14th INTERNATIONAL CONFERENCE ON

HEAT ENGINES AND ENVIRONMENTAL PROTECTION

May 27-29, 2019
Mátraháza, Hungary

PROCEEDINGS
of selected papers

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Preface

The Proceedings of the 14th Conference on Heat Engines and Environment Protection is in the reader's hands. The Conference is organised by the Department of Energy Engineering, Faculty of Mechanical Engineering at Budapest University of Technology and Economics.

The history of conferences started 26 years ago. We preserve the original idea of the founders of the Conference: bringing together the specialist of the energy sector working either in the academic or in the industry for information exchange, strengthen and establish connections and giving opportunities for young professionals as well.

We kept the last time introduced changes like the technical tour and English for the language of the Conference thanks to the continuously rising numbers of attendees from abroad.

Since our Department organises the Conference, it is also an occasion to provide information about the research activity of our staff members and academic partners.

The Conference held on 27-29 May 2019 was attended by 21 international and 43 domestic participants, including students. They came from 14 countries and presented 50 papers, and selected 8 are included in this volume.

The conservation of nature and the efficient, secure, economic and social affordable supply of energy is the main task nowadays in energy engineering. The conference subjects were according to these goals that could be reached by the harmonised utilisation of renewable and the traditional energy resources. In the Conference, the renewable technologies were in focus but leaving space for the traditional energy issues and theoretical subjects as well.

During the three days, we were keen on creating a friendly atmosphere to promote forming of scientific and personal contacts. Moreover, working in the sessions, the information exchange between the participants continued during the breaks and social events and even in the technical tour.

At the end of this session, I would like addressing my thanks to all attendee rising of the scientific level of our Conference.

We are looking forward to meeting all of you at the next Conference in 2021.

Gyula Gróf
Head of Department of Energy Engineering

Special Thanks

To the members of the Organizing Committee:

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ENERGETIC AND ENVIRONMENTAL ADEQUACY OF BIOMASS THERMAL INSULATION MATERIALS

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Abstract: *Thermal behavior of a building is mostly determined by the type and capacity of utilized insulation material. Synthetic and other conventional mass-produced insulations are largely efficient in their primary role of decreasing heat flow through the building envelope, but their dynamic thermal behavior and overall environmental footprint are frequently worse than those of biomass-based materials. Diverse efforts towards the development of energy efficient but sustainable biomass insulation have been made. The analysis of thermal performance by steady-state and transient boundary conditions and Life Cycle Assessment of biomass insulation materials, recommend them as life-time energy efficient and resource-saving alternative to conventional thermal insulations.*

Keywords: *Dynamic thermal performance, Temperature profile, Embodied energy, Sustainability.*

1 INTRODUCTION

The construction sector has a severe environmental footprint due to the exploitation of non-renewable material and energy resources, land use and generation of waste materials during construction and demolition. It is also a massive energy consumer – for example in EU residential and commercial buildings are responsible for approximately 40% of global energy consumption and around 36% of CO_2 emissions [1]. At the global level the similar percentages are observed. Hence, the development of energy efficient and sustainable building structures, practices and materials, especially thermal insulation materials, is of substantial importance.

Various natural and synthetic materials have thermo-physical characteristics that enable them to severely retard conductive heat flow, so they can be applied as thermal insulation of outer walls of the building and support achieving of comfort conditions in inner rooms and heating (or cooling) energy savings. Fig.1 displays a basic classification of mostly used thermal insulation materials [2].

In addition to its main task to significantly reduce the heat losses (or gains), and to control surface temperatures, a competent thermal insulation also has to accomplish additional requirements such as: mechanical properties (required, by standards, for certain type the of insulation product: insulation panels/plates, loose-fill insulation, insulation foams, etc.), low water absorption and ability prevent water vapour flow and condensation, chemical and biological stability, non-toxicity, sufficient fire resistance, environmental sustainability, recycling possibilities, manufacturing feasibility, competitive pricing and, finally, the conformity with national regulations and local building practices and tradition.
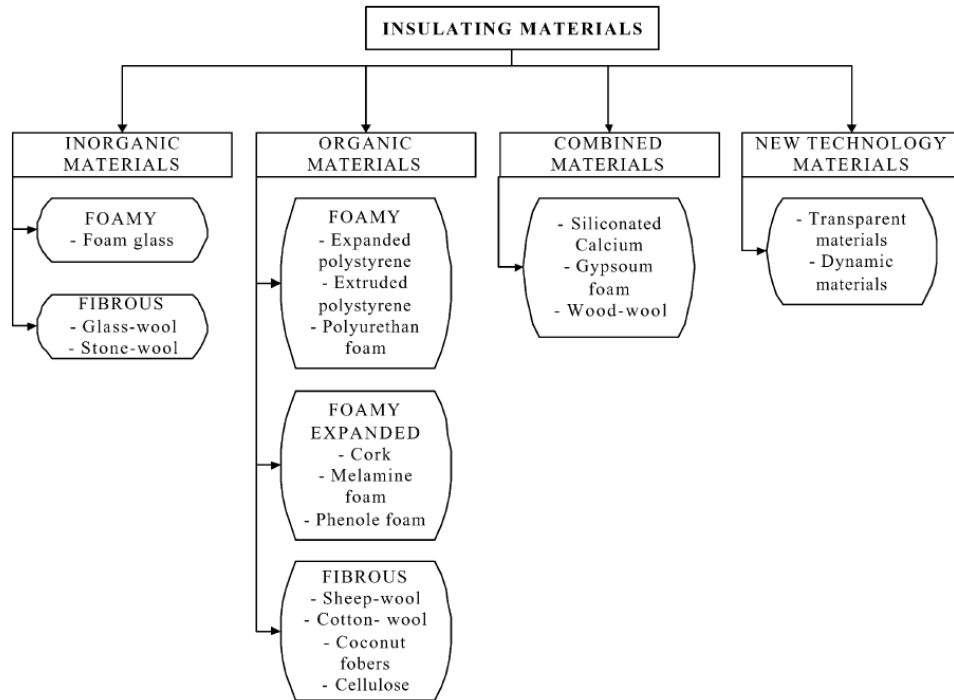
Fig.1. Classification of thermal insulation materials [2]

2 BIOMASS THERMAL INSULATION

Diverse biomass materials, as well as their mixtures with other materials, have been evaluated as thermal insulation: standalone biomaterials (various wood waste products, reeds, straw, bagasse, cattail, cotton, sunflower, hemp, jute, cork, seagrass, flax lan, corn cob, rice hulls, coconut fibers, date palm, etc.), their combinations (hybrid biomass insulations) and a whole range of bio-fibre composites with cements (Fig.2), lime, synthetic materials, etc. It can be claimed that nearly all common agricultural and forest residual materials have been considered [3-15].

Fig.2. Insulation panel of Miscanthus fibers with cementitious binder [14,15]

Main thermophysical properties (density, thermal conductivity and specific heat) and technical characteristics crucial for applicability (resistance to water vapor diffusion and flammability) of biomass-based materials and materials from recycled plastic, glass or fabrics are shown in Table 1, along with the same parameters for commercially established synthetic

and natural insulations. It is important to note that density of most insulation materials varies in a wide range, which causes a shift of other relevant properties. A typical fibrous material, for instance stone wool, can be manufactured with density between 30 and 200 kg/m^3, and consequently possess diverse values of thermophysical parameters (e.g. thermal conductivity).

Table 1. *Main characteristics of conventional and biomass-based thermal insulation materials*

Material	Density (kg/m^3)	Thermal Conductivity (W/(mK))	Specific Heat (kJ/(kgK))	*µ factor* – resistance to water vapor difusion	Flammability (based on EN13051 and DIN 4102)
Stone wool	30-200	0.033-0.041	0.8-1.0	<1	A1
Extruded polystyrene (XPS)	30-45	0.029-0.037	1.45-1.70	80-200	E
Expanded polystyrene (EPS)	15-35	0.028-0.037	1.25	80-200	E
Recycled glass	100-165	0.038-0.05	1.0	Very high	A1
Recycled PET	15-60	0.034-0.039	1.2	3	B2
Recycled cotton	25-45	0.039-0.044	1.6	1-2	E
Cotton stalks	150-450	0.059-0.082	NA	NA	NA
Straw bale	80-120	0.06-0.10	0.6	<1	B2
Wood	550-900	0.14-0.70	2.4-2.8	50-70	B2
Wooden wool	300-350	0.08-0.14	NA	3-5	B2
Reeds	130-190	0.045-0.056	1.2	1-2	E
Celulose (pure)	30-60	0.033-0.04	1.3-2.1	1-5	B2
Hemp	20-90	0.04-0.05	1.5-1.8	1-2	B2
Cork panels	130-220	0.04-0.045	1.7-2.1	NA	B1
Corn cob	170-330	0.10	NA	NA	NA
Rice hulls	105-115	0.05	NA	3	B2
Miscanthus panels (with mineral binder)	1050-1270	0.06-0.11	1.4-1.8	NA	B1

Some biomaterials, such as reed or straw, can be used directly in their natural form. However, most biomass needs additional treatments to obtain the final product, which can be in the shape of loose material, roll batts, flexible or rigid slabs, etc. with respectively varying mechanical and physical properties. This emphasizes the importance of proper characterization and standardization of biomass insulations, especially in the case of their industrial-scale production.

3 THERMAL PROPERTIES

The decisive characteristic of insulation material is its *thermal conductivity λ* [W/(mK)]. By steady-state heat transfer conditions the thermal conductivity is sufficient for evaluation of

heat flow and temperature change inside the material of given thickness. Nevertheless, the building envelope (insulated outer walls) is mostly exposed to complex quasi-periodic boundary conditions influenced by daily changes of air temperature, humidity and flow, sun intensity and direction. Hence it is also important to recognize the parameters responsible for the dynamic behavior of the material, such as *thermal diffusivity a* [m^2/s] and *thermal effusivity e* [Ws$^{0.5}$/(m^{2}K)]:

$$a = \frac{\lambda}{c \cdot \rho} \ , \tag{1}$$

$$e = \sqrt{\lambda \cdot c \cdot \rho} \ . \tag{2}$$

Thermal diffusivity is determined by the values of thermal conductivity, *density ρ* [kg/m^3] and *specific heat c* [J/(kgK)] and expresses dynamics of temperature change inside the body due to the conductive heat flow. It allows comparing the material's ability to conduct and to store thermal energy during a time-dependent heat transfer process. Thermal effusivity is important for transient thermal behavior of the surface of a material. It describes the rate at which material releases (or absorbs) heat to (or from) its surroundings or objects in contact (e.g. contact of insulation and building's wall). It is responsible for the feeling of cold or hot touch. Both parameters are decisive for insulated wall dynamic thermal behavior and building comfort.

Mass used synthetic insulation materials, such as extruded and expanded polystyrene, possess superiorly low values of thermal conductivity (Table 1). Nevertheless, in comparison to biomass-based insulations their thermal diffusivity is 2-3 times higher. For example, if an increment of temperature is applied to one side of an insulation material, the depth to which the temperature will change significantly 10 min later is between 26 and 38 mm in case of various natural materials and 63 mm for expanded polystyrene [3]. In general, an insulation material characterized by a high value of specific heat can provide low thermal diffusivity values even with low density - a material characterized by thermal conductivity under 0.05 W/(mK) and specific heat over 1.4 kJ/(kgK) can be considered very performing also in unsteady-state conditions [4]. Compared to common mass produced thermal insulations, the bio-fiber based insulation materials have mostly slower temperature response and higher thermal inertia.

3.1 DYNAMIC THERMAL PERFORMANCE

During a 24-hour day the temperature profile of a building`s outer wall changes dynamically as a function of outside and inside boundary conditions and type of the wall. Dynamic thermal response of the wall is especially important in case of high diurnal ranges, e.g. desert climate in summer or sudden changes of outside boundary condition due to the cold wind in winter. In summer conditions the heat wave propagates towards the inner surface of the building envelope, while its direction in winter conditions is reversed.

The temperature profiles of sun-exposed wall surfaces and ambient air in a high-load summer condition are displayed in Fig.3. At the outer wall surface the temperature change (*temperature amplitude*) is determined by solar radiation and convective heat exchange with ambient air. The temperature amplitude of the heat wave decreases during its propagation through the building envelope as a function of thermophysical properties and thickness of the wall and insulation layers. For thicker and more resistive materials (larger *thermal mass*) it takes longer for heat wave to pass through. At the inner wall surface the wave`s amplitude is considerably smaller. The ratio of temperature amplitudes at the inner (*Ai*) and at the outer wall surface (*Ao*) is defined as *Decrement factor*, and the time that the heat wave needs to propagate from outer to the inner surface is called *Time lag*.

The reduction in cyclical temperature of the inner surface compared to the outer surface of the building envelope is crucial for comfort, energy consumption, and overall climatization

costs. For example, an insulated outer wall which experiences a 40°C variation in external surface temperature during the day, and has a decrement factor of 0.2, will have variation in internal surface temperature of only 8°C. Additionally, the walls built of and insulated with materials having favorable thermal lag values (10-12 hours) allow the external heat to enter only when the ambient temperature starts to decrease, limiting the risk of overheating.

Diverse investigations have confirmed that individual materials generate different time lags and decrement factors and that thickness of insulation layer has significant influence [16-20]. The importance of utilization of optimized thermal insulation is indisputable since, e.g. 10cm thick outer brick wall has decrement factor of 0.9 and thermal lag of around 3.3 hours only, which means that indoor temperature fluctuations will be harsh, as temperature peaks will be rapidly transmitted to the interior of the building. The similar wall, insulated at the external side with 10 cm of thermal insulation material covered with 2cm of plaster ($\rho=1800$ kg/m³; c=0.8 W/(mK); λ=0.90 W/(mK)) would, depending on the insulation material applied, have approximate dynamic thermal characteristics shown in Table 2 (extrapolation based on [6]). The adoption of reeds instead of stone wool insulation contributes to the reduction of decrement factor of around 7% and the increase of time lag of 14%. In case when reed insulation is used instead of EPS, the improvements are even better - decrement factor is decreased by approximately 11% and time lag increased by 26%. The cork insulation shows the best dynamic thermal properties, mainly due to its higher specific heat.
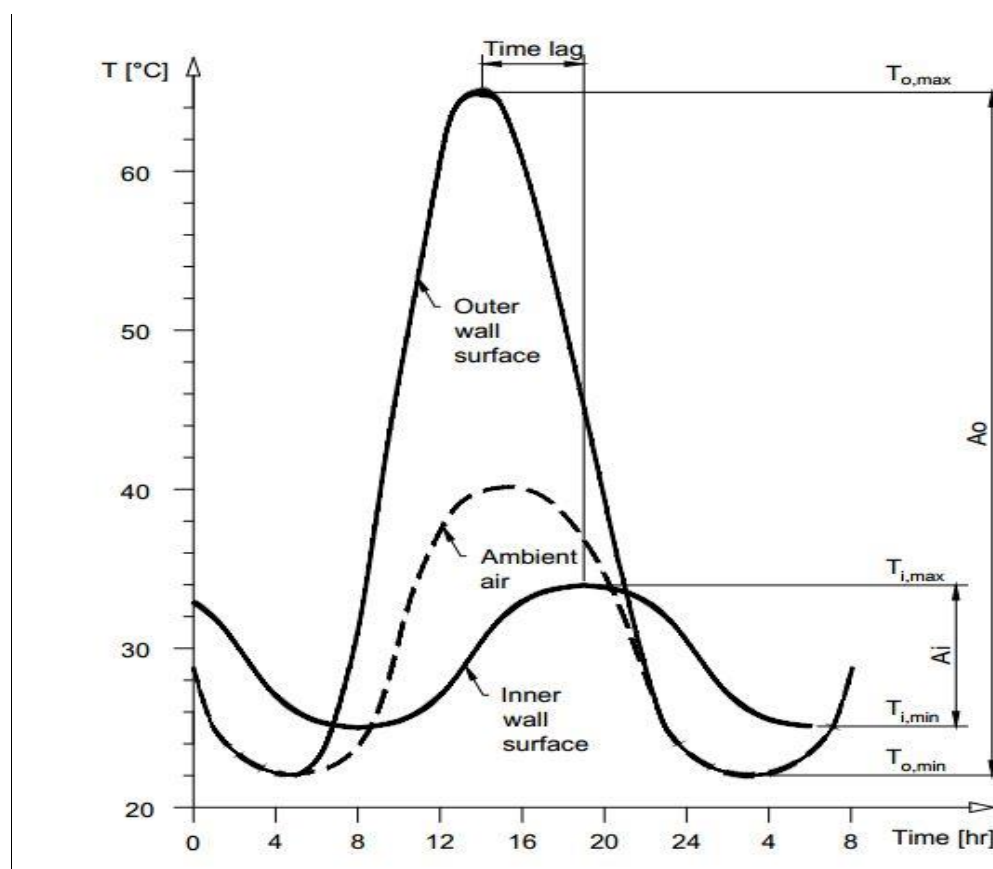

Fig.3. *Dynamic temperature profiles of ambient air and surfaces of a sun-exposed wall*

It can be concluded that the low values of density of synthetic insulations (EPS, XPS, etc.) weaken their dynamic thermal properties and disable them to have better thermal wave shift results.

Table 2. *Approximation of dynamic thermal properties of 10cm brick wall insulated with different materials*

Insulation material	ρ (kg/m^3)	c (kJ/(kgK))	λ (W/(mK))	Decrement factor	Time lag (h)
Stone wool	70	1.0	0.033	0.42	7.6
EPS	22	1.3	0.035	0.44	6.9
XPS	32	1.7	0.032	0.42	7.4
Reeds	190	1.2	0.056	0.39	8.7
Hemp	90	1.7	0.040	0.39	8.5
Cork	130	2.1	0.040	0.33	10.0

The total amount of heat transferred conductively through the insulation of a certain thickness during 24h is controlled solely by the value of thermal conductivity and can not be reduced by increasing heat capacity or density of the material. Nevertheless, the increase of heat capacity and density of the insulation material do decrease fluctuation of the heat flux through the wall, as well as its maximal values. The increase of heat capacity and density also contributes to the increase of time lag. Such minimization of heat flux variations and optimization of time lag are highly beneficial for comfort, energy efficiency and overall energy consumption of the building.

