishwasher. By doing the dishes the process also guarantees (or should at least) hygienical treatment of the dishes. (Klingshirn, Näger, Pakula & Stamminger 2022, 53-54.)

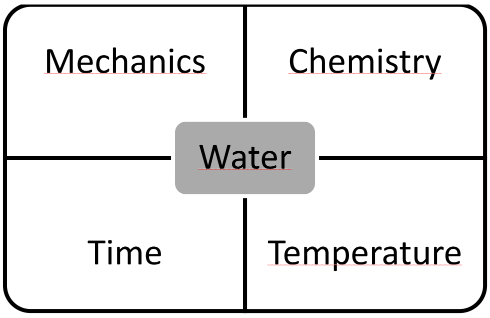

Fig. 3 Sinner’s circle (Johansson & Somasundaran 2007)

There are four factors affecting the outcome of the washing process – temperature, chemistry, mechanical action and time. This is called the Sinner’s circle (Figure 3) and is mainly referred to in laundry washing, but also surface cleaning (Johansson & Somasundaran 2007). The four factors must be optimally coordinated in order to work. Only the interaction of all factors provides the desired cleaning effect. On the other hand, the reduction of one factor requires the intensification of other factors to achieve the same cleaning result. Water is in key position as it mediates the interaction between all the four factors. (Klingshirn et al. 2022, 56.)

The dishes are put into different baskets for different purposes. The conveyor dishwasher moves the basket through a tunnel of compartments that each have a specific function in the process. The first step in the dishwashing process in to apply sprays of detergent solution that remove soil and residue from the dishes. In the next compartment rinsing is done by sprays of water (depending on the machine fresh or re-used) in order to rinse the detergent off the dishes. The sanitizing of the dishes in the rinse stage is pursued with either hot water or chemical sanitization solutions. Dishwashers do not disinfect dishware but rather minimize the microbial population on the surface in order to fulfil a standard level of sanitization.

As un-sanitized contact surfaces are a direct or indirect source of foodborne illness, it is important to recognize the need of good sanitization in the dishwashing cycle. Water and energy consumption are mainly set by the different machine manufacturers through a comprehensive list of parameters and parts, which usually attain a good quality of soil and microorganism removal from the dishes. (U.S. Department of Health and Human Services 2005.)

4.2 Water

In addition to the four components of cleaning, water is of great importance. Water act as a solvent for water-soluble substances, carrier of the cleaning and rinsing chemicals, transmitter of the mechanical action on the dirt and carrier of the thermal energy to achieve sufficient temperature for good cleaning action and hygiene.

Special requirements are placed on the quality of the water and the basic need would probably be that the water is drinkable. If the water is drinkable, we can assume the composition supporting the needs specified above and start looking at the hardness, which essentially is determined by the content of dissolved calcium (Ca^{2+}) and magnesium (Mg^{2+}) in the water – usually expressed in the unit millimoles per litre (mmol/l). It is also common to use the unit "degrees of German hardness" or °dH. (Ritter 2010, 134-135.)

Water hardness in Finland ranges by estimation between 2 °dH and 15 °dH depending on location, higher number defined as harder water. Hardness can be noticed in the dishwashing process as lime deposit in the dishwasher or on the dish ware. A soft water is classified between 1,5-8 °dH, medium hard is 8-14 °dH and over that is hard water. (Klingshirn et al. 2022, 56.)

According to Finnish Environment Institute (2022) groundwater in Finland is usually soft. This is because the bedrock in Finland is dominated by acidic rock types such as granite. However, the possibility of hard to medium hard water exists – adding to the lime deposits building up in drainage and appliances that use or heat water. On the other hand, too soft water corrodes the metallic piping which means that dangerous substances are released into the water from the pipes. (Finnish Environmental Institute 2022.)

4.2.1 Water consumption

Prerinsing dishes before putting them in the dishwasher is something that estimated half of users do, depending on user training and properties of the machine. Cleaning by hand is also normal in some user segments like day care centres although according to Richter & Stamminger (2012) under half of the users (43%) in a test group report they do not manually wash dishes. Due to this insight, it would be interesting to also rule out the reason why pre-rinsing or hand-rinsing is done – dissatisfying cleaning results, instructions from the employer or supervisor or because of technical setup in the dishwasher.

For us to recognise the different technical outputs of different professional dishwashers, Figure 4 categorizes the machines by type and proportions. According to Rüdenauer et al. (2011), smaller machines consume more water per 100 items, whereas larger machines (multi-tank and conveyor) are designed for low water consumption allowing an average of 11 litres per 140 items or 7,9 litres per 100 items. The study has been conducted in several different customer and usage segments. (Rüdenauer et al. 2011)

In the same survey Rüdenauer et al. (2011) also compared the different user segments between each other, in order to get data on whether the segment water consumption differ from each other in manual dishwashing water consumption. Between the segments, catering, canteen and hotels used the most water and surprisingly were also the biggest implementers of pre-rinsing and manual dishwashing. (Rüdenauer et al. 2011.)