4 LIFE CYCLE ASSESSMENT AND EMBODIED ENERGY

Environmental adequacy is among the main objectives for the development and utilization of biomass-based thermal insulation materials. There have been numerous attempts to valorise and quantify the foreseen superior sustainability of biomass insulation over classical insulation materials. The best developed and most detailed environmental tool, with a substantial literature base, nowadays is *Life Cycle Assessment* (LCA) methodology [21,22]. LCA evaluates the impacts of products and services on the environment and human health during the life cycle. The product is followed from the extraction of raw materials, through its production and use phases to its disposal (*Cradle to Grave* approach). The environmental burdens are quantified through various indicators concerning pollutant and carbon emissions energy flows, etc. All the inputs and outputs are mass and energy balanced and analyzed.

Some LCA variants do not consider the whole life cycle but rather some phases: *Cradle to Gate* approach enables assessment of partial product life cycle from resource extraction to the factory gate (before reaching the consumers), with use and disposal phases omitted.

LCA observe the processes and impacts normalized to the quantity named *functional unit* (f.u.). For assessment of thermal insulation materials, the functional unit is defined as the mass of material, per 1m^2 of insulated wall area, needed to obtain a thermal resistance of 1 m^{2}K/W.

In the evaluation of thermal insulation materials especially important are energy oriented LCA and the concept of *Embodied Energy* (EE). In Cradle to Grave approach EE is defined as the sum of total energies needed to construct (*Initial EE*), maintain (*Recurrent EE*) and demolish, reuse, recycle and dispose (*Demolition EE*) a building [23]. The energy needed to operate the building (heating, cooling, etc.) is excluded from the analysis.

However, there is no unique method for calculating the embodied energy during the production of materials, as well as during the building maintenance, demolition and materials recycling/disposal. There are numerous databases with various charts of embodied energy with different values for the same corresponding material [24]. Their cursory implementation into the calculations frequently causes inconsistencies in the results. Besides, EE determination is also influenced by location of the building site, through modes of transportation, sources of primary energy used, unique manufacturing practices and distances from construction sites to manufacturers, suppliers, and landfills [23]. Accordingly, it is very challenging to present the

exact values of EE for different insulation materials. The data collection given in [25] rates EE per kg of insulation in the following ranges: glass wool 14-29MJ/kg, mineral wool 10-27MJ/kg, expanded polystyrene 30-160 MJ/kg, extruded polystyrene 40-105 MJ/kg, polyurethane 74-140 MJ/kg and cellulose-based materials 3-21 MJ/kg. Similar findings, per functional unit of insulation material, are shown in Fig.4.

Due to the multiple constraints, the generalization of the results of EE studies is ambiguous, but it might be claimed that natural materials, especially cellulose-based materials i.e. most of the plant biomass, perform notably better than conventional, particularly synthetic, insulation materials.

The participation of embodied energy in the total lifetime energy of conventionally insulated buildings is usually up to 20% [23,26]. The lifetime energy demand can be reduced by improving the building's thermal insulation, in which case the need for operational energy decreases while embodied energy increases. The participation of EE in the lifetime energy can exceed 40% in the case of *low energy* buildings [27], or be even higher in the case of *net-zero energy* buildings [28]. Consequently, excessive use of thermal insulation (especially if utilized materials have high EE values) might be counterproductive in terms of building's lifetime sustainability.
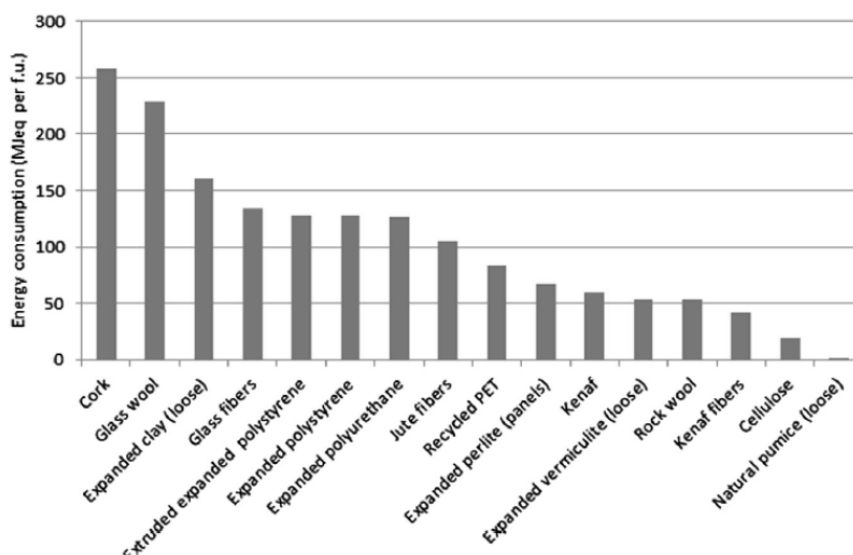

Fig.4. Embodied energy of functional unit of insulation material [6]

5 CONCLUSION

Improvement of thermal performance and sustainability of buildings through the introduction of novel thermal insulation materials has to include a thorough understanding of transient thermal behaviour of insulated outer walls. Increased outer wall thermal inertia and the ability to time-shift the thermal wave improve comfort and decrease overall energy consumption, especially by large diurnal temperature differences. Biomass-based thermal insulation materials have demonstrated a superior dynamic thermal performance, observed through the values of the thermal decrement and the time lag, compared to the conventional insulations.

Consideration of environmental adequacy of biomass insulations in the frame of LCA methodology has confirmed that utilization of biomass-based insulation materials, with lower embodied energy contents than the conventional, especially synthetic, thermal insulations, is beneficial for lifetime energy demand and overall sustainability of a building.

The biomass-based thermal insulations need further development in order to reach satisfying technical characteristics. The fire resistance and durability, as well as mechanical properties, water vapour diffusion resistance, moisture sensitivity, microorganisms and pests safety, manufacturing methods, mass production feasibility, ease of installation and cost-effectiveness, need to be thoroughly studied and improved. Finally, the present-day product standards and legal regulations for conventional thermal insulations are not fully applicable to biomass materials, so the appropriate testing and certification procedures need to be developed, confirmed and incorporated in order to facilitate successful market access of biomass-based thermal insulations.

ACKNOWLEDGMENT

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9

ALTERNATIVE MOBILITY - DRIVE AND SUPPLY CONCEPTS OF THE FUTURE

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Abstract: The transport sector, as part of the German "Energiewende", is responsible for around 26% of Germany's total primary energy consumption and thus also for around 28% of energy-related CO_2 emissions. In practical terms, however, the Energiewende within the transport sector is only at the beginning of its development. This assessment is underpinned in particular by the fact that the share of renewable energies in the transport sector has been stagnating at around 5% for about a decade. Accordingly, the transport sector is a major challenge for the next decade or until 2030, especially because of the climate protection targets set by the German government. After IZES has set up and extensively tested a quasi-independent charging station for battery electric vehicles over the last few years, within the framework of the project GenComm a hydrogen refuelling station will be built at the IZES site in the InnovationCampus Saar by the beginning of the year 2020. After completion, this will be the first hydrogen refuelling station in Saarland, which will be non-public. The planning is well advanced and the main components of the refuelling station have already arrived at the manufacturer and will be installed there until December 2019. Vehicles powered by fuel cell technology are the next evolutionary step in electro mobility after the battery electric vehicles that have become established in the meantime. On 22 March 2019, the first Toyota Mirai, a H2-powered fuel cell vehicle, in the Federal state of Saarland was registered for IZES gGmbH with the registration of the vehicle and the forthcoming commissioning of the refuelling station, the "Hydrogen age" has now also begun in Saarland as an essential component of the future energy supply.

1 INTRODUCTION

In the public discourse, the term "Energiewende" mostly stands - in a strongly reduced form - for the restructuring of the electricity supply from fossil fuels to renewable energy sources. For the success of the Energiewende as a whole, however, the sectors of heat and transport/mobility are also of central interest. Compared to the electricity sector, the "heat and traffic Energiewende is still in its early stages and has so far only been given secondary consideration. In 2018, the renewable share of gross electricity consumption was about 38%, in the heating sector only about 14% and in the transport sector only 5.6%. These figures clearly show that the energy system transformation can only succeed if all three relevant sectors are developed with the same intensity and in a cross-sectoral way towards a conversion to renewable energy sources. In order to achieve a successful transition to renewable energies in all sectors of the Energiewende, it is essential from today's point of view to initiate a coupling of renewable electricity production with other sectors and to establish it in the medium term. In order to achieve the climate protection goals, set by the Federal Government of Germany, the "electrification" of the transport sector by means of battery and/or fuel cell electric vehicles based on renewable energy sources on the one hand and the rapid further development of production processes for liquid or gaseous as well as synthetic or bio-based fuels on the other hand are key issues for the future in view of the differing requirements profiles for different vehicle uses.

2 INTERNATIONAL OBLIGATIONS AND STRATEGIC GOALS

The present work deals mainly with the passenger car sector and individual traffic. From the author's point of view, it seems very likely that three different drive concepts will compete with each other in the area of private transport in the future. These include the combustion engines commonly used today with diesel or petrol as well as battery and fuel cell electric vehicles. Other drive concepts such as natural gas engines will also be available as niche products. From today's point of view, there will be no "silver bullet". At present, the three drive concepts mentioned above have specific advantages and disadvantages as described below.

One advantage of vehicles powered by internal combustion engines is the range of the vehicles, in some cases well over 1,000 km, in conjunction with a close-meshed network of refuelling stations covering the entire area. Petrol or diesel engines have undergone continuous development over the past 150 years and have now reached a very high level of development. By using new materials and higher operating pressures in the future, the efficiency of these engines can be further slightly increased. A further bonus is the very large selection of available vehicle manufacturers and an even larger selection of differently equipped and motorised models. Combustion-powered vehicles are available in all price categories, equipment variants and size classes. The serious disadvantages of the combustion engines are the high pollutant and GHG emissions caused by the use of fossil fuels and the declining confidence of the population in the respective manufacturer's specifications due to the diesel scandal. Another political disadvantage is the dependence on oil-producing countries.
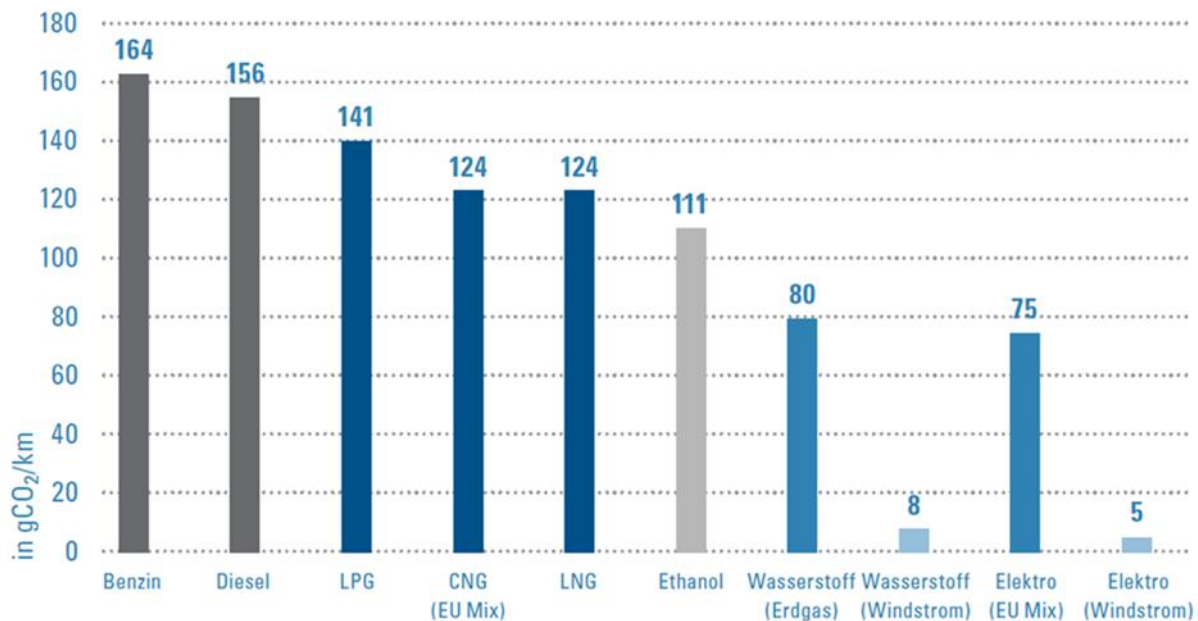

Fig. 1. *CO2 emissions of different fuels in g/km [Source: NOW GmbH, Energy Turnaround in Transport in the Municipal Environment, September 2019]*

The advantages of battery-powered vehicles are the very low pollutant and GHG emissions resulting from the use of renewable electricity, see Fig. 1. The electric motors used are highly efficient. In addition, the efficiency of the vehicles is further increased by means of recuperation or recovery and storage of braking energy. Furthermore, the operation of the vehicles is very quiet and, due to a smaller number of installed parts, very low-maintenance compared to combustion engines. Disadvantages at present are the comparatively high price of the vehicles, the stability or cycle stability of the battery systems used, which has not yet been

proven over a long period of time, and the usually short range. Further disadvantages are the charging time of the batteries, which usually takes more than one hour at normal charging stations, and the relatively high weight or low energy density of the batteries commonly used today. In addition, from today's perspective, the 100% supply of regenerative electricity, which is not yet guaranteed in the national balance framework, must be addressed, so that an expansion of battery-electric vehicles must go hand in hand with a significant expansion of renewable energies at European level.

The advantages of fuel cell electric vehicles are also the significantly reduced or very low pollutant and GHG emissions of the vehicles. However, these emissions are slightly higher than those of battery-operated vehicles, see also Fig. 1. The fuel cells used are supported by a battery and are therefore also capable of storing and recovering braking energy. Compared to internal combustion engines, operation is also very quiet and comparable to that of battery electric vehicles. With the vehicles available on the market today, ranges of up to around 600 km can be achieved. Disadvantages at the present time are the comparatively high price of the vehicles and the fact that the fuel cell systems used have not yet proven their stability or cycle stability over a long period of time. A further disadvantage is the current inadequately dense network of filling stations in Germany and the very small selection of vehicles. As of October 2019, there are about 80 hydrogen refuelling stations in Germany and only two vehicles, the Toyota Mirai and the Hyundai Nexo, are available, some of them with very long delivery times. The GLC F-CELL from Mercedes Benz can currently only be leased.

In addition, it can be noted that the H2 to be used as fuel does not necessarily have to be produced nationally from renewable energies because of its transportability, but can also be imported from countries with a high solar surplus (e.g. Southern Europe, MENA region, etc.).

Due to expected future developments and optimisation measures, the above mentioned advantages and disadvantages of the three different mentioned drive concepts may shift or even change into the opposite. With regard to the model variety of battery and fuel cell electric vehicles, there will be a significant increase in the medium term. For example, around 20 new battery electric vehicles were presented at the International Motor Show in Frankfurt in September 2019. It is to be expected that acquisition costs will also fall significantly as market penetration begins or increases. The objective is that the increased sales of these technologies, which have been further developed to make them suitable for everyday use in the medium term, will simultaneously reduce the sales figures for internal combustion engine vehicles in the future. A further important and reinforcing reason for this development - not at least pushed by the current climate protection movements - will be the increasing social change in the perception of our own mobility behaviour as well as the apparently increasing scepticism or decreasing acceptance of fossil fuels by potential users.

By providing a sufficient quantity of synthetic fuels in the medium term, such as hydrogenated vegetable oils (HVO), with improved combustion characteristics resulting in higher efficiency and reduced pollutant and GHG emissions, vehicles powered by internal combustion engines can again become an interesting alternative. Fig. 2 gives an overview of the different energy contents of the fuels used today per volume (gaseous: standard cubic metre (Nm3), liquid/solid: litre (l) both under normal conditions) or per mass.

When comparing the different types of fuel, it is remarkable that the energy density of hydrogen in terms of mass is significantly higher than that of all other fuels, but is significantly lower in terms of volume than that of natural gas types L and H. When comparing liquid fuels, HVO has approximately the same values as diesel or petrol. Batteries according to today's state of the art are significantly behind all other fuels in this comparison. These parameters must be taken into account in particular in the context of the desired performance (speed, range, available space, etc.) of the respective vehicle type as well as the area and purpose of use (individual/heavy goods traffic, public transport, etc.).
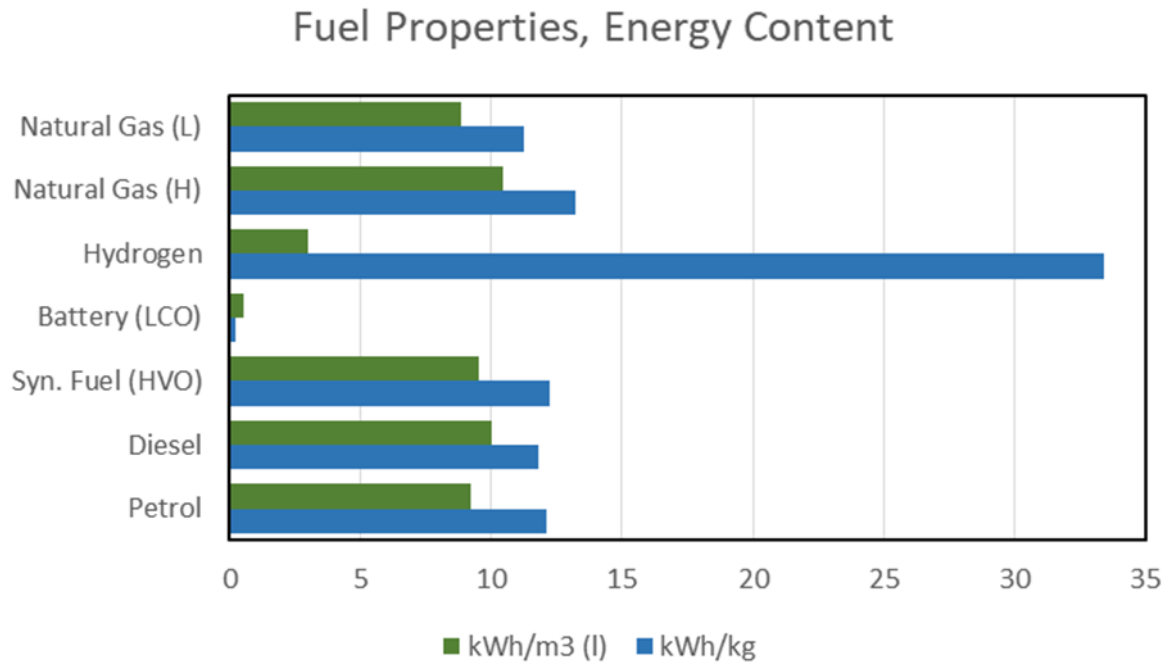
Fuel Properties, Energy Content

Fig. 2. *Energy density of various fuels, including Li-Ion batteries (Source: IZES)*

Finally, it should be added that, according to current estimates, alternative drive concepts alone will not be sufficient to achieve the objectives set in the transport sector. Rather, they must be part of a holistic mobility strategy.

3 THE OPTICHARGE/OPTICHARGE[+] PROJECTS

The main topic of the OptiCharge project, which was completed at the end of 2018, was the development of an optimised, storage-supported charging management system for a quasi-autonomous powered charging station operated with renewable energy. A research platform - consisting of a vanadium redox flow battery (30 kW; 120 kWh), a PV array with around 10 kWp on the roof of a carport and four independent AC charging points - was planned, set up and operated within the project period. Fig. 3 shows the completed charging station/solar carport for battery vehicles.

As connecting components, an energy management system and a corresponding booking system for the company's own vehicles were developed and tested in everyday operation. By the employment of the energy management system in the context of the project, under consideration of the needs of the individual vehicles, the own consumption of the entire plant should be optimised and at the same time the net purchase be minimised.

Within the follow-up project OptiCharge+ the existing R&D platform will be extended by several components, such as a user-oriented charging-, network- and extended energy management system as well as a DC-Micro-Grid and a DC charging option. In addition, there will be a connection to the Internet of Things. The result is a modern charging infrastructure for battery electric vehicles. In addition to demonstration operation, the primary objectives of the project are to increase overall plant efficiency, grid compatibility and user comfort and, as a result, to increase the technological maturity of the components used. This should be an important step towards a socio-economic marketability of the components used.

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Fig. 3. *The IZES solar carport for battery electric vehicles, including a PV array on the roof as well as the containerised Vanadium-Redox-Flow-Battery in the background (Source: IZES)*

4 GENCOMM

The aim of the sub-project solar-powered "hydrogen refuelling station" within the framework of the Interreg VB NWE project GenComm is the construction and operation of a renewable hydrogen refuelling station consisting of a PV array, electrolyser, high-pressure storage tanks and refuelling facilities for fuel cell electric and, if necessary, hydrogen combustion engine vehicles; see Fig. 4.
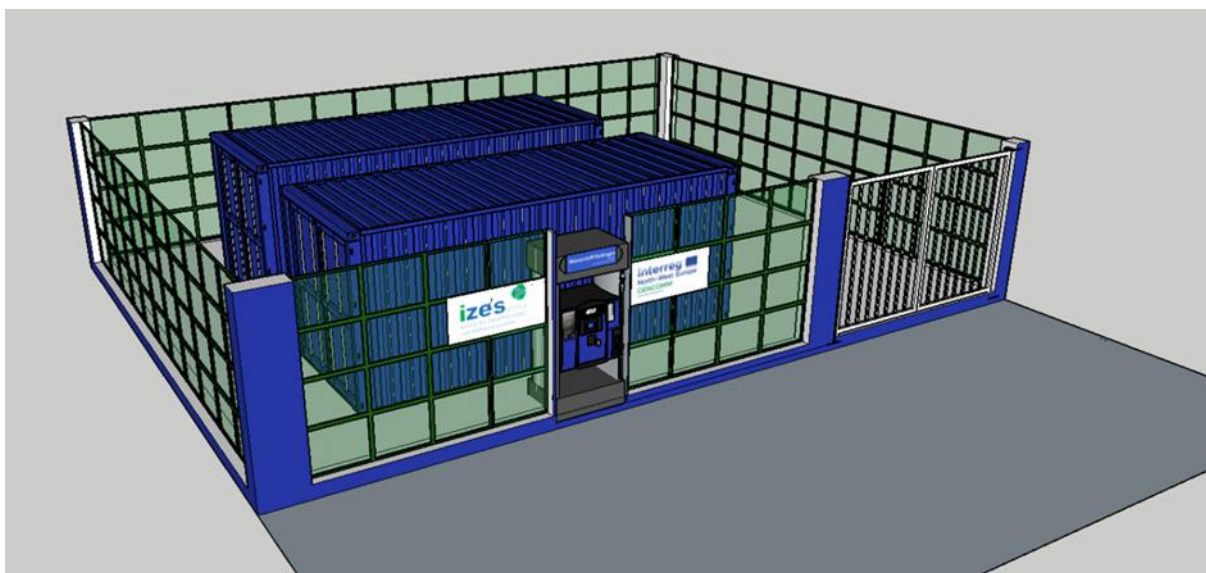

Fig. 4. *Schematic drawing of the planned hydrogen refuelling station in Saarbrücken (Source: IZES)*

The reason for the planning of the refuelling station was that it has not yet been possible to refuel a hydrogen-powered vehicle in the southwest of Germany, especially in the Saarbrücken/Saarland area. Previous efforts to supplement a hydrogen refuelling option at an existing public refuelling station either failed or, as of November 2019, are still in the planning/approval phase. The maximum production capacity of the non-public refuelling station planned as part of GenComm is around five Nm3 H2 per hour, with a maximum delivery pressure of 700 bar. The Hydrogen is produced directly on site by electrolysis. The electricity

required for this is also produced directly on site using a PV system with around 30 kWp. Two different technologies, a PEM and an AEM electrolyser, are used for electrolysis. In particular, the AEM electrolyser is to be scientifically investigated or increasingly operated. The maximum storage capacity for hydrogen is around 55 kg, divided into two different pressure levels (10 kg at 950 bar and 45 kg at 450 bar). The purity of the produced Hydrogen is 99.999% or corresponds to quality level 5.0. Optionally, a battery storage unit can be integrated later into the system in order to optimise the own consumption of the PV system as well as to protect the electrolysers (e.g. in case of fast load changes). Fig. 5 shows the diagram of the refuelling station planned by IZES.
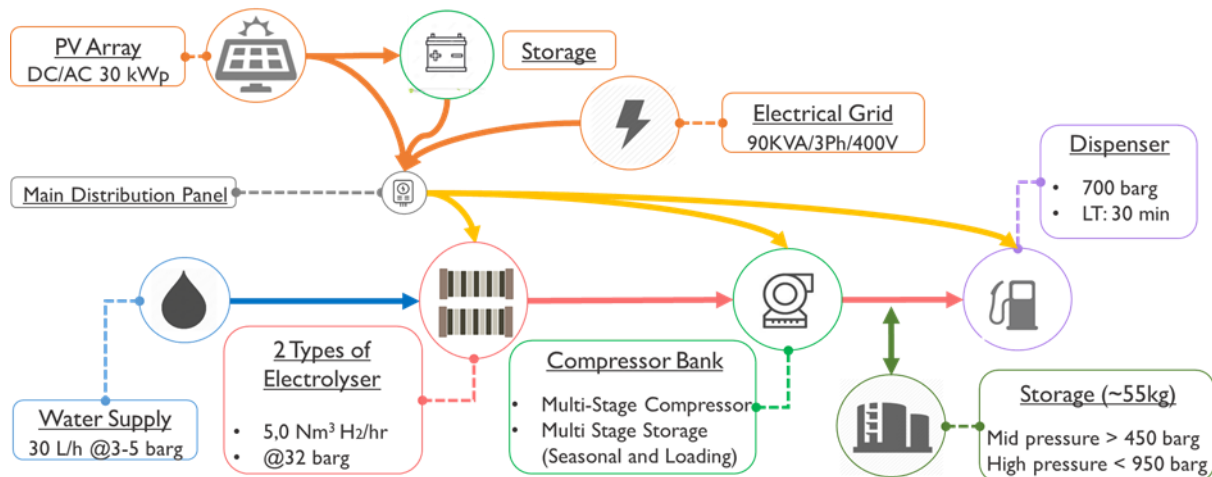

Fig. 5. *Schematic diagram of the planned hydrogen refuelling station (Source: IZES)*

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SUSTAINABILITY ASSESSMENT OF RENEWABLE ENERGY IN THE EUROPEAN UNION WITH SPECIAL ATTENTION TO HUNGARY

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Abstract: Bioethanol has been used as an alternative fuel or fuel additive in transportation. Its use as energy resource may slow the depletion rate of fossil resources. Sustainability of the replacement of fossil resources with corn-based bioethanol was assessed by using the ethanol equivalents (EE). The calculations were based on first generation corn-based bioethanol technology as practiced at industrial scale. Based on the EE values, the required volume of corn and the corresponding size of land was calculated, and compared with the actual lands used for corn production. The assessment shows that in spite of the significant renewable energy use in the EU, an increase of the renewable energy portfolio is required in Hungary.

Keywords: Sustainability, Ethanol Equivalent, Fossil Energy, Renewable Energy, Bioethanol

1 INTRODUCTION

Energy security is one of the important issues of mankind besides food and water supply, and the climate change independently of economic and political conditions [1]. With increasing population, the World's primary energy consumption could increase from 13,276 Mtoe (million tons oil equivalent) in 2016 to 17,157 Mtoe by 2035 [2]. The total primary energy consumption of the European Union was 1642 Mtoe in 2016, which is 12% of the World's total consumption. According to the annual statistical energy report published by British Petroleum significant part of the energy has been produced from fossil resources in spite of the increasing contribution of the different types of renewable energy resources. Analysing the share of different resources in energy consumption in the EU-28 in 2016, 75% was based on fossil resources, and the rest on 12% nuclear energy and 13% renewable energy (Fig. 1). Noteworthy that the nuclear accident in Fukushima, Japan in 2011 did not influence the nuclear energy's contribution in the EU-28 significantly, though a slight decrease of nuclear energy from 199.7 Mtoe (in 2012) to 190 Mtoe (in 2016) could be observed. Hydroelectric power and other renewables together provided 214.3 Mtoe, which corresponds to 13% of all the primary energy [2].

The replacement of fossil resources (natural gas, crude oil, and coal) with different types of renewable energy resources has become the main goal of sustainable development [3]. The successful substitution of fossil resources by renewables will require the combination of all types of the currently available renewable resources. It should be noted however that the renewable energy portfolio is highly dependent on the geographical location [4].

The theory behind was to analyze if only one type of renewable resources would be selected, could we really cover our primary energy needs with this lonely resource? Biomass is the oldest energy resource and can directly utilized to produce thermal energy or electricity in power plants. Alternatively, biomass can be converted to ethanol, frequently called bioethanol, which has been made from corn or sugar cane at industrial scale for decades. Our analysis assumes the use of biomass as a feedstock to generate bioethanol at first because it can be used as a fuel-additive in transportation [5, 6, 7], as a fuel of gas turbines in energy generation [8], or as a carbon-feedstock in the chemical industry [9-10]. Furthermore, lignocellulosic bioethanol, known as a second-generation bioethanol, has gained importance in the last 10 years

[11]. Bioethanol is a favoured bio-based product because of dual reasons: its energy content and carbon-atom content.
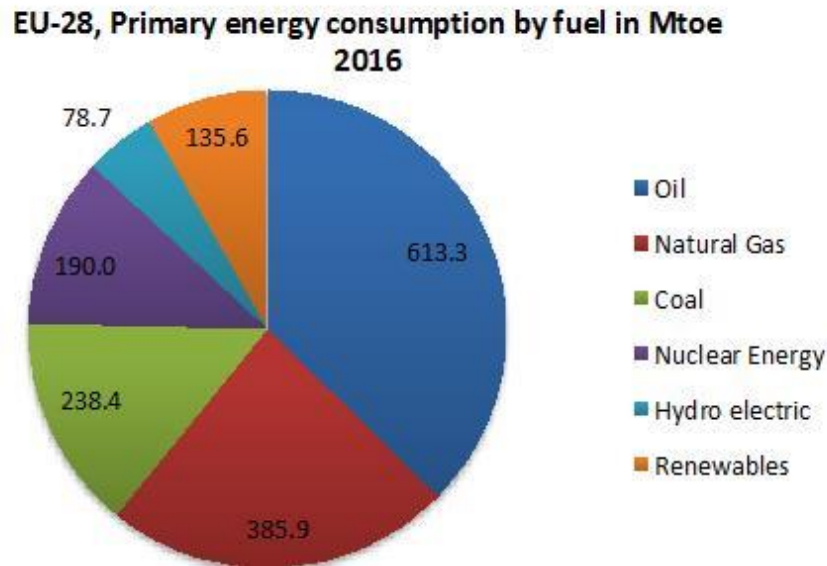

Fig.1. Primary energy consumption of EU-28 by fuel in 2016

In the case of Hungary, the fossil resources represented almost 80% of the total 21.9 Mtoe primary energy, while 16% was nuclear energy and the rest 4% was renewables in 2016 [2].
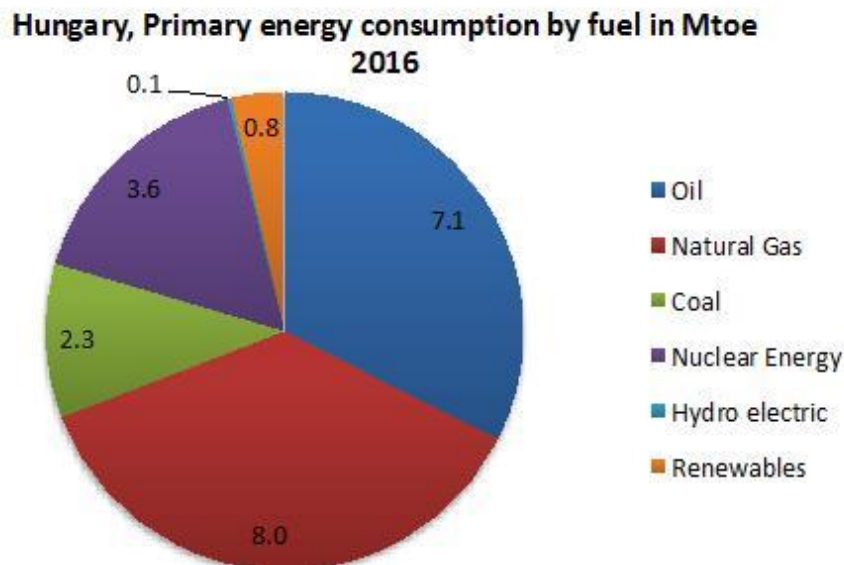

Fig.2. Primary energy consumption of Hungary by fuel in 2016

Additionally, when growing plants to produce ethanol, it can contribute to zero CO_2 emission. Consequently, we have selected bioethanol as a potentially sustainable renewable energy resource and analysed EU-28's and Hungary's primary energy resources by means of ethanol equivalent.

It should be noted that sustainability assessment represents a great challenge, especially when the definition of sustainability includes economic or social aspects. Dramatically different methods are available and one could be readily lost in the huge number of methods [12]. Among the numerous approaches, we have used the recently developed ethanol equivalent [13] as a sustainability metrics to ensure that the results are independent of vested or conflicts of interests of all stakeholders.
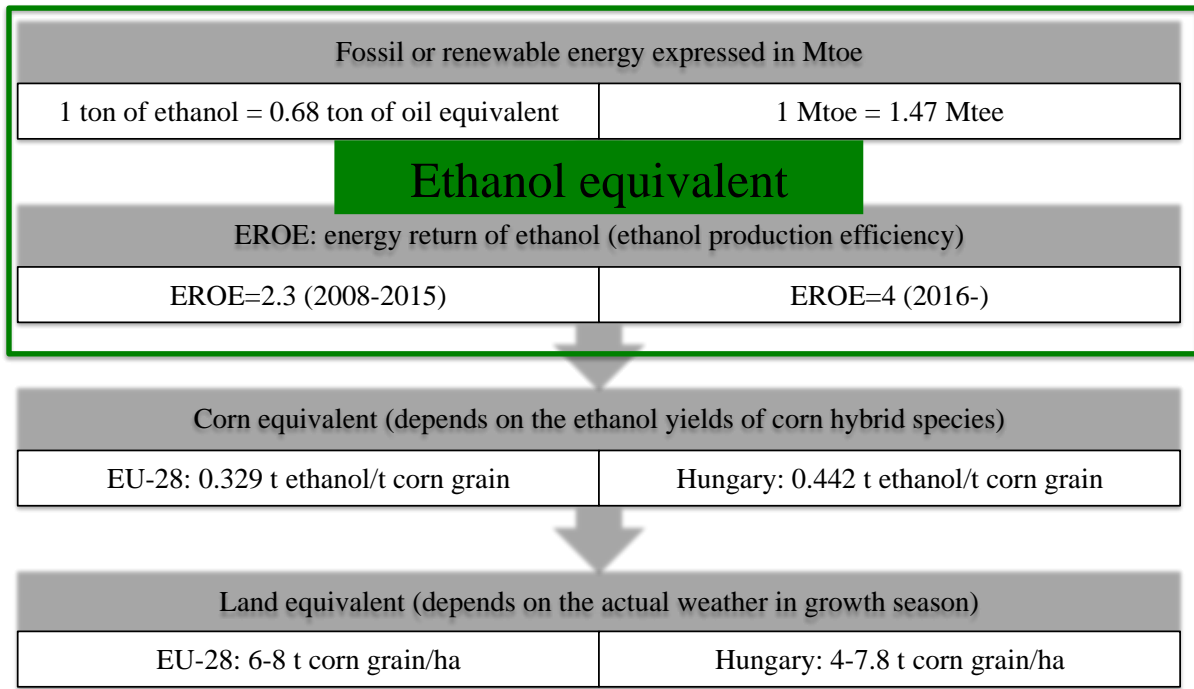
2 CALCULATION METHODS

Ethanol Equivalent (EE) was defined as "the mass of ethanol expressed in million tons ethanol equivalent, needed to deliver the equivalent amount of energy from a given feedstock using energy equivalency or produce the equivalent amount of mass of a carbon chemical using molar equivalency" [13]. Consequently, the energy production and consumption data can be easily turned to EE. By using the commercial data for bioethanol productivity of the first generation bioethanol technology from corn [14], the corn requirements can be readily calculated. By knowing the actual corn productivity on a given agricultural land, which might vary from year to year due to seasonal changes due to the continental climate in Europe and the Carpathian basin, a required land equivalent can also be calculated. The methodology and the summary of the calculations are shown on Scheme 1 and can be found in detail in reference [13]. It should be note that the Ethanol Return of Ethanol (EROE), i.e. the ethanol production efficiency, must be taken into account during the calculation of total EE. At industrial scale ethanol production, the EROE was 2.3 until 2016 [14] and since then it was increased to 4 [15], which means that 1 unit of ethanol is needed to produce 3 units of ethanol.