<table>
<thead>
<tr><th>Category-Number</th><th>Water supply</th><th>Number of tanks</th><th>Operating principle</th><th>Type of loading</th><th>Type of wash ware</th><th>Application</th></tr>
</thead>
<tbody>
<tr><td>Undercounter water-change</td><td>Water change operation</td><td>0</td><td rowspan="3">Program automats</td><td rowspan="2">Front</td><td>Mainly glasses, cups, cutlery</td><td>Semi-professional</td></tr>
<tr><td>Undercounter one-tank</td><td rowspan="3">Tank operation</td><td rowspan="2">1</td><td rowspan="2">Dishes, large utensils</td><td rowspan="3">Professional</td></tr>
<tr><td>Hood-type</td><td>Basket</td></tr>
<tr><td>Conveyor multi-tank</td><td>2 or more</td><td>Conveyor type</td><td>Basket pass-through</td><td>All dishes</td></tr>
</tbody>
</table>

Figure 4. Categorisation of professional dishwashers

The significantly large use of water in pre-rinsing and manual dishwashing can be concluded from earlier text and reduced in all user segments by avoiding pre-rinsing, something that also would be in line with sustainability questions.

One could also question the need for increased pre-rinsing in dishwashing process, due to organisational goals in environmental questions. On the other hand, in cases of heavily soiled dishes a pre-rinse would sustain less dirt introduced into the dishwasher, hence cleaner result and improvement in sanitization.

4.3 Detergent

For us to understand the need of detergent in the dishwashing process, the substances compromising hygienic dishes need to be categorised. Contaminants that mark the residue on the dishes may be food, napkin remnants, lipstick, tea stains and other impurities that must be removed in the dishwashing process. The contaminants can be divided into a couple of groups. (Cunningham 2022, 19-22.)

Mineral deposits are examples of various forms of compositions such as calcium carbonate commonly referred to as limescale. These look like white or yellowish deposit, sometimes even gritty minerals settling out of water. They can be removed with an acidic detergent or by alternating alkali and acid detergent cycles. By using strong chelating agents, the forming of these compositions can be avoided. (Cunningham 2022, 19-22.)

Fats and natural oils from animalic sources like milk, poultry and other meats can quickly adhere to surfaces and act much like normal fats. As fats are triglycerides, caustic soda (NaOH) breaks them apart. Also, by cleaning above the melting point of the fat or oil with NaOH will give the most effective method of removing the fat from the surface. Generally, this temperature is above 49°C. Emulsified substances are kept in a stable state of suspension in the water with the help of detergent. (Lee, Cartwright, Grueser & Pascall 2007.)

Another group of contaminants include tannins from coffee and tea as well as proteins from meat, fish, potatoes, cheese and so on. Several substances cannot be chemically altered but are also kept in a state of suspension in the water. This process is called dispersing and includes for example cellulose components of vegetables or aromatic herbs and fruit, but also solids such as ash, soil particles, dust and sand.

Usual ingredients in professional detergents for dishwashing are largely inorganic salts like carbonates and phosphonates. The latter is not to be mistaken for phosphates, which were used before in professional dishwashing detergent[1]. (Lee et al 2007.)

DIN 10512 which is standard for one-tank machines and composition of typical detergent and rinse aids for professional use, when testing the machines and providing evidence that the machine fulfils all hygienic requirements.

Amongst standard compositions machine manufacturers have mentioned potassium hydroxide, sodium silicate and minor usage of oxidising agents[2]. Bleaching or oxidising agents are mainly based on either oxygen (hydrogen peroxide, sodium percarbonate, sodium perborate) or chlorine (hypochlorite). Chlorine bleaches in the textile washing process, have the advantage of disinfecting properties even at low temperatures whereas, for example sodium percarbonate show less bleaching capacity at temperatures below 60°C (Li, Lu, Liang, Gao, Jiang 2022). However, studies from the case-company have shown good efficacy of sodium percarbonate in the dishwashing process which has led to the introduction of several bleaching agents in the portfolio.

[1] Phosphates were effectively banned in the EU in domestic laundry detergents from 6/2013 and in dishwasher detergents from 1/2017 (EU Detergent Regulation 259/2012).
[2] Oxidising agents are not a part of the standard test detergent defined in DIN 10512.

Limitations on the total content of phosphates and other phosphorus compounds in a laundry detergent product, is limited in the European Union to a total not greater than 0,5 grams in the recommended quantity of the detergent to be used. For automatic dishwashing the total content is lower than 0,3 grams in the standard dosage. (EU Detergent Regulation 259/2012.)

The phosphorus in phosphonates is not relevant to eutrophication. For the detergent to be effective, the phosphonates are needed in magnitudes much lower than phosphate. According to EPA[3] phosphonates from detergents are a minor contribution to total phosphorus in sewage, less than 1 % when considering other sources like food waste, water treatment, food industries etc. (European Phosphonates Association – input to the revision of the EU Ecolabels related to detergents 2015.)

4.4 Temperature

The temperature of a food contact surface in a specific time span at which the surface is kept at the temperature, affect the rate at which microorganisms will thermally inactivate or be reduced alongside with the kinetics of the water pressure on the surface. Thermal inactivation of a various range of pathogens in foodstuff and perishable goods has been studied in many cases (Blackburn et al. 1997; Juneja & Marmer 1999; Morris & Potter 2013).

The effect of temperature (heat) on microorganism inactivation on the contact surface depends mainly on the surface temperature and the length of time during which the surface is exposed to heat. The water in machines in Finland is mainly heated with electrical resistors controlled by parameters set by the manufacturer, although some machines heated with steam are still in operation. Outlined machine type in this research are connected to hot water supply which, depending on the location, vary in temperatures from +50-65°C (Ministry of Social Affairs and Health 545/2015 7§).