The metrics based on million tons of Ethanol Equivalent or mtEE is a similar translational tool to BP's metrics based on "Mtoe" or "million tons oil equivalent" for the energy industry, e.g. Mtoe shows the mass of crude oil in million tons needed to deliver the equivalent amount of energy from a given energy-feedstock using energy equivalency.

Table 1. Calorific equivalents provided by British Petroleum [2]

Calorific equivalents	
One ton of oil equivalent equals approximately:	
Heat units	10 million kilocalories
	42 gigajoules
	40 million Btu
Solid fuels	1.5 tons of hard coal
	3 tons of lignite and sub-bituminous coal
Electricity	12 megawatt-hours
One million ton of oil or oil equivalent produces about 4400 GWh (=4.4 TWh) of electricity in a modern power station.	
	1 barrel of ethanol = 0.58 barrels of oil equivalent
	1 ton of ethanol = 0.68 ton of oil equivalent
	1 ton of biodiesel = 0.88 ton of oil equivalent

From reverse perspective the energy equivalent of one gallon of ethanol equals to 3.74×10^9 Joules.

Fossil or renewable energy expressed in Mtoe	
1 ton of ethanol = 0.68 ton of oil equivalent	1 Mtoe = 1.47 Mtee

Ethanol equivalent

EROE: energy return of ethanol (ethanol production efficiency)	
EROE=2.3 (2008-2015)	EROE=4 (2016-)

Corn equivalent (depends on the ethanol yields of corn hybrid species)	
EU-28: 0.329 t ethanol/t corn grain	Hungary: 0.442 t ethanol/t corn grain

Land equivalent (depends on the actual weather in growth season)	
EU-28: 6-8 t corn grain/ha	Hungary: 4-7.8 t corn grain/ha

Scheme 1. Ethanol Equivalent Calculation methodology

3 RESULTS AND DISCUSSION

3.1. ANALYSIS OF FOSSIL ENERGY CONSUMPTION

EE of fossil energy consumptions and sum of renewables used in EU-28 and Hungary in 2015 and 2016 are compared and shown in Figure 3. EE of fossil energy consumption represents a significant contribution to the total EE and only 6.5% of EE is provided by the renewables independently of the ethanol production efficiency that grew from 2.3 in 2015 to 4 in 2016. With the increase of the EROE value, the gross EE requirements were decreased. The increase in renewable energy consumption increases its EE value, as expected. In 2016 the share of renewables in primary energy consumption was increased simultaneously with decreasing fossil energy consumption, thus contributing to a lower EE value of fossil resources in 2016 than observed in 2015. This information totally correlates with Fig. 1.
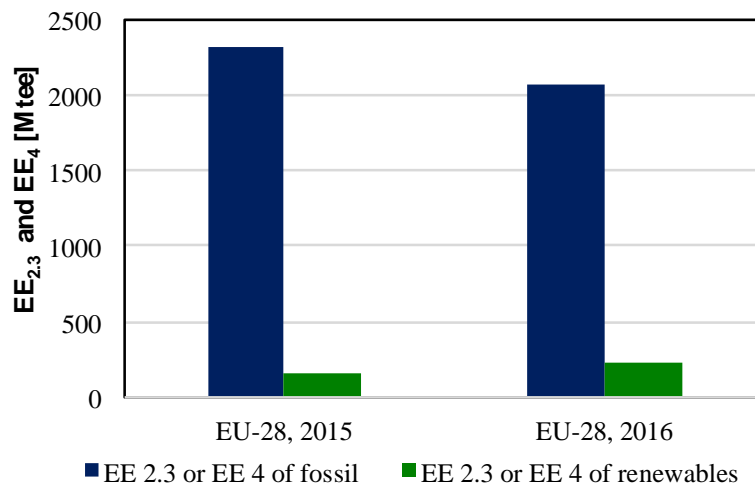

Fig.3. Ethanol Equivalents of fossil (blue bar) and renewable energy consumptions (green bar) in the EU-28 in 2015 (EE2.3) and 2016 (EE4).

Similar trends can be observed for Hungary as of for EU-28 (see Figure 4). The only difference is the share of renewable energy consumption in the total primary energy use; it is only 1.5 and 1.7% of the total primary energy consumption in 2015 and 2016, respectively, while it was a constant 6.5% in the EU-28.
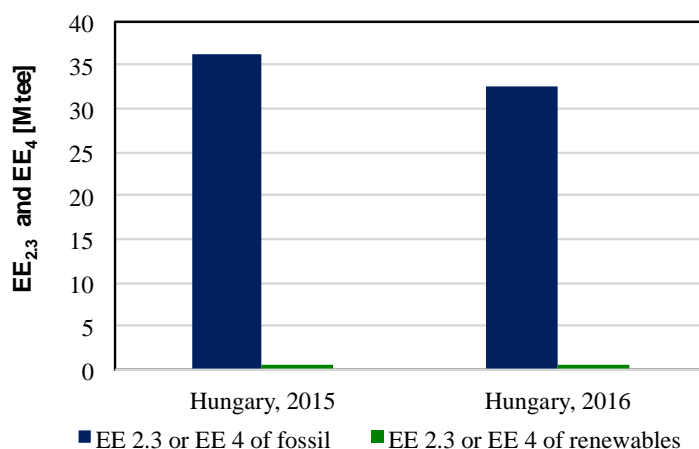

Fig.4. Ethanol Equivalents of fossil (blue bar) and renewable energy consumptions (green bar) in Hungary in 2015 (EE2.3) and 2016 (EE4).

3.2. ANALYSIS OF RENEWABLE ENERGY CONSUMPTION

The EE values of the annual shares of all types of renewables in the EU-28 between 2008 -2016 presented in Fig. 5. While fluctuating values can be observed for hydropower use, photovoltaic, wind, and geothermal and biomass energy consumptions steadily increased until 2015. This tendency drops in 2016 due to the increase in EROE value from 2.3 in 2015 to 4 in 2016. It can be concluded that the increasing efficiency of ethanol production reduces the gross EE values that greatly correlates to the observations made for USA [13]. Concerning the availability of the ethanol resources i.e. the bioethanol production in the corresponding years, the volume of the actually produced bioethanol has not been enough to replace the energy needs, even if it is compared to a single type of energy consumed in the lowest quantity.

A similar graph can be drawn for Hungary (see Fig. 6). Although the EE of the sum of geothermal and biomass-based energy is the highest, it varies between 0.25 and 0.39. EE of wind energy was increased between 2008 and 2012, however it shows a fluctuation later on. The contribution of EE of hydropower energy to the whole is not significant but this low value seems to be stable in the studied period. The EE value of photovoltaic energy has become noticeable in 2013 and continued to grow since then. Comparing the EE values with Hungary's bioethanol production, which has started to grow significantly from 2011, it seems to have enough bioethanol for the replacement of renewable energy resources. This is the only positive result of this analysis. In spite of the significantly increasing bioethanol production, it is still not enough for the replacement of fossil energy use: the produced bioethanol was 0.466 mt in 2016, while EE4 of fossil energy consumption was 32.58 mtEE (see Fig. 4), a far way to go by renewables.
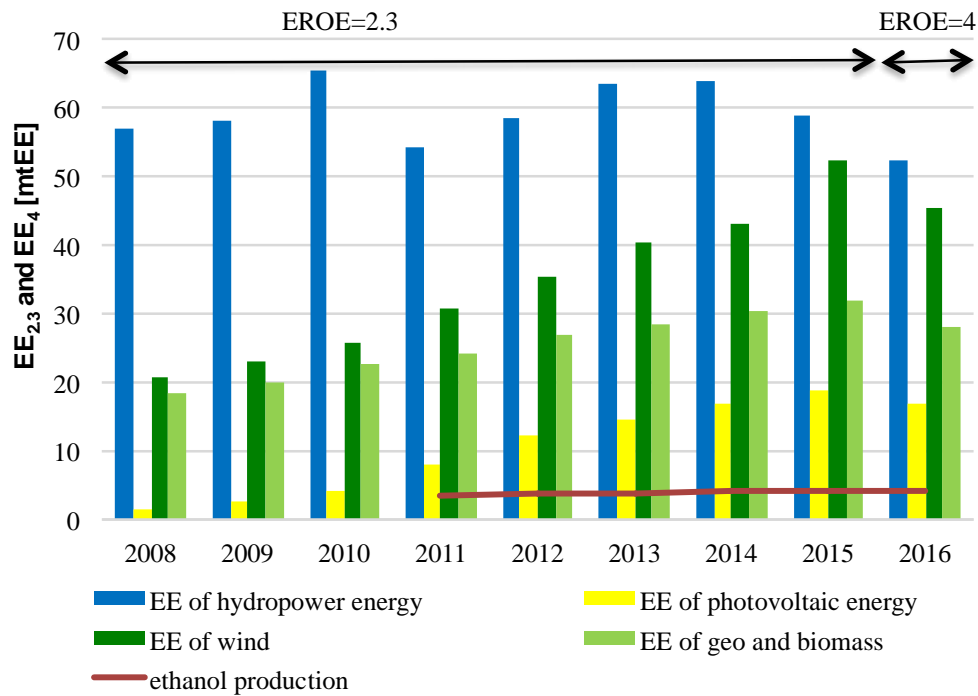
Fig.5. *Ethanol Equivalents of the share of different types of renewable resources in the EU-28 (EE2.3 between 2008-2015 and EE4 in 2016).*
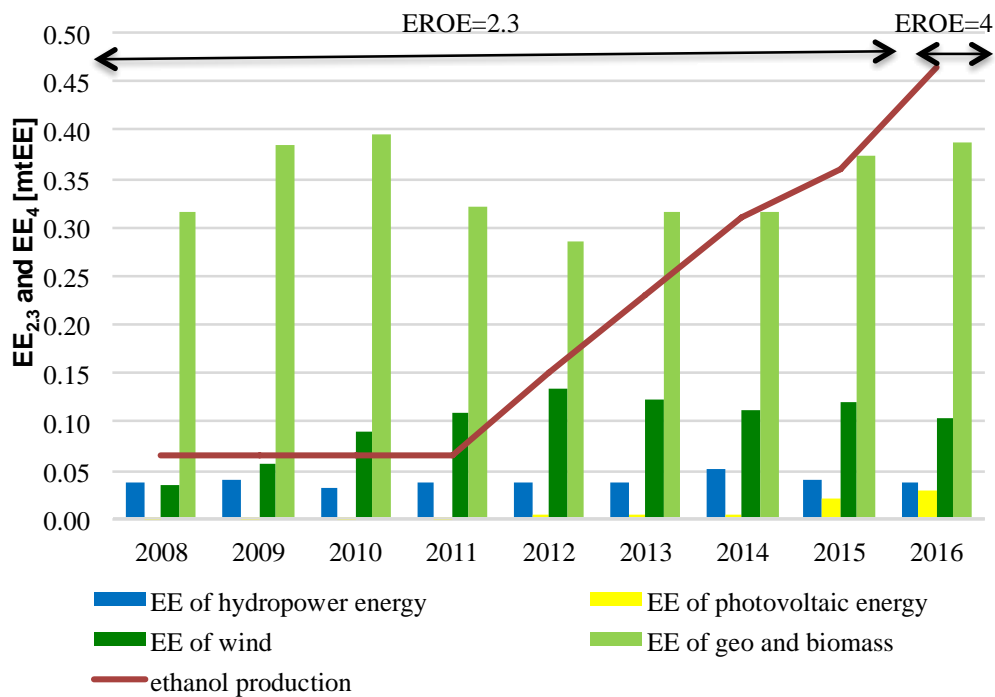

Fig.6. *Ethanol Equivalents of the share of renewable resources in Hungary (EE2.3 between 2008-2015 and EE4 in 2016).*

3.2. COMPARISON OF 1ST AND 1ST + 2ND GENERATION BIOETHANOL

Since the bioethanol production in Hungary has been significantly increasing, the comparison of 1st and 2nd generation bioethanol technologies is important. Starch-based bioethanol production using corn grain as raw material is the base technology and can yield

425-450 liters ethanol from a ton corn grain (see entries 1-3 of Table 2). By the cultivation of a special "corn hybrid", this yield can reach even 561 litres (entry 4, Table 2). Second generation technology uses the corn stalk from which an additional 88 litres ethanol can be produced (entry 5, Table 2.). Accounting the values in tons by combining 1st (entry 4, Table 2) and 2nd generation bioethanol technology (entry 5, Table 2.) a total 0.511 tons ethanol can be produced from 1 ton corn grain + corresponding quantity of corn stalk (entry 6, Table 2).

Table 2. *Bioethanol yields*

Entry	Generation	Biomass	Ethanol yield [L/t corn]	Ethanol yield [t/t corn]	Ethanol yield [L/ha]	Ref.
1	First	Corn grain	*425*	0.335	2651	[16]
2	First	Corn grain	*477*	0.376	2975	[17]
3	First	Corn grain	*450*	0.355	2807	[18]
4	First[a]	Corn grain	561	0.442	*3500*	[19][20]
5	Second[a]	Corn stalk	88	0.069	*650*	[19]
6	**1st [a]+2nd [a]**	**Grain+stalk**	**649**	**0.511**	**4150**	

As demonstrated in the previous section, a possible replacement of renewable energy with bioethanol is feasible Hungary due to the low renewable energy contribution to the total primary energy consumption, and the significant and continuously increasing bioethanol production. Thus, we have assessed the corn- and land equivalents of the fossil energy consumptions in Hungary between 2008-2015 (please note that the improved bioethanol production technology's efficiency in 2016 is left out of the analysis). When using the corn stalk as second generation bioethanol, the corn grain requirements can be reduced, moreover land equivalents can supply deep impact on the analysis.
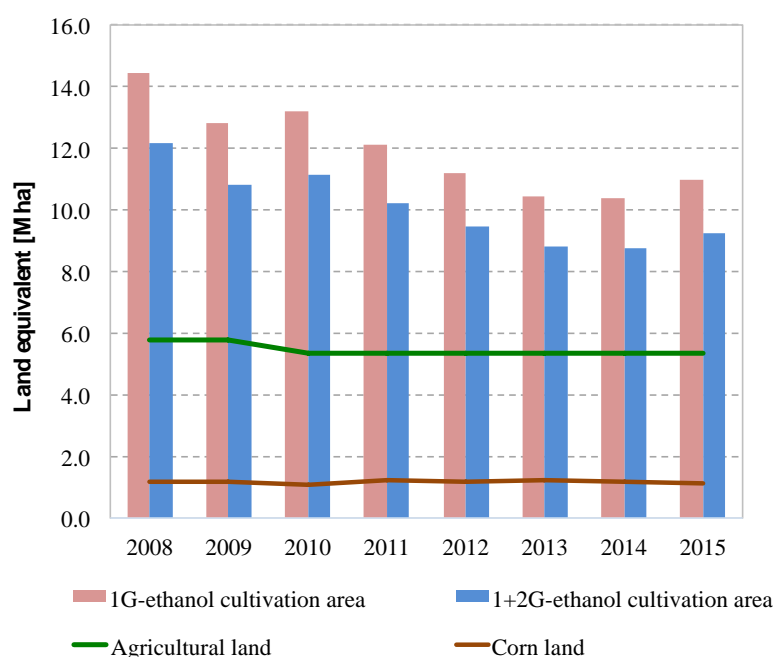

Fig.7. Corn land equivalents of fossil energy consumption in Hungary (corresponding to $EE_{2.3}$).

Corn land equivalents calculated according to Scheme 1 and shown in Fig. 7 clearly present the effect of the utilization of corn stalk to produce bioethanol. While the total fossil energy replacement by first generation i.e. corn grain based ethanol needs more than 10 Mha, the use of corn stalk from the same cornfield reduces the total land requirements by approximately 2 ha. Noteworthy, that the use of 1st and 2nd generation bioethanol together provides always less land needs than the 1st generation bioethanol alone. However, this land equivalent is much over the currently used lands for corn cultivation in the whole period studied, moreover, it is 1.5-times more than Hungary's agricultural land. In comparison to Hungary's total land (9.3 Mha), land equivalents calculated for year 2013 and 2014 are almost the same as the size of the country.

4 CONCLUSION

Our analysis clearly shows that the ethanol equivalents of fossil energy consumptions are extremely high in both EU-28 and Hungary and the current bioethanol production could not cover the EE needs (independently of the ethanol production efficiency by using EROE of 2.3 or 4). Further analysis on renewable energy resources showed that the contribution of renewable energy to primary energy needs was 6.5% in the EU-28 and less than 2% in Hungary. The eventual replacement of total renewable resources by biomass-based ethanol could be feasible in Hungary from 2014 due to Hungary's fast growing ethanol production. Considering a combination of first- and second generation bioethanol the land requirements could be reduced by 1.7–2.1 million hectares compared to the land needs of first generation ethanol production, which is always over 10 million hectares.

Finally, it can be concluded that the currently used fossil resources are still playing a significant role in the energy portfolio, and we could not replace them with biomass-based renewables right now. Although the replacement of all types of energy consumptions by bioethanol seems a unintelligible exercise for Hungary, the successful substitution of fossil resources by renewables in the future will require, in addition to the expected increased use of nuclear energy, the combination of all types of the currently available renewable resources (hydropower, photovoltaic, wind, geothermal and biomass based energy).

ACKNOWLEDGEMENTS

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IDENTIFICATION AND TECHNICAL ANALYSIS OF SYNERGY POTENTIAL OF AN INNOVATIVE BIOCATALITIC METHANATION PROCESS

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Abstract*: Power-to-gas (P2G) is one of the most decisive technologies in future energy systems. The technology enables the conversion of carbon dioxide into bio methane by using surplus renewable energy. Authors have developed an innovative, laboratory scaled power-to-gas prototype that is based on a bio catalytic methanation process, and they operate it in Hungary, since April 2018. Based on their practical experiences gained from operation and development, synergies between feedstock and by-products (carbon dioxide, heat, oxygen, water) are analysed and opportunities for scaling up, as well as their further utilization in other technologies are discussed.*

Keywords*: power-to-gas, bio methane, synergies.*

1 INTRODUCTION

the decarbonisation of the energy sector. Carbon Capture and Storage (CCS) is one of the key point of the EU future energy and sustainability strategy. According to the EU legislation, "Member States with fossil reserves and/or high shares of fossil fuels in their energy mix should support CCS through the pre-commercialisation stage in order to bring down costs and enable commercial deployment by the middle of the next decade" [4]. In addition, EU has the commitment to upgrade natural gas fired power plants to enable the implementation of CCS and / or Carbon Capture and Utilization (CCU) technologies.

In order to reach 20-20-20 goals in EU Climate strategy, the growth of shares of Renewable Energy Resources (RES) is crucial. Unfortunately, the two most promising forms of renewable energy, namely wind and solar, produce electricity depending on weather conditions, and generally independent of demand. The contrast in production and demand results in balancing, grid stability and negative RES electricity prices frequently. The Transmission System Operator is authorized to The European Biogas Association anticipates that there is no other way to comply with the climate commitment made at the COP21 in Paris just to effect the energy transition in all sectors, which also applies to the gas sector [5].

Power-to-Gas technology is widely considered as a grid balancing tool for TSOs, an energy conversion facility that facilitates the RES sources and technical and financial opportunity to generate high-concentration bio methane that could satisfy natural gas standards injected into gas infrastructure. As an exclusive license owner of a biomethanation process, Power-to-Gas Hungary Ltd. has a commitment to carry out both R&D activities and open door to commercial scaled P2G reactors in the Central and Easter Europe region. [6]

As of April 2018, Power-to-gas Hungary Ltd. (P2G Hungary) has been operating a bench scale prototype and running experiments that focus on output efficiency increase and drop of added amount of nutrients. [6,7] In accordance with the technical and biochemical specifications of the adapted biomethanation process [8,9] and the know-how gained from practical operation of the P2G Hungary prototype [7,10], the utilization of by-products of prospective commercial-scaled P2G plants is essential.

Two scenarios of by-product utilization are reviewed hereinafter putting the focus on synergies between bio-facilities and P2G plants:

1. Upgrading raw biogas of anaerobic digestion (AD) plants by inserting P2G technology chain into the biogas production/supply chain
2. Utilizing carbon-dioxide gas by-products of bioethanol plants as a feedstock in P2G facilities

High potential can be identified in the adaption of P2G technology at facilities that have carbon-dioxide rich flue gas streams. The existence of contaminants – such as oxygen - in the flue gas stream has detrimental effect on biocatalyst and gas compound separation is far too expensive. Flue gas streams are typical feedstock for P2G facilities using thermo-catalysts. [11]. Low carbon-dioxide ratio of flue gases (3 - 15%$_{(V/V)}$) is also considered as a limiting factor of the adaption of biomethanation processes [12]. The biogas upgrading and bioethanol production plants emit CO2 gases that can be utilized in P2G facilities at low cost and with no additional energy supply [13].

2 MATERIAL AND METHODS

The power-to-gas prototype unit is located at a Hungarian power plant site. A laboratory, wherein the prototype unit was deployed, was established inside the main premises of the building. The components of the bench scale, mobile prototype are shown in Fig. 1.

The applied power-to-gas process consists of two phases:
- power-to-hydrogen and
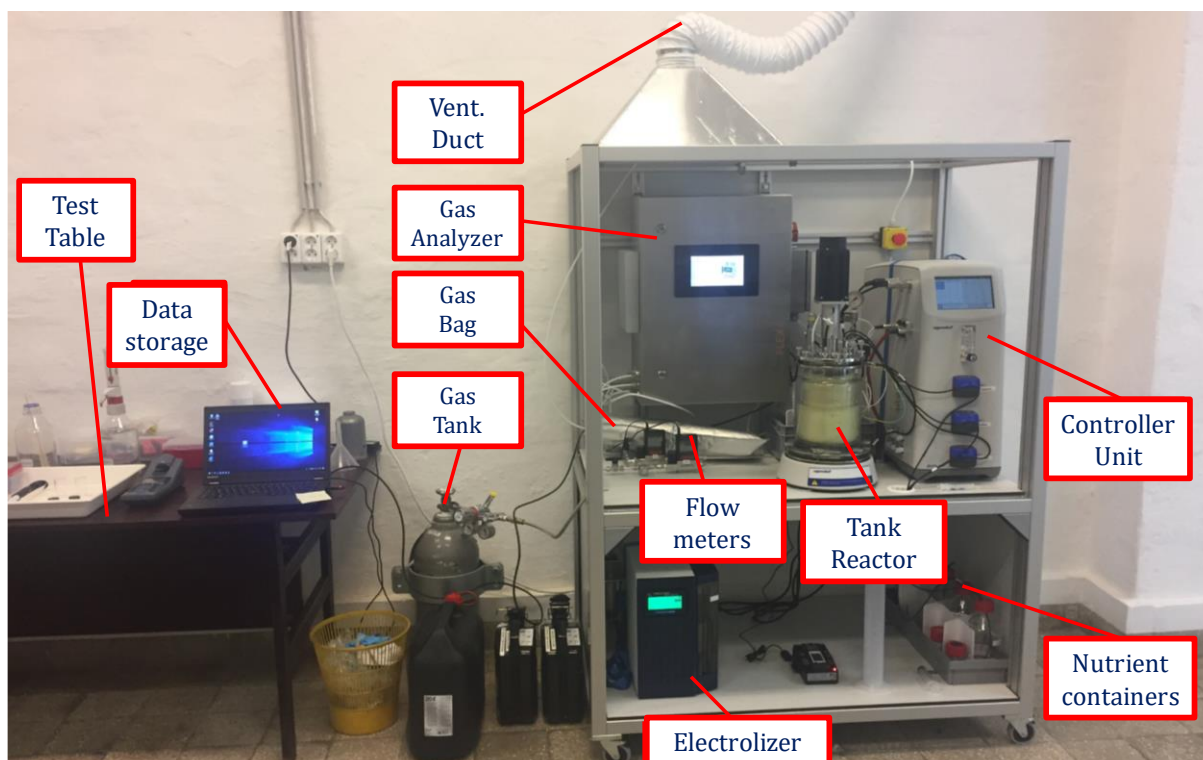- hydrogen-to-methane (methanation).

Fig.1. Main component units of the benchscale prototype (2018)

The end product is bio methane. The biomethanation process is provided by a proprietary biocatalyst, an optimized strain of Archaea (Methanothermobacter thermautotrophicus). The robust, highly selective and efficient strain was developed by Prof. Laurens Mets at the University of Chicago (IL) [14]. The methanation occurs in a thermophilic anaerobic continuous stirred tank reactor at atmospheric pressure in the prototype and at the pressure of 8-10 bar$_g$ in commercial scale case. Scaling-up mechanism (from laboratory to commercial

size) of P2G technology is ensured by the conformity of the adapted process controlling systems and feedstock features [15-17]. Since both methanation and hydrogen generation via electrolyser produce heat in commercial-scaled facilities, thus there is no need to use external heating. Furthermore, for providing appropriate temperature range of 62 – 70 °C for the metabolism of archaea the heat generated must be transferred from the facility.

Biogas can stand as the feedstock of the reviewed P2G process. Biogas is a mixture formed mainly of methane and carbon dioxide by degrading and stabilizing in anaerobic conditions. It typically it contains 50–70%$_{(v/v)}$ of methane, 30–50%$_{(v/v)}$ of carbon dioxide, less than 1%$_{(v/v)}$ of nitrogen N2, and 10–2000 ppm of hydrogen sulphide. Biogas can be used for a number of purposes, including electricity production (most common), heat generation and as a raw product for industries [18, 19]. The traditional way of producing bio methane product from biogas is the separation of methane and carbon-dioxide gas components by using membranes, water physical scrubber, pressure swing adsorption, etc. The purification of biogas to natural gas standards is called "biogas upgrading" which implies removal of carbon dioxide, water vapour, as well as typical contaminants such as dust and particles. Hydrogen sulphide is usually absorbed and removed from the product gas stream by bio filters [20]. The other way to gain bio methane, which complies with natural gas standards, are P2G processes, which based on the conversion of carbon dioxide component of biogas by using either thermo-catalysts (e.g. nickel, ruthenium) or biocatalysts. The thermo-catalytic reaction is based on Sabatier process, which is carried out at temperatures of 250 – 400 °C with the pressure of 1 - 80 bar [20]. Volatile nature of RES can be followed by P2G processes using biocatalyst. Commercial scaled P2G biomethanation plant has been operating in Avedore (DK) since 2016 [25].

First generation biofuels refer to biofuels made from sugar, starch, vegetable oils, or animal fats using conventional technology. The basic feedstock for the production of first generation biofuels are often seeds or grains such as maize, wheat, which yields starch that is fermented into bioethanol, or sunflower seeds, which are pressed to yield vegetable oil that can be used in biodiesel [21]. The major technology stages of large-scale bioethanol production is grinding, saccharification of starch, microbial (yeast) fermentation of sugars, distillation and dehydration [22]. Corn – as the most significant crop in Hungary – can be processed to bioethanol either by wet or dry milling technology. Dry milling technology yields higher capital return per volume of ethanol, while wet milling enables the separation of other valuable components in the grain before fermentation to ethanol [23]. Regarding the industrial process, current technology allows for production of 320 to 402 litres of ethanol per metric ton of corn [24, 25]. The by-products of corn-based bioethanol production are distillers' dry grain with soluble (DDGS) and carbon dioxide. The latter gaseous by-product is the result of fermentation – depending on the adapted technology, approx. 30%$_{(m/m)}$ of the processed corn is converted to carbon dioxide. In 2018, under the umbrella of EU funded "Store&Go" project, a P2G methanation facility added to an existing power-to-hydrogen plant with 1 MW$_{el}$ electrolyser capacity in Falkenhagen, Germany [25].

3 RESULTS

Based on the location, existing infrastructure, layout of the biomass processing (bioethanol and biogas precisely) plants several opportunities may emerge in terms of the exploitation of synergies. Combined heating plants of AD facilities produce electricity and waste heat. A P2G plant can be integrated into the technology/production line as it is shown in Fig. 2.
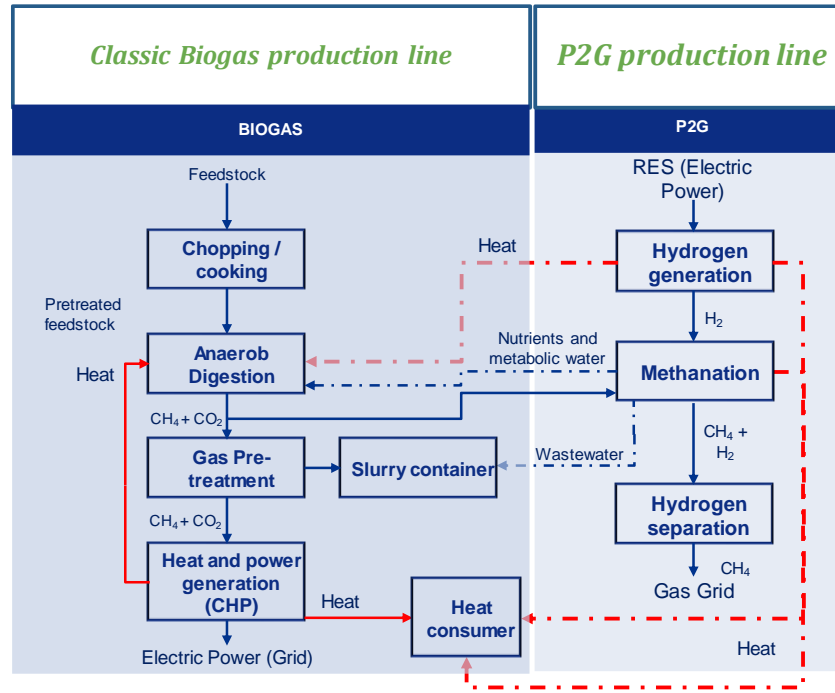
Fig.2. *Synergies of AD and P2G plants*

Biogas produced in AD tanks can be transferred to P2G biomethanation system without the separation of methane and carbon dioxide gas components. After the carbon dioxide conversion with purification is carried out, the yielded bio methane flux can be injected into the gas infrastructure in whole or in part, depending on the value of the remaining quote in feed-in-tariff system. Heat generated at electrolyser modules and methanation tank can be used for AD reactor heating since the temperature of electrolyser units is above 73 °C, which exceeds the required temperature for biogas production. The amount of waste heat equals 1/3 portion of the total installed electrolyser power output approximately. Metabolic water and removed biocatalyst can be fed into the AD slurry container or into AD reactors depending the recipe of AD feedstocks. Some features of an integrated P2G and AD plant are shown in Table 1.

Table 1. *Main features and values of an AD plant with 1 MW_{el} CHP capacity*

	Feature	Value
AD plant	CHP electric capacity (MW_{el})	1
	CHP thermal capacity (MW_{th})	1.14
	Theoretical biogas yield (Nm^3/y)	3 686 636
	Methane content (%)	62
	Biogas LHV (kWh/Nm^3)	6.2
	Annual operating hours	8 000
	Carbon dioxide content (%)	38
	Methane yield (Nm^3/y)	2 285 714
	Carbon dioxide yield (Nm^3/y)	1 400 922
	Average available carbon dioxide flow rate (Nm^3/h)	175
P2G plant	Required hydrogen flow rate (Nm^3/h)	700
	Metabolic water yield (m^3/h)	1.4
	Reactor feedstock load (Nm^3/h)	1 161
	Transferred methane flow rate (Nm^3/h)	285.7
	Electrolyser energy consumption rate ($kWh/Nm^3 H_2$)	4.7
	Maximal P2G electrolyser capacity (MW_{el})	3.3
	Maximal P2G electrolyser capacity (MW_{th})	1.1

The main difference in the integration of P2G plant to AD and bioethanol plants is in the form of carbon dioxide feedstock. At the fermentation stage of bioethanol production line raw carbon dioxide is generated which can be fed into P2G reactor directly, after vapour condensation. The block diagram of a maize processing bioethanol plant and an integrated P2G plant is shown in Fig. 3.
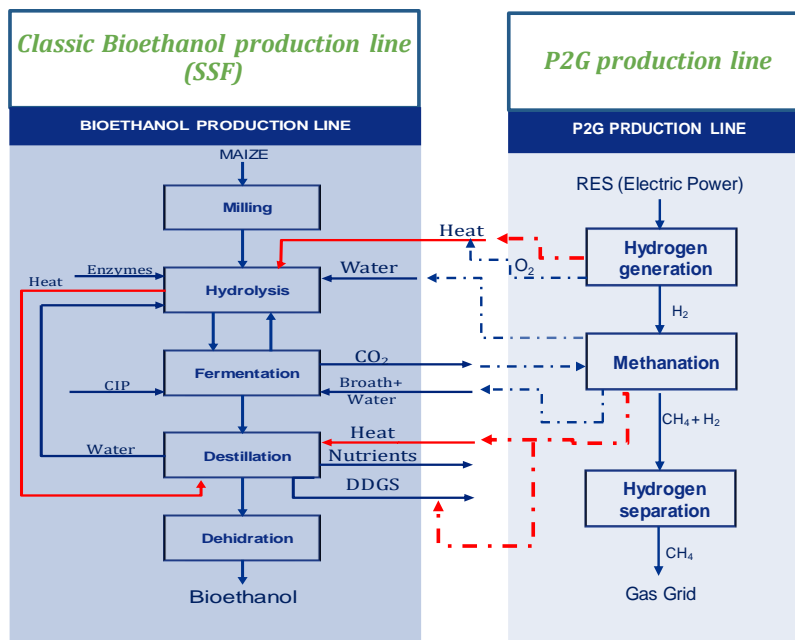

Fig.3. *Synergies of bioethanol and P2G plants*

Waste heat of P2G technology can be used for preheating the equipment of hydrolysis stage and/or distillation columns and/or DDGS dryers. Although the required temperature of each stages is above 100 °C, P2G waste heat can be utilized in cascades for preheating. The integration of a theoretical bioethanol plant with 100 000 t/y maize processing capacity and a P2G plant is shown in Table 2.