[3] European Phosphonates Association

4.5 Rinse-aid and drying

In a separate process step, a rinsing solution consisting of water and rinsing agent is sprayed over the cleaned items to remove all residues of the cleaning solution. The rinsing solution has a reduced surface tension due to the rinsing agent, which means that the water runs off the wash ware particularly well, thus improving the drying of the wash ware. The final rinse often raises the temperature of the items to be washed further above the level for cleaning, which also supports fast drying. This also increases the hygienic result of the process. (Klingshirn et al. 2022)

4.6 Machine type and maintenance

Multi-tank conveyor type dishwashers consist of module-based tanks attached to each other in order to create a pass-through tunnel, in which the basket moves through the different functions on the modules. The machines usually are combined of a pre-washing zone that re uses water from the primary wash tank in the washing zone.

The last module(s) are in the final rinse zone using fresh water and, in some cases, hot air to dry the dishes. The size and number of the modules usually define the capacity of the machine (baskets / hour) and can vary in both width and height depending on manufacturer. In Figure 6 below is gathered generic information regardless manufacturer or brand.

Main criteria	**Data**
Program	
Number of dishwashing programs	3
Washing capacity	1700 – 6 000 dishes / hour
Cycle time	90 – 180 sec
Tank temperature (washing)	usually between 55 °C and 65 °C
Boiler temperature (rinsing)	usually between 80 °C and 85 °C
Construction details	
Width	4 700 – 7 400 mm (machine only)
Depth	varies depending on module

Weight	ca. 1 300 kg
Tank volume	130 – 750 litres, avg. 230 litres
Electricity and water connection	
Voltage	3N PE 400V
Total load	30 – 60 kW

Figure 6. Generic specification of typical multi-tank conveyor dishwasher (Source: Different machine manufacturers technical data sheets)

4.6.1 Energy, water and detergent usage

Dishes often enter the dishwasher in a temperature of about 25 °C (room temperature). The first zone re-uses water from the dishwashing tank and is about 35 °C “wastewater” for the pre-rinse. Due to convection of the heat on the much colder plates and radiation through (often) badly isolated walls and roof, approx. -10 kW is used compared to intake. Depending on model, water intake is about 320 l/h of cold water that circulates through a heat exchanger to the tank or boiler, where electrical resistors heat the water to required level.

According to Meiko (2022) 22 % of the incoming energy is used to upkeep motors, pumps and ventilation as well as the conveyor belt or rack. Most of the energy however is used for heating the water, hence dish goods and the air. Because of the structure of a conveyor dishwasher, a loss of 42 % in energy through exhaust air, even though the dishwasher would be equipped with a heat exchanger or recovery system to preheat the fresh cold water.[4]

Second largest energy loss is from wastewater. On a generic conveyor dishwasher about 300 liters of warm water (about 35,5 °C) leave the wash-cycle process every hour and take about 9,1 kW/h of heat out of the system. This equals of 26 % of the total energy consumption (Figure 7.)

[4] Calculation based on data in Figure 7.

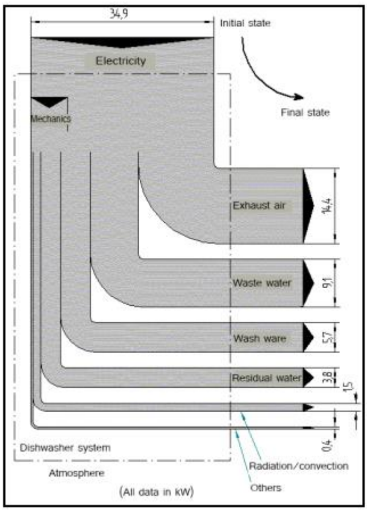

Figure 7. Energy in- and output of a Meiko conveyor-type-dishwasher. (Rüdenauer et al. 2011.)

Meiko has reported a typical consumption of energy, water and detergent in a professional conveyor-type dishwasher with cold water connection and electrical heating as showed in Figure 8.

	Energy	***Water***	***Detergent***
Nr. of dishes	1 515 900		
Specific consumption	2 kWh/100 dishes	13 litres/100 dishes	44 g/100 dishes
Operation mode (annual consumption, ideal conditions)	30 318 kWh[5]	197 067 litres	667 kg
Real-life user behaviour			
Additional consumption through real-life workload	+10 %		
Additional consumption through maloperation	+5%		
Operation mode (annual consumption, real life user behaviour)	34 259 kWh[6]	222 686 litres	754 kg
Difference	+11-12%		
Initial filling (annual consumption)	1 728 kWh	33 000 litres	111 kg
Standby	1 716 kWh		

Figure. 8 Energy, water and detergent consumption of a professional one-tank conveyor type dishwasher with cold water connection, electrical heating (Danish Technological Institute 2022.)

A considerable part of energy is consumed when heating the dishes and likewise equally large part of energy gets lost through hot dishes and other wash ware at the end of the process. This also depends on the material of the wash ware, but for

[5] kWh / 190 days / 4 active hours of dishwashing equals 39,9 kW
[6] kWh / 190 days / 4 active hours of dishwashing equals 45 kW

reference we can mention porcelain, which is a commonly used wash ware, has a heat capacity of about 1080 J/kg*K (1 J = 2,778 * 10^{-7} kW). (Material properties www-page 2022.)