Table 2. *Main features and values of a bioethanol plant with 100 000 t/y maize processing capacity*

	Feature	Value
Bioethanol plant	Feedstock (corn) (t/y)	100 000
	Bioethanol yield (l/h)	4 500
	DDGS yield (t/y)	32 000
	Carbon dioxide yield (t/y)	32 000
	Annual operating hours	8 000
	Specific natural gas demand (MJ/t maize)	1 330
	Total heat demand (MWh/y)	36 945
	Average heat capacity flux (MW_{th})	4.5
	Average natural gas consumption (Nm^3/h)	492
	Average available carbon dioxide flow rate (Nm^3/h)	2 036
P2G plant	Required hydrogen flow rate (Nm^3/h)	8 144
	Metabolic water yield (m^3/h)	16.4
	Electrolyser energy consumption rate (kWh/Nm^3H_2)	4.7
	Maximal P2G electrolyser capacity (MW_{el})	38.3
	Waste heat capacity (MW_{th})	12.7
	Bio methane yield (Nm^3/h)	2 036

31

4 CONCLUSION

P2G biomethanation facilities can be integrated into both AD and bioethanol production line. In both cases, generated waste heat of electrolyser units and reactor tanks can be transferred and used for preheating the adequate stages. Putting financial consideration into the foreground – depending on the remaining quote of the feed-in tariff system of an AD site – CHP units can be replaced in whole or in part by a P2G facility. If CHPs were terminated, the waste heat flux of the integrated P2G facility could provide fully the required heat flux for the AD plant and heat consumers. Based on the mass balance of a bioethanol plant and the average carbon dioxide flow rate of fermentation stage, the integrated P2G plant can ensure considerable amount of waste heat – almost three times more than required. Contrary to AD utilization, the usual temperature of heat consumers of bioethanol process is over 100 °C, thus waste heat can be used for preheating only. In order to increase plant efficiency oxygen gas component shall be utilized (e.g. such as aeration at waste water treatment processes).

ACKNOWLEDGEMENTS

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SIMULATION OF POOL BOILING HEAT TRANSFER USING RPI MODEL

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Abstract*: In the present simulation, the pool boiling heat transfer of water at atmospheric pressure on a horizontally heated cylindrical copper tube investigated. An Eulerian-Eulerian multiphase model of two fluids formulation together with a boiling model which represented by Rensselaer Polytechnic Institute (**RPI**) model adopted in this study. Boiling parameters such as bubble diameter, frequency, nucleation density selected from closure correlation in literature were used to address the mass and heat transfer of pool boiling. Efforts have been made to correct the bubble waiting time coefficient in quenching heat flux part. The results of the boiling curve and the heat transfer coefficient of the present model are validated with those experimental results in the literature and shown good agreement. Moreover, a vapour volume fraction contours at different superheat temperatures are presented.*

Keywords: *Pool boiling, Eulerian Multiphase model, RPI model, boiling curve.*

1 INTRODUCTION

There is a demand for efficient cooling mediums to remove high heat flux from equipment works with this matter in one hand, and the continuous efforts to make those systems or equipment miniaturize to save the energy and reduce the cost on other hand. Cooling with air could offers a limited range to cooling that equipment so, fluids cooling medium considered to be more efficient than air [1][2]. Boiling heat transfer model might be good choice to remove high heat flux in relatively small superheat temperatures due to the latent heat of vaporization during boiling process [3]. Pool boiling heat transfer type widely used in many industrial applications such as boiler tubes, evaporators, cooling of electronic devices, heat exchangers, and cooling of nuclear reactors [4]. During the pool boiling process, there are different regimes that happen, and those regions start with natural convection regime to one phase vapour regime. Among all regimes of pool boiling; the nucleate pool boiling regime is considered as a most important and complex one due to the latent heat and the stronger and complex nonlinear interactions of other related sub-phenomena. Many researchers have been tried to develop a mechanistic model for nucleate boiling regime but there still until now no any comprehensive model to predict this regime completely. Pool boiling from horizontal heated tube has many applications in industrial and has govern by several factors. Some of those factors related to the properties of working fluids, and others associated to topology of the heater itself. Fig. 1. illustrates the factors affect the pool boiling from tubes submerged in fluid. In the present simulation, Eulerian- Eulerian multiphase model was used to mimic the pool boiling performance of water from horizontal copper heated tube. The boiling model under Eulerian-Eulerian two fluids model parallel with Rensselaer Polytechnic Institute RPI model which incorporated in Fluent Ansys software was selected to simulate this phenomenon. This model treated the heat flux from heated tube to fluid via three mechanisms convective, evaporative and quenching heat fluxes. Boiling curve and heat transfer coefficient for nucleate regime were predicted in this simulation. In addition, contours of vapour fraction and streamlines of vapour velocity were introduced in this study. Results show that the heat transfer coefficient and boiling

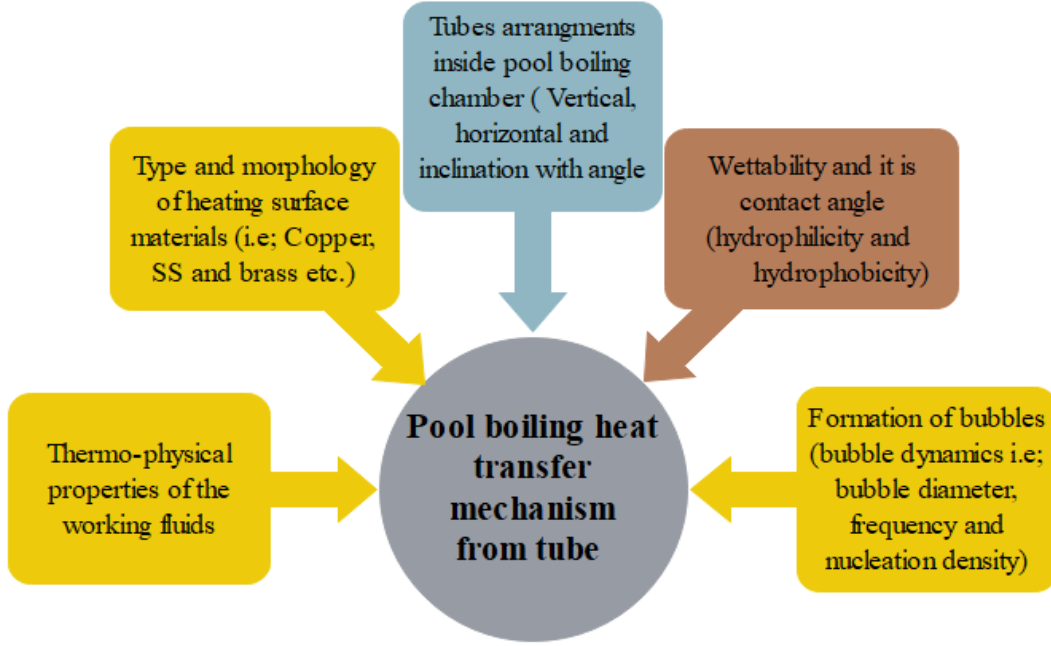curve were in good agreement with well-known correlation and experimental works in literature.

***Fig.1.** Factors influenced pool boiling on heated tube.*

2 PHYSICAL GEOMETRY

Eulerian two fluids model, as well as interphase mass, momentum, and energy transfer models, is employed to consider the non-equilibrium between two phases (water) and (vapour). The physical geometry used in present simulation is a 2D chamber with a horizontal copper heated tube, and this geometry was same that used in experimental study of Cieslinski and Kaczmarczyk [5] in order to validate the present model. Pool boiling at wall is modeled by the RPI wall boiling model which proposed by Kurual and Podowski [6]. The water phase is treated as a continuous phase while vapour phase as dispersed phase.

3 MODEL FORMULATION

3.1. GOVERNING EQUATIONS

Two sets of conservation equations governing the balance of mass, momentum, and energy of each phase are presented as follows [7], [8]:

Continuity equation:

$$\frac{\partial(\rho_k \alpha_k)}{\partial t} + \nabla.(\rho_k \alpha_k v_k) = \dot{m}_{kj} \tag{1}$$

Momentum equation:

$$\frac{\partial(\rho_k \alpha_k v_k)}{\partial t} + \nabla.(\rho_k \alpha_k v_k v_k) = \alpha_k \nabla P - \rho_k \alpha_k g + \nabla[\alpha_k \mu_k^e (\nabla v_k + (\nabla v_k)^T)] +$$
$$(\dot{m}_{kj} v_k + \dot{m}_{jk} v_j) + S_{kj} \tag{2}$$

Energy equation:

36

$$\frac{\partial(\rho_k \alpha_k E_k)}{\partial t} + \nabla.(\rho_k \alpha_k v_k E_k) = \nabla[\alpha_k k_k^e(\nabla T_k)] + (\dot{m}_{kj}E_k + \dot{m}_{jk}E_j) + S_{kj} \qquad (3)$$

Where the subscripts of k and j are phase denotations (k, j= l for liquid phase and k, j= g for vapor phase.

3.2. THE HEAT FLUX-PARTITIONING MODEL (RPI)

In the present work, basic RPI model under boiling model which be proposed by [6] was introduced to predict the boiling of water over a horizontal cylindrical tube. The total heat flux from the heated tube to the water partitioned into three main mechanisms, namely the convective, quenching and evaporative heat flux as follows:

$$\dot{q}_{total} = \dot{q}_{conv} + \dot{q}_{quen} + \dot{q}_{evap} \qquad (4)$$

The heated surface is subdivided into area of a bubble created $A_{bubbles}$ and a portion, which is covered by the bulk liquid $(1 - A_{bubbles})$. The convective heat flux $\dot{q}_{conv}$ is expressed as following:

$$\dot{q}_{conv} = h_{single}(T_s - T_l)(1 - A_{bubbles}) \qquad (5)$$

Where; h_{single} is the single-phase heat transfer coefficient, and $(T_s - T_l)$ is the difference between the surface and liquid temperatures. The second term is the quenching heat flux $\dot{q}_{quen}$, which models the cyclic averaged transient energy transfer associated to liquid filling on the heated surface vicinity after bubble detachment, and it is expressed as following:

$$\dot{q}_{quen} = C_w \frac{2k_l}{\sqrt{\pi \lambda_l t}}(T_s - T_l) \qquad (6)$$

Where; k_l, t, C_w, and $\lambda_l = \frac{k_l}{\rho_l C p_l}$ are the conductivity of the liquid, periodic time, bubble waiting time coefficient and the diffusivity of the liquid. The last term is the evaporative heat flux $\dot{q}_{evap}$, which is written as following:

$$\dot{q}_{evap} = V_d N \rho_v h_{fv} f \qquad (7)$$

Where; V_d is the volume of bubble based on bubble departure diameter, N is the nucleation site density, ρ_v and h_{fv} are the vapour density and latent heat of vaporization respectively. Finally, f is the frequency of bubble departure.

4 NUMERICAL SOLUTION AND BOUNDARY CONDITIONS

Fig 2. shows the heating surface is a horizontal copper tube with 10 mm, outside diameter, and the dimension of the pool boiling chamber was (150 × 100 mm) and this same chamber which be used in [5]. In this work, the nucleate boiling was carried out at transient state by and the transport equations are discretized by using finite volume method FVM that is solved via commercial CFD code (Fluent 19.2). To build the computational mesh, we used the meshing tool available in ANSYS. The physical domain in this study involved a structured uniform meshes based on a rectangular shape. All the closure correlations related to nucleate boiling of nanofluids that adopted in this work incorporated to the fluent solver as a build function. The boundary conditions for this enclosure as shown in picture: top is open to outlet pressure, sides and bottom walls are adiabatic, centre heated tube was considered as temperature constant boundary.
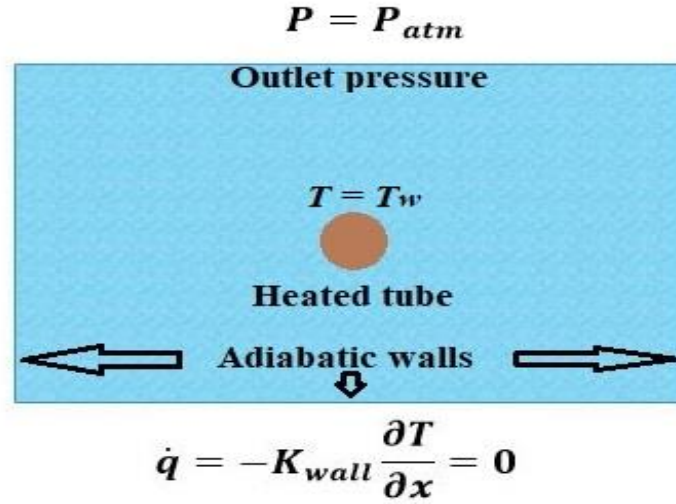
$$P = P_{atm}$$

Outlet pressure

T = Tw

Heated tube

Adiabatic walls

$$\dot{q} = -K_{wall}\frac{\partial T}{\partial x} = 0$$

Fig. 2. The chamber of pool boiling used in present study.

5 RESULTS AND VALIDATION

The results of the pool-boiling curve for a range of heat fluxes 15 – 90 (kW/m2) against the superheat temperatures are presented in Fig 3. The present simulation validated with the experimental work of Cieslinski and Kaczmarczyk [5] and the results of pool boiling curve were in good agreement with this experimental study. In this simulation, we focused to correct the bubble waiting time coefficient, which is presented in quenching part by try and error method until getting results close to experimental work. After that, we correlate this coefficient to superheat temperatures by fitting the curve with forth order polynomial function with coefficient of determination (0.9998). Fig 4. Shows this correlation could be used under the range of this simulation to predict the pool-boiling curve of water using aforementioned parameters.
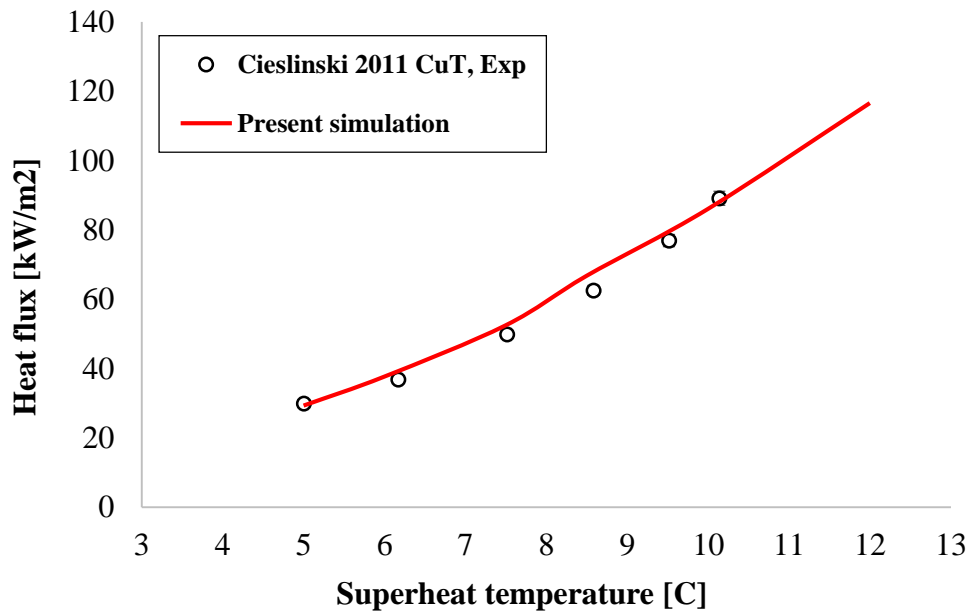
Fig. 3. Pool boiling curve for present simulation and experimental work for nucleate boiling regime.
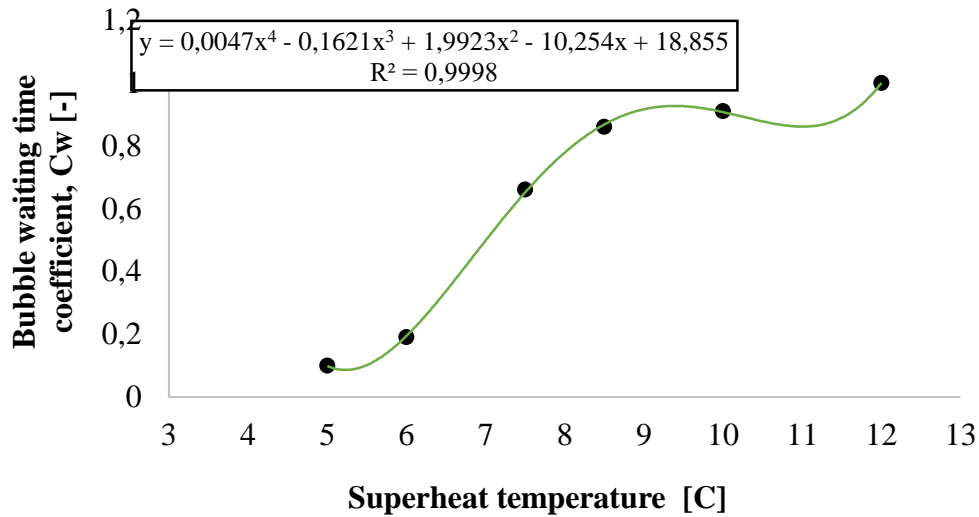
$$y = 0{,}0047x^4 - 0{,}1621x^3 + 1{,}9923x^2 - 10{,}254x + 18{,}855$$
$$R^2 = 0{,}9998$$

Fig. 4. *Bubbles waiting time coefficient Vs. superheat temperature for water pool boiling curve in present study.*

Fig 5. Demonstrated the bubbles formation that represented by contours of volume fraction concerning time. At time (t = 200 ms) the bubbles begins to form on circular horizontal heated tube, and we can see that those bubbles starts to sliding from bottom to sides of tube then to top of heated surface. As time increased to (t = 500 ms) bubbles, start to travel the heated surface to the bulk fluid, and this is due to the buoyancy effects which lift the bubble to the top of chamber. The height of this pool boiling was chosen a quite higher than the experimental of [5] as mentioned in previous section in order to keep the validation porpuse, and due to the short distance between the heated tube and the surface of fluid the bubbles could not deform or shaped inside bulk fluid to other forms then they were deform in the top surface.
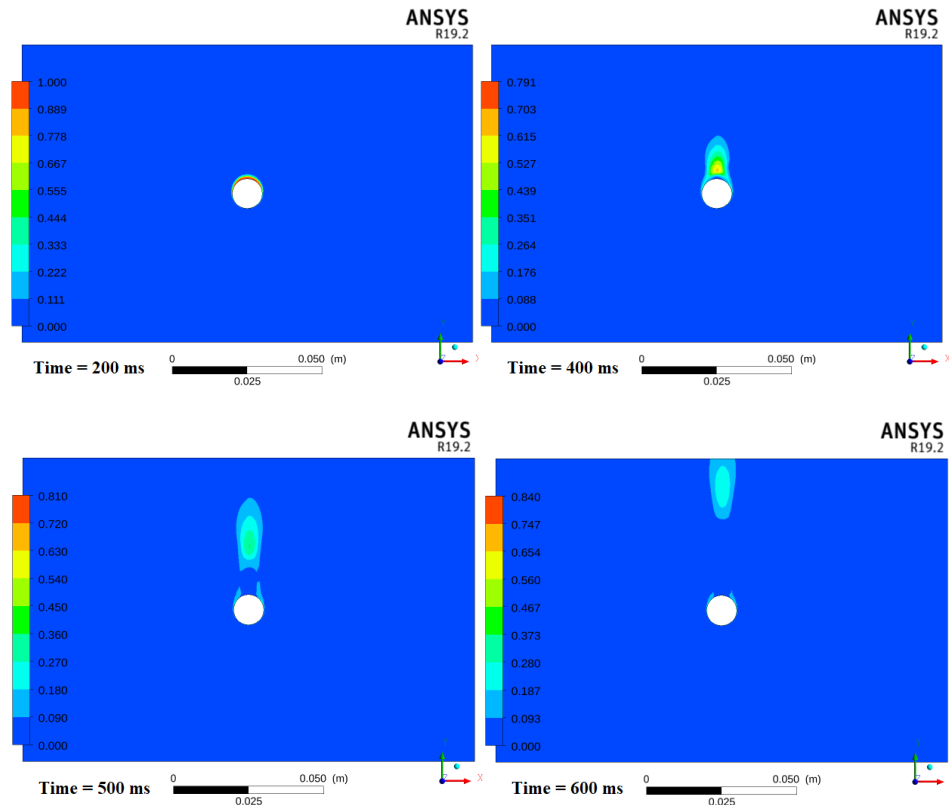

Fig. 5. *Contours of vapour volume fraction with time at superheat temperature (7.5C).*

6 CONCLUSION

In this work, simulation of water pool boiling process using two fluids model, which included the RPI boiling sub-model, was numerically investigated. The RPI model used to simulate this phenomenon alone with boiling build-in parameters associated to dynamics of bubbles, and we can conclude from this study following points:

1- Nucleate pool boiling regime in range of superheat temperatures (5- 12 ℃) has been investigated, and the results of boiling curve validated with experimental work in literature and shows good agreements.
2- Bubble waiting time coefficient correlated to superheat temperatures with nucleate boiling region. Hence, a new forth order polynomial function presented in this work to introduce this coefficient.
3- Vapor volume fraction contours were physically match the visualization study of bubbles sliding from horizontal tube in literature.

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ENVIRONMENTAL IMPACTS OF FRESH MILK PRODUCTION: AN LCA CASE STUDY IN HUNGARY

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Abstract*: The environmental impact of a Hungarian fresh milk production company was estimated by the help of LCA and compared with reference fresh and UHT milk. The life cycle assessment (LCA) model of fresh milk production was created in thinkstep's life-cycle assessment modelling software, GaBi. Gate-to-gate approach was applied as only the production of fresh milk was modelled, with its supply, processing, packaging, delivery sub-steps, raw milk production and end-of-life were excluded. CML 2001 impact assessment method was used, and the following impact categories were investigated: GWP 100, AP, EP, POCP, HTP*

Keywords*: life cycle assessment (LCA), environmental impact, fresh milk, UHT milk.*

1 INTRODUCTION

The products, their manufacturing and dispose of them have an impact on our direct and indirect environment, and hence on us. These effects should be examined, which is particularly true for the food industry, including the dairy industry.

As in many countries worldwide, in Hungary, the dairy sector plays an important role in the economy. It has strategic importance because it occupies a special place in our diet besides the nutrient sources of plants and animals. For a long time in Hungary, one-quarter of total food consumption is made up of milk and dairy products. [1] For this reason, the dairy industry activities are a constant burden on our environment. These effects are also worth considering because in the recent years the production of these products has decreased by 26% in our country [2], but the annual milk consumption of 1 person despite the fluctuation stayed around 160 litres. [3] From an environmental point of view, dairy products have a significant impact throughout their life cycle, whether we are dealing with the production or the processing of waste after consumption.

One must realize that from a customer point of view, the question of buying milk is not as simple as we first think of it. One can choose according to several aspects: for example, shelf life, and packaging composition. When choosing a product with a long shelf life (few months), the composition of the packaging material is much more complicated than choosing fresh milk (shelf life is 7-9 days) which is packaged with only 1 material.

For above-mentioned reasons, authors investigated whether fresh milk or UHT milk production has a higher impact on our environment.

2 LIFE CYCLE ASSESSMENT (LCA)

As humanity will always need an increasing amount of food due to population growth, it is particularly important to look at the environmental impact of the food industry's products and the technologies they use. Life-cycle assessment (LCA) is a good way to test the entire environmental impact throughout the whole life of a product or service. The cradle-to-grave assessment starts from raw material extraction, through the manufacturing and use phase, to the end-of-life (EoL) disposal phase, while Cradle-to-cradle is a specific kind of cradle-to-grave

assessment, where the end-of-life disposal step for the product is a recycling process. Cradle-to-gate assessment includes the resource extraction and manufacturing phase, the use and disposal phases of the product are omitted.

LCA not only helps identify the so-called "hot spots", but also helps to choose solutions that mitigate (or eliminate) the environmental effects of a process.

ISO 14040 and 14044 standardize the methodology of LCA, with the following steps: goal and scope definition, inventory analysis (LCI), impact assessment (LCIA), and interpretation [5].

In this paper, the application of this method is introduced to the production of fresh milk (fresh and UHT). First, the life cycle of milk is introduced, followed by the LCI of a Hungarian fresh milk company, the think step's GaBi model and the results of the assessment.

2.1. GOAL AND SCOPE DEFINITION

The life cycle begins with the extraction of raw materials. Milk is produced on farms, then it is transported to the dairy plant, where it is processed, that is it passes through pre-storage, homogenization, pasteurization and post-storage. [6] In the last step it is packaged, then it is transported to the supermarkets and shops. After consuming it, the packaging becomes a waste that must be properly treated (Fig. 1.).
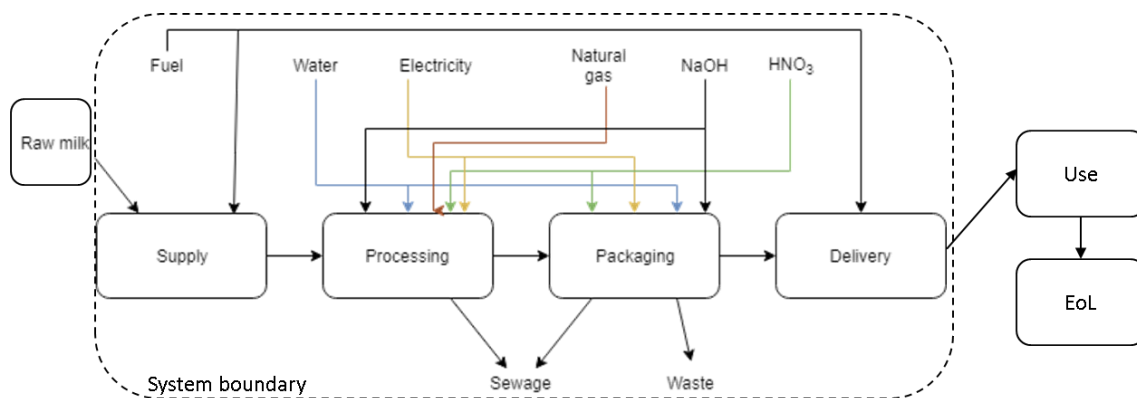

Fig. 1. *The system boundary of fresh milk production*

In this study, only the processes in the dairy plant (supply, production, packaging, delivery) were investigated, the other processes of the whole life cycle (raw milk production, EoL) were excluded.

The assessment was made in a small dairy farm (capacity 1500 liters/day), that has been operating since 1999 in a small town in western Transdanubia of Hungary, called Celldömölk.

The analysed product is fresh milk wrapped in a polythene bag. In this case, fresh milk means that after processing, the shelf life is 7-9 days in closed packaging and can be consumed up to 2 days after opening. [7] During the production, only the homogenization and pasteurization step is where the product undergoes heat treatment, which is not about preservation, but about the destruction of bacteria (eg. TBC) that are dangerous to human health. The weight of the final product may vary from 1035 to 1040g.

Fig. 2. shows the detailed model, with the energy and material production processes, that are all available in the GaBi Education Database. To have better geographical representativeness if it was available Hungary specific (electricity, natural gas) or EU specific (tap water, plastic waste on landfill, polythene film) processes were chosen. But in the case of wastewater treatment and some material production (nitric acid, sodium hydroxide) only German specific processes were available. Truck transport is a global average process. The energy and material flows refer to the functional unit, that is 1 kg of the final product.
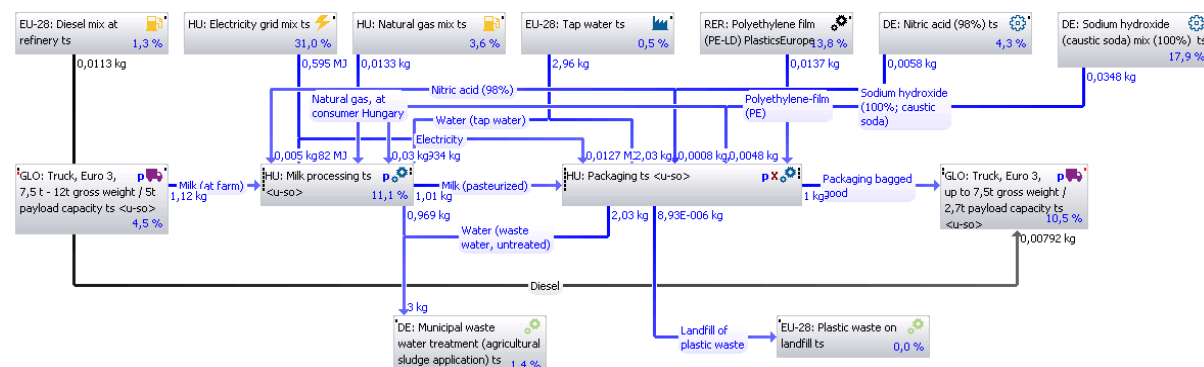
Fig. 2. *Detailed Gabi model of fresh milk production*

2.2. LIFE CYCLE INVENTORY (LCI)

The Life Cycle Inventory (LCI) phase involves the compilation and quantification of inputs and outputs for a product system. [5].

The LCI data are obtained from the manufacturer of the product. The primary data were available (water, and electricity consumption) and secondary were calculated based on the received data (e.g. water demand for milk processing and packing steps). The input and out data for fresh milk processing is summarized in Table 1.

Table 1. *1 kg of fresh milk production input and output data*

INPUT	Quantity	Unit	Data source
all milk supply	1,12	kg/kg	available at the manufacturer
raw milk	1,01	kg/kg	
scrap milk	0,14	kg/kg	
water	2,96	kg/kg	calculated based on the received data
electricity	0,59	MJ/kg	
natural gas	0,01	kg/kg	
sodium hydroxide	4,81	g/kg	
nitric acid	0,8	g/kg	
packing	0,01	kg/kg	available at the manufacturer
supply	50	km	calculated based on the received data
delivery	100	km	
OUTPUT			
waste	$8,93*10^{-6}$-	kg/kg	calculated based on the received data
sewage	2,96	kg/kg	
CO_2 content of flue gas	$2,67*10^{-6}$	mg/m³	
CO content of flue gas	$5,32*10^{-6}$	mg/ m³	
NO_x content of flue gas	$9,31*10^{-6}$	mg/ m³	
CH_4 content of flue gas	$8,7*10^{-7}$	mg/ m³	
SO_2 content of flue gas	$6*10^{-8}$	mg/ m³	
final product (fresh milk)	1	kg/kg	available at the manufacturer

2.3. LIFE CYCLE IMPACT ASSESSMENT (LCIA)

Through LCIA the environmental impacts of fresh milk production were categorized. The inputs and outputs are first assigned to impact categories [9], and their potential impacts quantified according to characterization factors [8].

The global warming potential (GWP 100) is a measure of the emission of greenhouse gases (GHG) such as CO_2, PFC, and CH_4, and is expressed as kilogram CO_2-equivalent and spans a time horizon of 100 years.

The acidification potential (AP) is a measure of emissions that cause acidifying effects on the environment and is expressed as kilogram SO_2-equivalent. The most common acidifying compounds are sulphur dioxide and nitrogen oxide.

The eutrophication potential (EP) is a measure of emissions that cause enrichment of nutrients in the environment and is expressed as kilogram phosphate-equivalent.

The photochemical ozone creation potential (POCP) is a measure of precursor emissions that contribute low-level smog (summer smog), produced by the reaction of NO_x and hydrocarbons under the influence of ultraviolet light. It is expressed as kilogram ethylene-equivalent.

The human toxicity potential (HTP) is a measure of toxic emissions that have impacts on human health and can cause carcinogenic or non-carcinogenic diseases. It is expressed as kilogram 1,4-dichlorobenzene-equivalent [10].

The results in Table 2. show that the highest environmental impact of dairy processing is CO_2 eq. emission. The value of Global Warming Potential (GWP 100) is 0,21 kg CO_2 eq, which means, 0,21 kg of CO_2 equivalent greenhouse gas enters the atmosphere when the dairy plant produces 1 kg final product. It is caused by the high electricity demand for cooling during the whole process-chain (31%), and the 13-17% share of packaging material and caustic soda production and milk transport. GWP 100 is 1-3 orders of magnitude higher than the other 4 environmental impact categories.

Table 2. LCIA result of 1 kg fresh milk production

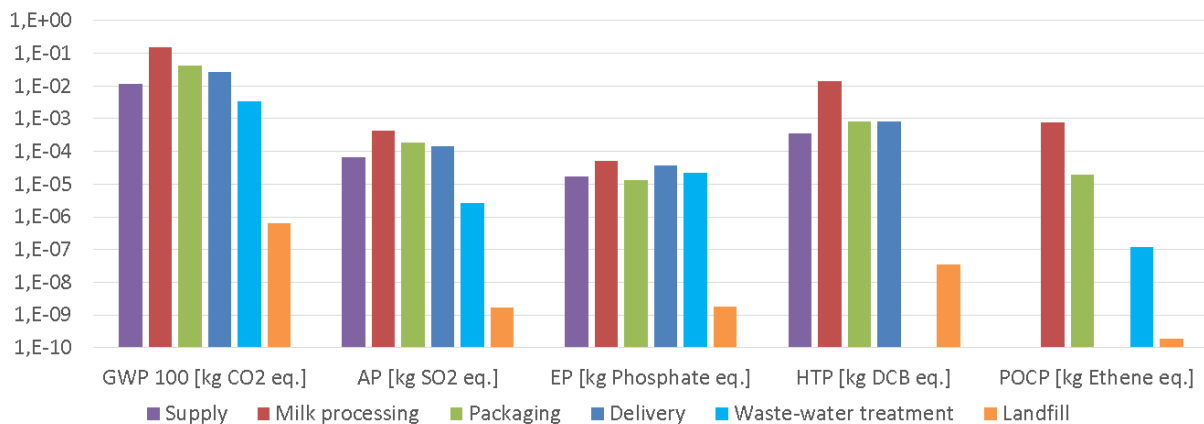| Impact category	GWP, kg CO_2 eq.	AP, kg SO_2 eq.	EP, kg Phosphate eq	HTP, kg DCB eq.	POCP, kg C_2H_2 eq.
Total	0,21	8,20E-4	1,41E-4	1,62E-2	6,75E-4

Fig. 3. GWP (100 years), and AP, EP, HTP, POCP of fresh milk production

Fig. 3. shows the GWP 100, AP, EP, HTP and POCP for each step of the fresh milk production. More than 60% of total GWP is caused by milk processing (pre- and post storage,

homogenization and pasteurization), and 98% of total electricity is consumed during this step. More than 15-15% comes from packaging and transport, and the share of waste-water treatment and landfill are altogether less than 2%.

These results of AP, EP, HTP and POCP show the same, that the processing step, with its sub processes, has the highest impact on our environment with its 35-90% share depending on impact category. Transport (supply and delivery) and packaging have a significant share in the environmental impacts, depending on impact category, 7-38% and 5-22%, respectively. Waste-water treatment (except in the case of AP, where its share is 16%) and landfill are negligible.

2.4. INTERPRETATION

A Serbian dairy product LCA study [11] was used for comparison and validation of the Hungarian fresh milk production LCA. The Serbian study was a cradle-to-gate analysis of tree subsystems (dairy farm, dairy plant and waste treatment) with 1 year of data collection through questionnaires and site visits of 6 dairy plants. The environmental impacts were calculated with CCaLC methodology. The input and out data for UHT and pasteurized milk production are summarized in Table 3. The functional unit is 1 kg of the final product, the energy and material flows refer to this unit.

Table 3. LCI of the Serbian Study

Input data for 1 kg of milk production	UHT Quantity	Pasteurized Quantity	Unit
Raw milk	1,00-1,02	1,00-1,02	kg
water	1,65-2,49	1,32-3,60	L/kg
electricity	0,02-0,18	0,01-0,65	MJ/kg
Thermal energy	0,27-0,65	0,08-0,40	MJ/kg
Sodium-hydroxide	2,5-7,13	0,15-7,13	g/kg
Nitric acid	0,05-3,13	0,05-3,14	g/kg
Transportation of raw milk	-	1,9-272,7	kg-km
Transportation of other materials	-	48,88-5557,44	kg-km
packaging	0,026-0,03	0,028-0,056	kg
Output data for 1 kg of milk production			
Waste	-	0,004-0,03	kg/kg
Waste water	1,64-2,4	1,32-3,60	L/kg
UHT milk	1	1	kg

The difference between fresh milk and UHT milk is that the UHT milk is pasteurized at 130-150 °C for a few seconds, while the fresh milk at 85 °C for a few seconds. The other steps in milk production are the same except for packaging, as the fresh milk is packed in a polythene bag while the UHT milk is packed in a "tetra pack" box.