5 HYGIENIC REQUIREMENTS

5.1 Cleaning validation

Hygienic and spotless dishes are a key feature on how to provide good dishwashing process. Sanitizing performance on a professional dishwasher can be measured in many ways, although when inspecting the residue of food and organic material of left-overs on the surface one can outline the microbes to be investigated.

For example, Escherichia coli can be measured in the process, to establish the relationship between operating conditions and sanitizing performance. The compatibility of quality standards can additionally be discussed after obtaining results. Overall, a microbiological surface hygiene monitoring test can be done to measure earlier mentioned E. coli, Enterobacteriaceae and different yeasts and moulds. (Feliciano 2012.)

According to EHEDG[7] setting up cleaning validation is a process of implementing various activities in order to simultaneously verify, monitor and validate the result of ensuring food products and processes to meet safety and product quality requirements. (EHEDG Guideline 2022.)

5.2 ATP Bioluminescence

ATP[8] bioluminescence is a rapid sanitation test increasingly adopted in food service establishments for monitoring cleanliness and sanitized food processing equipment and food-contact surfaces (Corbitt et al. 2000).

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[7] European Hygienic Engineering & Design Group
[8] Adenosine triphosphate

Measurement is conducted with a sensitive device called luminometer, where results are expressed as RLU[9]. Nowadays the meters have been developed to give accountable results within seconds, which enables the ATP bioluminescence to be used as monitoring method within HACCP (Hazard Analysis and Critical Control Point) plans (Davidson et al. 1999).

Adenosine triphosphate is basically the currency molecule of all living cells – when the cell dies, the molecule rapidly decomposes to a state of non-measurable. The use of bioluminescence is quite normalised in ATP measuring as it indicates a fairly easy way to interpret level of residue on a surface. The ATP measures a quantity result based on the luminescent reaction between ATP and two compounds, extracted from fireflies, called luciferin and luciferase. When the surface is swabbed, the sample is exposed to ATP-releasing agent and the ATP-activated light-producing enzyme luciferin and luciferase. (Turner et al. 2010.)

The light produced, and by the way read in the ATP sample device is an catalyse reaction between the two enzymes and hence an indication of the amount of living organisms on the sample. If the ATP detection device discovers contamination, the surface can be sanitized and retested. In dishwashing process ATP can be used to measure all organic soil as indicator of cleanliness, quite beneficial in food industry as it determines general forms of surface contamination including microbial cultivable/non-cultivable and organic contamination. (Aycicek, Oguz & Karci 2006; Turner et al. 2010.)

ATP measuring also has limitations as it does not in any way give information on the identity of the organism presented in the sample or measure the contribution of a particular source. Secondly, as this is an enzyme-based technique it is exposed to inhibition by a variety of agents used in cleaning methods such as possible interference of detection with residual bleach solutions. Thirdly, the number of ATP per cell may vary depending on the strain and environmental metabolic factors. Unfortunately, there is not yet a simple way to convert quantity of microbial ATP to quantity of bacterial cells. (Okibe & Johnson 2011; Turner et al. 2010; Linklater 2010.)

[9] Relative Light Units

6 OUTCOME OF RESEARCH

6.1 Energy price level in Finland

The total price of electricity consists of three parts formed by electrical energy (33%), part consisting of sold electricity (34%) and taxes (33%). Often the confirmation of electricity price is charged monthly, and the amount consumed, can vary from household and property. Electricity is also billed in Finland slightly differently, depending on the type of contract the user has made. (Sahkon kilpailutus www-page 2022.)

Consumption charge, i.e., the price of electric energy consumed is always the same in general electricity (cent / kWh) no matter time or month. Time electricity on the other hand, divides the consumption fee for day and night and in seasonal electricity. The consumption fees are then divided between winter electricity and electricity consumed during other periods of use. (Elinkeinoministeriö, 2018.)

In exchange-based electricity, the price is determined according to the spot price of electricity exchange Nordpool which changes from moment to moment. Depending on contracts and the market situation, the price of electricity is usually 5-8 cents / kWh. Price fluctuations in exchange electricity will throw the price all between 0 – 20 cents / kWh in normal cases. (Sahkon kilpailutus www-page 2022.)

The rest of the electricity price is tax. In addition to electric energy and electricity transmission, consumers pay value added tax, electricity tax and maintenance security fee for their electricity. The electricity tax is invoiced together with the electricity transmission and its amount is affected by the amount of electricity consumed. Currently the electricity tax bill is about 2,79 cents / kWh. (Sahkon kilpailutus www-page 2022.)

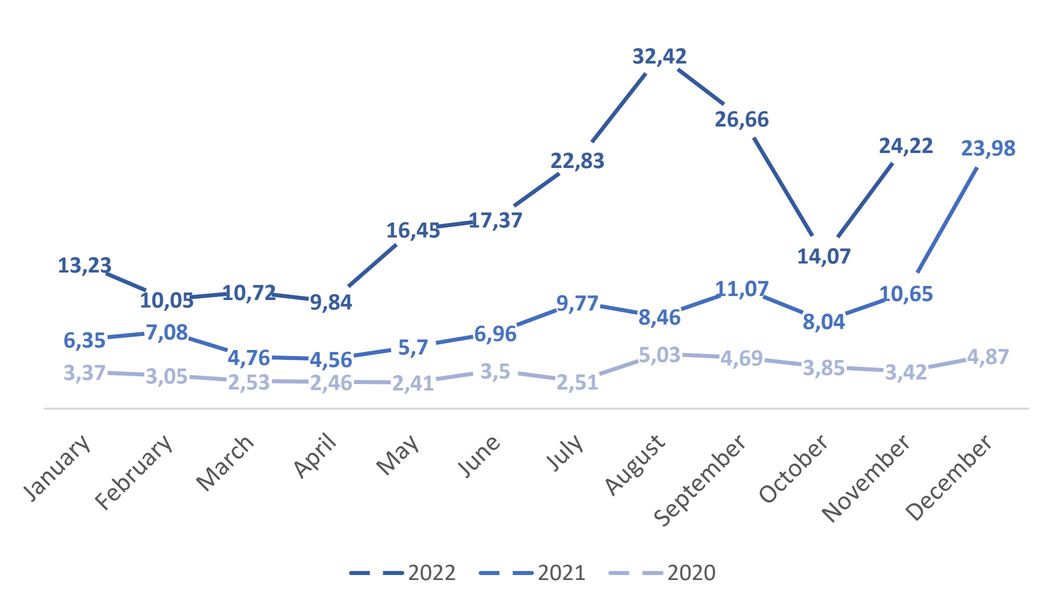

Figure 9. Electricity spot price (cents) in Finland (Sahkon kilpailutus www-page 2022).

6.2 Financial analysis

Total cost is divided into the different areas of consumption in the dishwashing process, water, energy and detergents. The data for energy in Figure 8 is used as a general input of source in order to estimate the cost of normal to semi-normal usage of a conveyor dishwasher in a professional kitchen. The data in Figure 9 is used as input for cost.

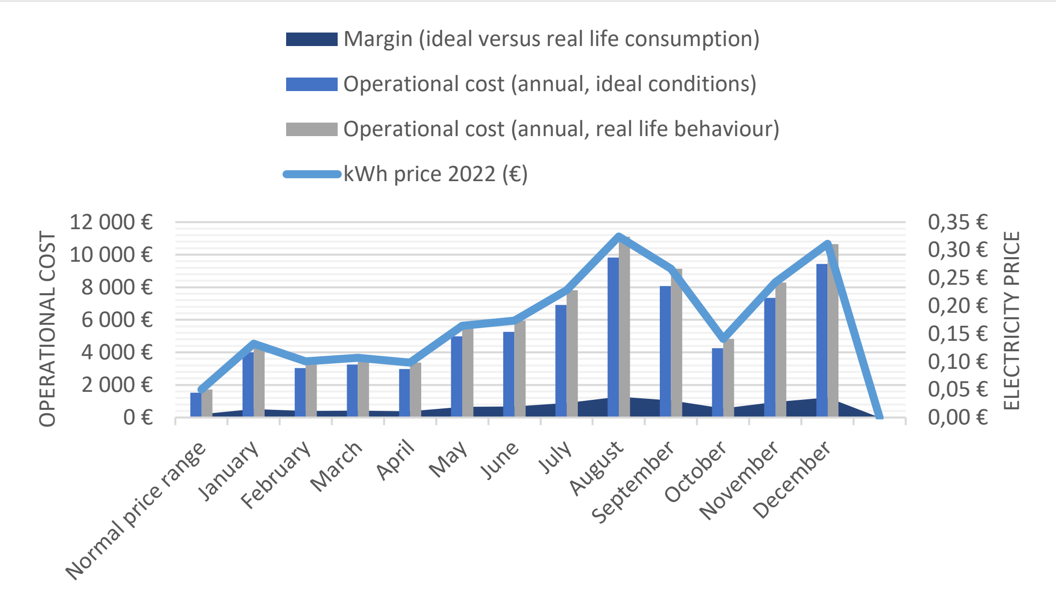

Figure 10. Difference in ideal operation and real-life operation cost.

Conveyor dishwashers are commonly used in bigger schools and municipal kitchens in Finland; hence the annual usage is divided into 190 days. Efficient dishwashing time, according to test sites in kitchens in Pirkanmaa, Finland, is about 4 hours per day and this supports the numbers as it shows an average of 45 kW total input (see Figure 6).
Difference between normal real-life use, which includes margin of error regarding usage, filling, malfunction etc., and optimal usage still support an additional cost reduction relative to the consumption of 11-12 % (filling and standby time included). The margin grows relatively when price gets higher.

6.3 Market analysis

Market research was conducted in Pirkanmaa, Finland which consisted of the different municipals trading in through an acquisition and public limited company in order to source deliverables and purpose focused products to the different users. When talking public educational institutions, a total of 40 were included in the research, of which all are using the outlined type of dishwashers. The research did not include make or age of the machine, nor were all the machines measured for energy consumption, but rather average data was provided to gather a big picture.

As the information in Figure 8 is outlining the usage data of a one-tank conveyor dishwasher, it is safe to conclude that the numbers shown in Figure 11 will be lower than the average due to different sized machines in different professional kitchens. As the purpose of the research was to find a good business case, lower than average data will indeed suffice in order to show the profitability of plausible actions in lowering the energy consumption.

When adding these machines into one conclusion of symbiose regarding energy consumption, a thought one would expect the municipals to entertain as good business, it can be defined that the annual cost savings could be climbing over 50 000 € in August 2022 as the energy price rises over 32,42 cents / kWh. Equally the cost savings reduce to around 5 000 € in a normal energy price range of 5 cents / kWh.

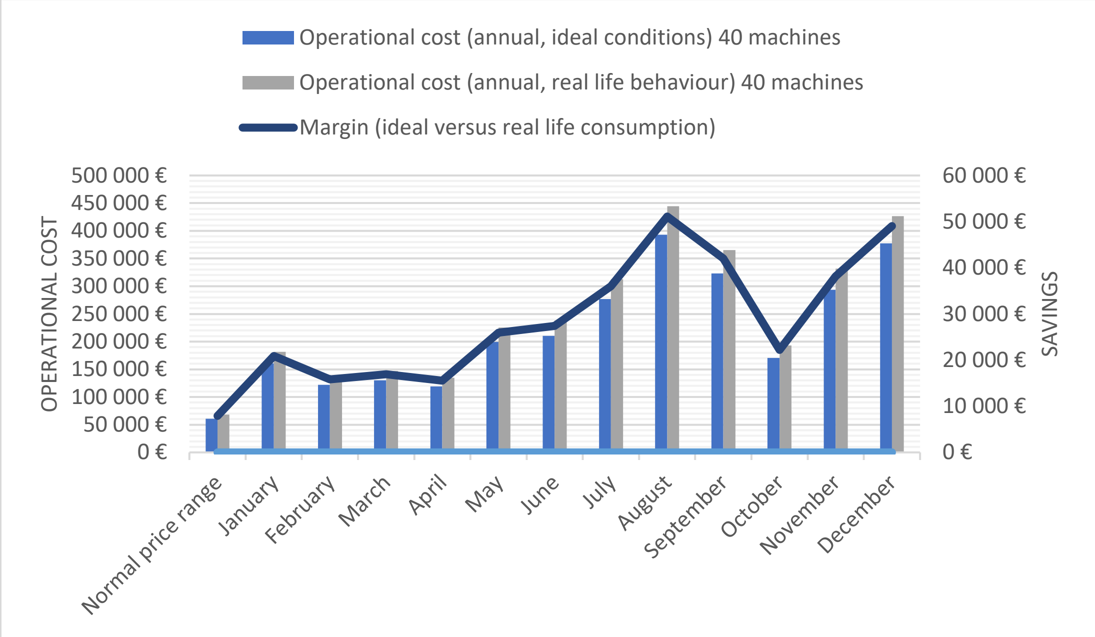

Figure 11. Cost and cost savings as result of optimized energy consumption in a professional conveyor dishwasher.

Market analysis shows that simply by dividing the machines used in one ring of common sourcing and taking 40 machines into account, the savings would be large if the energy prices stay in current zone. Either way the natural outcome of risen logistical and raw-material expenses are more expensive machines which in turn leads to less frequent renewal of the dishwasher.

7 CONCLUSION AND REFLECTION

As earlier concluded, the energy consumption in the dishwashing process depends on the temperature of the dish ware which in turn depends on general room temperature ambient to the dishwasher. Also, energy loss can be detected through convection and loss of heated air.

Soiling of the dish ware can alter significantly from day to day especially when talking about utensils and pot washers, but also in conveyors. Heavily soiled wash ware is usually pre-rinsed outside the dishwasher's process which means more water and energy used. It has also been noticed in the test sites that heavily soiled dish ware causes the usage of different programs in the dishwasher, something that alters the energy consumption due to longer running cycles, more water consumption and hence more detergent used. As a final cause, heavily soiled dish ware might also lead to additional running cycles – the same object is put through the cycle multiple times if the result is not satisfying.

The quality of the water plays a considerate role in energy consumption especially when comparing ideal conditions with real life usage. In ideal conditions the hardness of water should not exceed 6 °dH, everything above that will result in higher energy, water and/or detergent consumption. In Nordic countries the water hardness level varies quite a lot, therefore special softener devices and filters are installed where the hardness level exceeds the threshold. The hardness of water affects the resistors negatively due to the limescale building up on them, causing increased energy demand to heat up the same amount of water. The more limescale found in the dishwasher, the higher energy consumption. Limescale does also affect other parts, like clogging up the rinse arms and decaying pumphouses and pipelines.

It was concluded earlier that the average dishwashing process in a machine consumes about 100 to 160 litres of water per 1 000 plates, water that must be heated up from input temperature to the temperature of rinse or wash tank. An additional energy input of 0,14 – 0,2 kWh/°C was registered in the research as effect of lowering the input water temperature.

As discussed, heat and moisture are expelled from the room through insufficient insulation and convection – hence the result of energy savings are directly parallel to ventilation of the space, condition of dishwashing machine and which technology is used in the machine. Earlier stated heat recovery system or heat pumps adequately ease the need to pour energy into keeping ambient temperature and humidity within expected levels.

There is definitely a profitable cause in the energy consumption of professional dishwashing process and the developers, manufacturers and users are constantly trying to find better ways of working to cut cost. However, there are not available common ground in consistent measurement methodology regarding consumption and performance data for professional dishwashers, especially when talking about energy. This leads to the idea that reported data or data provided by manufacturers is neither comparable nor subject to any control. This can be seen as uncertainty amongst the user crowd or regular consumer which would like to buy a product with low environmental impact or with the intention to have least life-cycle cost.

The challenges are indeed finding the right data on energy consumption, if any included at all. When gathering information from the different manufacturers web pages or brochures there were quite often comparing numbers to something, for example Electrolux is comparing to similar product claiming 60 % reduction in energy consuming on their web site. In some cases, the value is not communicated at all.

There is no doubt that the process of washing dishes in a professional kitchen is multifaceted and depends on various factors regarding the machine, ambient conditions and user behaviour. Usually, the purchase choice is based on non-comparable information and unrealistic bolded claims between the competing manufacturers. This also led to disadvantages between the manufacturers if marketing realistic data about the dishwasher – as supposed to overly optimistic data about energy and water consumption. This will inevitably lead to deferred development of technologies in the area and in my opinion but a relatively large dent in the idea of trying to make environmentally eligible machines that use less energy, water and detergent.

By adding up the different scenarios of dishwashing process in a professional kitchen, some points might help to recognise the consumption and cost picture of it. Essential data of determining the efficiency of a specific dishwasher, counter applying the standardised rules of sanitized wash ware are to be expected. Due to large variation in user behaviour, it is nearly impossible to approach the problem merely on data from a few machines. The data might also differ from day to day according to the incapable user, lack of training and other possible reasons like machine malfunction.

Even though the result in Attachment 1 shows a slight growth in surface microbiological growth when lowering the wash tank temperature, there is still possibility to deduct a quite hygienic result even in washing temperatures around 45 °C. By lowering to this temperature, it would be possible to estimate half the on-time of heating resistors in the tank, keeping in mind the test only covered medium soiled items in soft water and optimised detergent dosage.

Naturally adjusting one of the parameters would affect the others accordingly. The tested dishwasher has static pump that delivers both detergent and rinse-aid, so the dosing is relative to the amount of water the machine fills, measuring by conductivity. Although the test shows higher RLU measurement when lowering the tank water temperature, we might deduct an increasing microbiological growth due to the different possible residues mentioned in earlier text as some soil requires the higher temperature to bond with the chelating agents in the detergent diluted water.

Nowadays, there has also been great turnover in the workforce due to lockdowns, advancing the idea of creating multi-tasked workforce independent of place, but rather capable of switching between different locations and kitchens. Such phenomenon should also be flagged amongst the foodservice providers. A profitable suggestion would be to change the user behaviour through trainings and good way of working guidelines, rather than seeking out to re program the dishwasher by tweaking temperatures or detergent usage. As the calculation in Figure 11 shows, the more expensive energy is, the bigger possibility to save through usage. This would also include keeping the machine intact regarding components, upkeeping a healthy precisely scheduled maintenance and minimizing the downtime / stand-by time.

To answer the research question precisely, there is not much one can affect the dishwashing process withing the current standards, mostly because of the structure and design of the outlined dishwasher. However, through modifying user behaviour and doing extensive training, I believe that big municipals can make profitable modifications when regarding energy consumption in the dishwashing process.

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Attachment 1 Research data

Measured data	Measurements					
	1	2	3	4	5	
Temperature in room	22,2	23,1	24,5	23,7	22,7	
Inlet water temperature	48,1	52,5	51,4	50,8	53,8	
Temperature of the item going in the machine	21	20	21	22	21	
Tank temperature	55	52	48	45	40	
Boiler rinse temperature	84	82	82	80	82	
Program	2	2	2	2	2	*
Capacity of the dishwasher	165	165	165	165	165	**
Dosage detergent	1,7g/l	1,7g/l	1,7g/l	1,7g/l	1,7g/l	
Dosage rinse-aid	0,05g/l	0,05g/l	0,05g/l	0,05g/l	0,05g/l	
Degree of soiling	Medium	Medium	Medium	Medium	Medium	***
ATP measurement	RLU 2	RLU 2	RLU 1	RLU 8	RLU 10	
Electric power kW	31,5	31,5	31,5	31,5	31,5	
Cycle runtime	4 min	4 min	4 min	4 min	4 min	
Energy measurement / cycle kW	1,52	1,47	1,41	1,4	1,2	

* Two programs available 165/90 racks/h
** First program
*** Estimation by sight

Equipment:
Shelly 3EM energymeter 3-ph N 120 A clamps
Fluke 324 meter+temperature sensors
SystemSure Plus luminometer
UltraSnap-test for luminometer
Electrolux WTM 165

Attachment 2 Electrolux WTM 165 ERA technical sheet

	WTM165ELA 534105	WTM165ELB 534107
EGENSKAPER		
Energisparsystem ESD	●	
Anslutning	Elektrisk	Elektrisk
Matningsriktning	Från vänster till höger	Från vänster till höger
Energisparsystem - ESD HACCP Felindikering	●	
Varmvattenanslutning °C	50	50
Kallvattensanslutning °C	15	
Antal korgar/tim	165, 90	165, 90
Tallrikskapacitet/tim. 1:a/2:a hastigheten	2970, 1620	2970, 1620
Luftutsläpp - m³/t	180	
Isolering	●	●
Utvändiga mått - mm		
längd	2098	2098
djup	884	884
höjd/med öppna dörrar	1771, 2119	1771, 2119
1:a Kemdisk		
temperatur - °C	55-65	55-65
tankkapacitet - l.	150	150
effekt pump - kW	3.3	3.3
Duo-spolning		
temperatur - °C	60-70	60-70
tankkapacitet - l.	23	23
pumpeffekt - kW	0.35	0.35
Sköljning		
temperatur - °C	84	84
Genomströmmarens kapacitet (liter)	12	12
Genomströmmarens effekt (kW)	16.5	16.5
Totaleffekt - kW	31.5	31.5
TILLBEHÖR		
ÄNDPLUGG RFR 12ST F.DISKARM.TUNNEL.MODUL	864239	864239
AVLOPPS-KIT F. MODUL+KOMPAKT TUNNELDISK	864150	864150
DISKKORG FÖR 5 BRICKOR "TEMPRITE"	867005	867005
KIT MED 6ST DISKKORGAR FÖR DISKMASKIN	867050	867050
KIT MED 9ST DISKKORGAR FÖR DISKMASKIN	867051	867051
SILIKONGARDINER KIT TUNNELDISKMASKINER	864245	864245
STÄNKSKYDD FÖR TUNNEL.MODUL. INMATNING.	865177	865177
TORKZON, 600 MM, TUNNELDISK VÄ>HÖ	864511	864511
TORKZON, 900 MM, TUNNELDISK VÄ>HÖ	864501	864501
TORKZON, HÖRNMATN. TUNNELDISK VÄ>HÖ	864513	864513

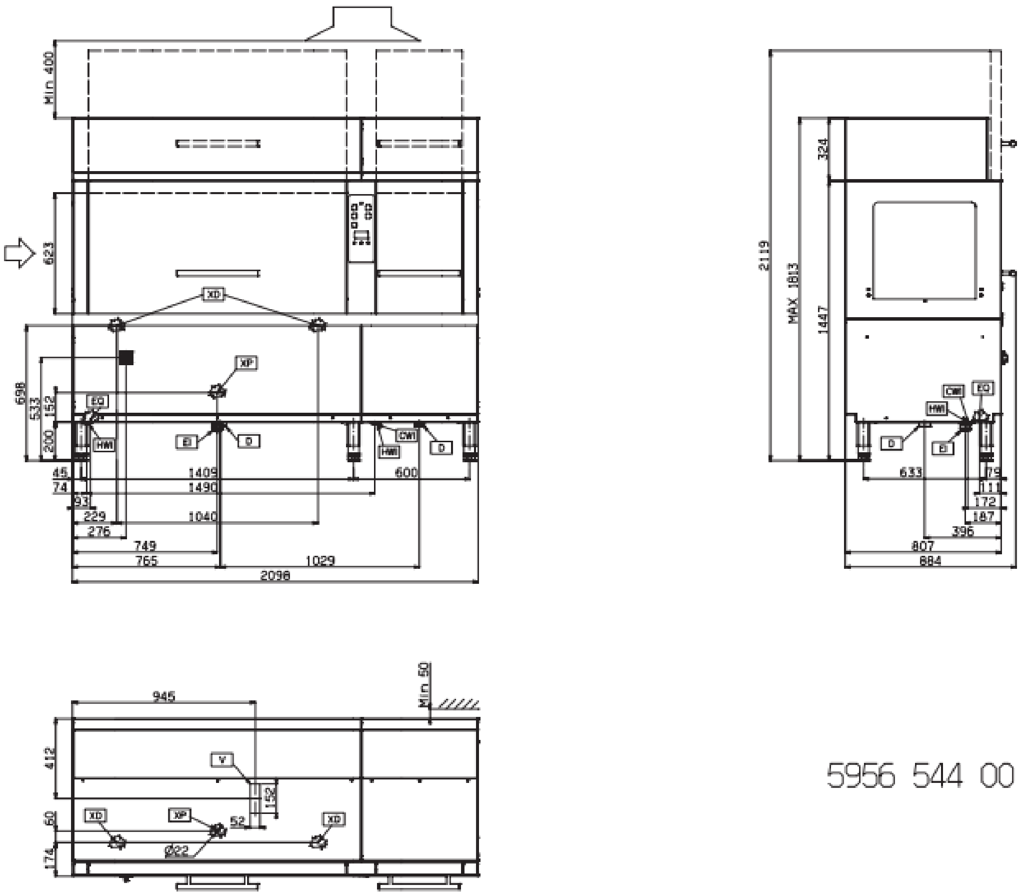
IEBB010

2013-10-02

Internet: http://www.electrolux.com/foodservice

Tunneldiskmaskin WTM 165, Vä>Hö
Electrolux Diskmaskiner

534105, 534107



BESKRIVNING	WTM165ELA 534105	WTM165ELB 534107
CWI - Kallvattensanslutning	G 3/4"	
D - Avlopp, diameter	G 1 1/2"	G 1 1/2"
EI - Elektrisk anslutning	400 V, 3N, 50	400 V, 3N, 50
EQ - Ekvipotentialskruv	●	●
HWI - Varmvattenanslutning	G 3/4"	G 3/4"
V - utlopp för ånga från kondensaggregatet	●	
XP - Anslutning för kem	●	●
XP - Anslutning för kemsensor	●	●