Fig. 4. shows the results of the two analyses presenting the LCIA results of the Hungarian fresh milk, the Serbian UHT and "pasteurized milk" (which is the same product as fresh milk) to validate the Hungarian fresh milk analysis. The comparison shows, as expected, fresh milk has lower GWP, AP, EP compared to UHT milk; but there are significant differences between fresh milk and pasteurized milk.

Possible cause of differences in the results, besides the different impact assessment methodologies, is the different composition of the electricity mixes, as that gives more than 40% of AP, HTP, 30% of GWP, and 20% of EP. Serbian electricity mix consists of 11% nuclear, 41% coal, 22% natural gas, 17% hydro, 4% oil and the remaining are various renewables. While the Hungarian electricity mix consists of 53% nuclear, 21% coal, 14% natural gas, and only 1% hydro with various renewables [12]. According to the GaBi model

calculation, the Serbian electricity mix has 2 order of magnitudes higher environmental impact for 1 MJ electricity.
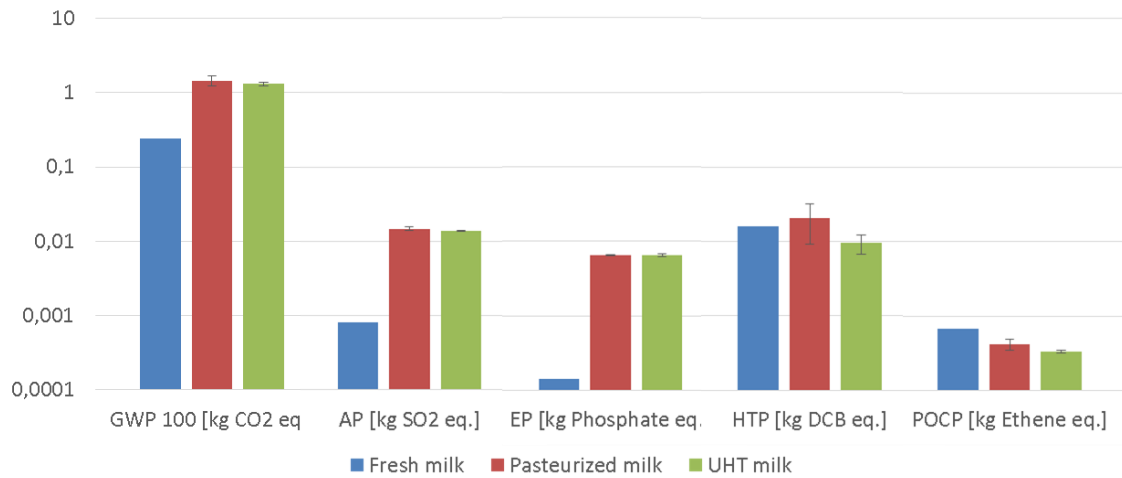

Fig. 4. *GWP, AP, EP, POCP, and HTP of Hungarian fresh milk, Serbian pasteurized and UHT milk*

3 CONCLUSION

The Serbian electricity mix has 2 order of magnitudes higher environmental impacts than Hungarian. So that the GWP, ad EP is one order of magnitude lower, and the AP is two order of magnitudes lower of Hungarian fresh milk compared the Serbian, the HTP is around the same, but the POCP of Hungarian fresh milk is 1,5-2 times higher than the Serbian milk products. For more accurate results, there are opportunities to improve the Hungarian fresh milk model. For example, the gate-to-gate analysis can be extended to a cradle-to-gate analysis, thus the raw milk production will be included in the model. Or the transport processes can be improved if the delivery data of detergents and packaging material would be available. Another way to develop the model is to collect data on electricity consumption for pre-and post-storage steps, or natural gas consumption for pasteurization.

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LIFE CYCLE ASSESSMENT OF HOUSEHOLD APPLIANCES IN THE ASPECT OF ENERGY EFFICIENCY

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Abstract: *Energy label is an important marketing tool to support consumers to make their own decisions when purchasing a new product. By the help of LCA, the current appliances of the examined household and the possible replacement A^{+++} class products ware compared. The four investigated scenarios (original case, a high energy-efficient, a reasonable and a cost-efficient case) are based on preliminary calculations considering the initial investment and the payback period. The life inventory contains the electricity and the water consumption (use phase) of all the products, furthermore the production phase of the appliances of the fourth scenario. The life cycle impact assessment besides PED reveals the environmental impact concerning four different impact category: GWP, AP, EP, POCP.*

Keywords*: LCA, energy efficiency, energy label, eco-design.*

1 INTRODUCTION

Climate change is a determinative topic in everyday life. Creating energy efficiency approaches become more common. The expected depletion of conventional fossil energy sources and the wasteful energy consumption that characterises everyday life are worrying, that turns out in the Earth Overshoot Day, which was on August 1. 2018. That means men live up the one-year stock in seven months. In order to solve this problem, one should not count only on large consumers. A simple household consumer can also do against climate change, preventing natural disasters, while reducing the home maintenance costs as well.

This paper is a case study, an extended „gate-to-gate" life cycle assessment (LCA) [1] of the replacement of household appliances with higher energy-efficient equipment, assuming four scenarios.

1.1. SCENARIOS

The investigated household appliances are: chopper, freezer, steam cleaner, multifunctional hand mixer, halogen bulbs (8 pieces), refrigerator, air conditioner, 3 laptop chargers, 8 led lamps, 3 mobile phone chargers, microwave oven, washing machine, vacuum cleaner, sandwich toaster, television, router, set-top box, iron and kettle. Authors paid attention to appliances that have energy labels and that significantly contribute to electricity consumption.

In all cases, the scenarios are based on the energy consumption of the equipment. The current devices classified into A or A^+ energy efficiency classes are purchased 2…2.5 years ago, therefore the old appliances considered to be sold. In order to decide which equipment should be replaced to reduce the environmental impact of the household, an environmental load/cost-efficiency factor (ECF) was defined. It is the ratio between simple payback time and electricity consumption saving of the new device. Authors subjective acceptance was that the appliance should be replaced if the new one saves at least 20% of the electricity consumption and pay off within five years, which gives 25 for ECF.

$$ECF = \frac{simple\ payback\ time}{electricity\ consumption\ savings} \qquad (1)$$

As a conclusion of the economic analysis can be stated, that the replacement of several devices would cause environmental impact reduction, but only four of them would be pay off in acceptable time: air conditioner, washing machine, vacuum cleaner and halogen bulbs. In the case of other devices, there is no return before the end of the expected lifetime. Therefore, the replacement of these appliances does not worth for consumers. Taking these statements into consideration, four different scenarios were compared.

Scenario 1 presents the original case and contains the data of the investigated household's equipment. Fig 1. shows the distribution of energy consumption.
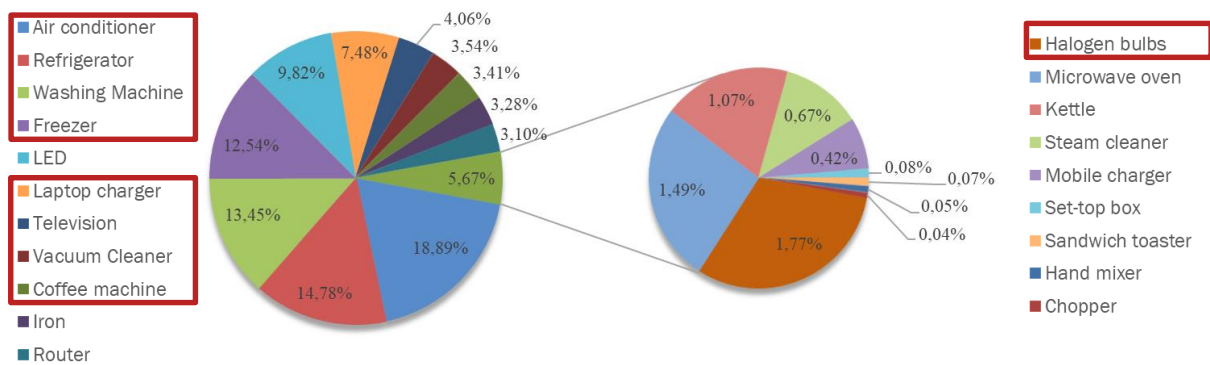

Fig. 1. *Distribution of annual electricity consumption of the household appliances*

In Scenario 2, all the examined appliances we replaced, if it was available, with an A^{+++} equipment. That is, the energy labelled appliances: air conditioner, refrigerator, washing machine, freezer, television, vacuum cleaner, coffee machine, and halogen bulbs. Electric coffee machines are currently not classified to energy classes, but some traders already categorised them. The laptop charger is also replaced. However, it does not have an energy label but significantly contributes to electricity consumption.

In some cases, the higher energy-efficient versions of the device, such as freezer, television and coffee machine, have higher consumption and therefore higher environmental impact. In case of a reasonable solution these specified appliances are not replaced. In Scenario 3 the energy labelled devices were replaced except for the freezer, TV, coffee machine.

Scenario 4 is a cost-effective approach. Only those appliances have been replaced that pay-off in a short time (considering the selling of the old appliances), thus the air conditioner, the washing machine, the vacuum cleaner and the halogen bulbs were replaced.

2 LIFE CYCLE ASSESSMENT (LCA)

2.1. GOAL AND SCOPE DEFINITION

This study is an extended gate-to-gate life cycle assessment, which means that besides the use phase, the manufacturing process of the main appliances (air conditioner, washing machine, vacuum cleaner, halogen bulbs and LEDs) is included as well. The annual environmental impact was modelled using GaBi 8.7 software. Fig 2. shows the detailed GaBi model, which central element is the Hungarian electricity mix, that is available in the GaBi Professional 2018 database. The tap water production and wastewater treatment are modelled with EU-28 average processes available in GaBi Professional 2018 database. All the other processes are created based on the consumptions of the appliances and literature data of their

production [2]-[5]. The material and energy flows are referring to one-year operation. The model can manage the four scenarios at the same time.
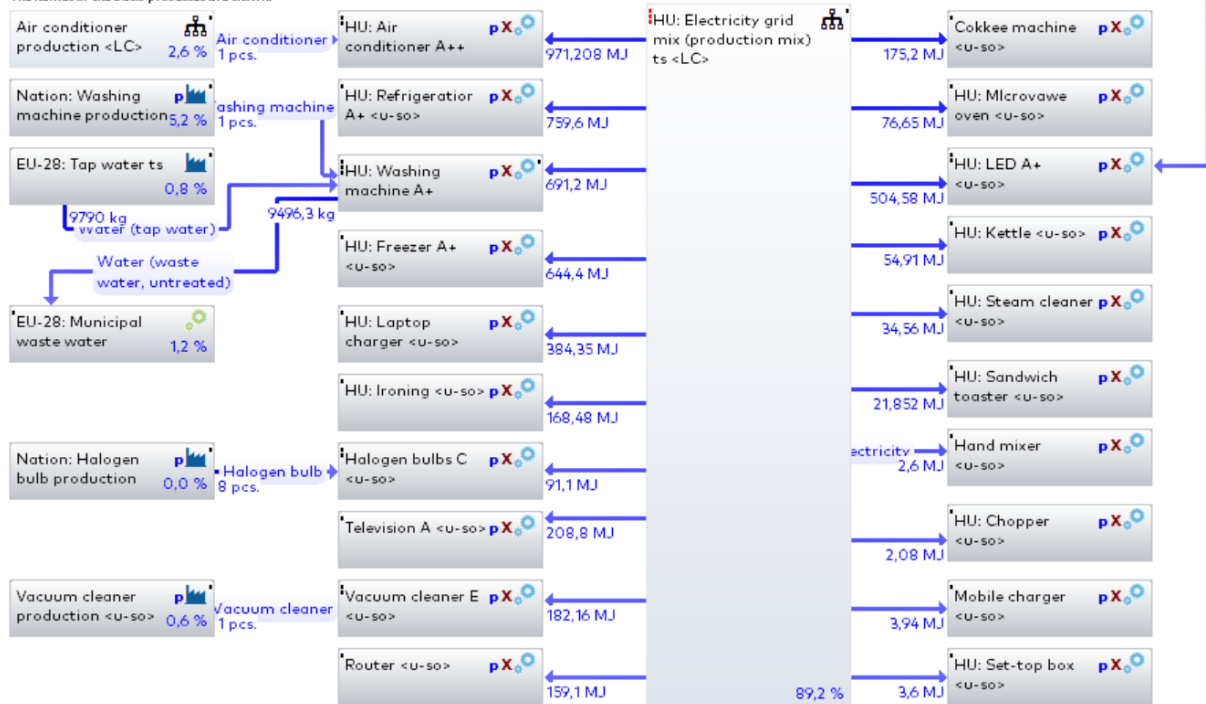

Fig. 2. GaBi model of the Household

2.2. LIFE CYCLE INVENTORY (LCI)

The input data are calculated and estimated annual energy consumptions of the household appliances. Estimation is based on the operating hours of each device, that depends on individual customer habits. The household is an average or low-consumption apartment. The annual electricity consumption is 1436 kWh, the annual water consumption of the washing machine is 9790 litres, and the wastewater of the washing machine is 9500 litres. The volume of wastewater was determined by measuring the remaining water in the load. The electricity inputs of the current and replacement appliances are shown in Table 1.

Table 1. Energy consumption of current and replacement appliances

Appliances	current, kWh/y	replacement, kWh/y	savings %
Air conditioner	269,78	166,00	38,47%
Refrigerator	211,00	169,00	19,91%
Washing machine	192,00	150,00	21,88%
Freezer	179,00	194,00	**-8,38%**
Laptop charger	106,76	73,91	30,77%
Television	58,00	67,00	**-15,52%**
Vacuum Cleaner	50,60	28,00	44,66%
Coffee maker	48,67	76,65	**-57,50%**
Halogen bulbs	25,31	5,84	76,92%
Other appliances	286,76	-	-

Annually at least 20% of total electricity consumption can be saved with higher energy-efficient devices. In the case of freezer, TV and coffee machine, the consumption of the new

device is higher because the replacement A^{+++} product is larger as no product with the same size or power was available.

2.2. LIFE CYCLE IMPACT ASSESSMENT (LCIA)

The impact assessment is based on the CML 2001 (2016) method for four energy impact categories: global warming potential (GWP, kg $CO_{2,e}$), acidification potential (AP, $kgSO_{4,e}$), eutrophication potential (EP, $kgPO_4^{2-}{}_{,e}$), and photochemical ozone creation potential (POCP, $kgC_2H_{4,e}$) [6]. The investigation also includes the primary energy demand (PED).

The environmental impact of the investigated household is proportional to electricity consumption. With replacing the washing machine, only a 3% reduction of water consumption can be achieved, that is 0.6-1.2% of the total environmental impact of the household.

Table 1. quantifies the primary energy demand (PED, GJ) of the original case and the primary energy savings compared to the original case, Scenario 1. The primary energy savings with the cost-effective approach is 13%, but in case of the reasonable solution, when only the environmental benefits are important it can be higher than 18% of the annual PED of the original case.

Table 1. *Primary energy savings compared to the original case*

Scenario 1	Scenario 2	Scenario 3	Scenario 4
16,9 GJ	14,20%	18,34%	13,02%

The environmental impact of the household with the current appliances and the reductions with the planned replacements in case of the different scenarios is shown in Table 2. Reduction can be achieved with each scenario, as the environmental impact is proportional to the electricity consumption if we assume that the manufacturing phase is more or less the same for current and replacement appliances. The share of production phase in GWP is only 2-27% depending on the appliance and consumer habits (Fig. 3).

Table 2. *Environmental load reduction in each scenario*

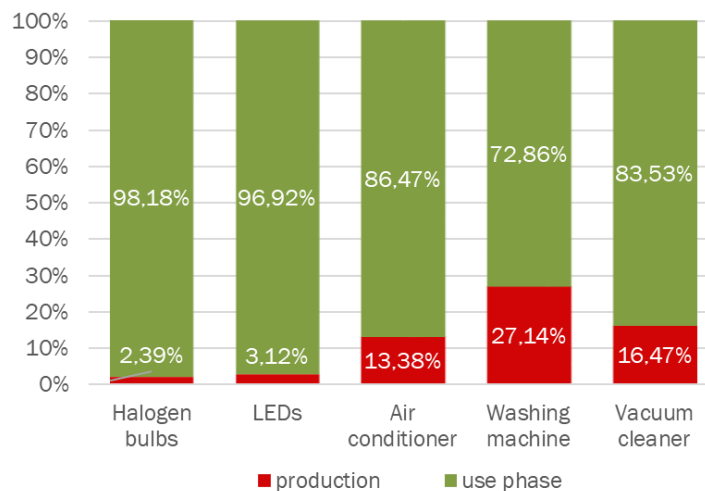|	Scenario 1 kg	Scenario 2 %	Scenario 3 %	Scenario 4 %
GWP	681	12,92	16,15	11,45
AP	1,23	13,17	16,42	11,79
EP	0,279	11,11	13,62	10,04
POCP	0,116	12,07	15,26	10,34

Fig. 3. Contribution of the production and the use phase to GWP, $CO_{2,\,eq}$

Scenario 3 would be the most favourable solution in the interest of reducing environmental damage, as depending on impact category 13,5-16,5% environmental impact reduction can be achieved. However, from an economic point of view, replacing all the household appliances does not worth for the consumer. But even with the cost-effective approach (Scenario 4), depending on the impact category, 10-12% environmental impact reduction can be achieved.

3 CONCLUSION

It is not always advisable to replace the current household appliance with the most energy-efficient A^{+++} class device, as the new device may have higher energy consumption than the current one due to size or power differences. Considering the economic issues, it may happen that the additional cost of an A^{+++} class device will not refund during its lifetime.

Form an environmental point of view Scenario 3 is favourable, as more than 18% of PED and 13,5-16,5% environmental impact reduction can be achieved. Even in the case of Scenario 4, considering the economic issues as well, 13% of PED and 10-12% environmental impact reduction can be achieved.

Further studies are required for more accurate results when the manufacturing of all appliances and all the phases of the life cycle (packaging, transportation, recycling and waste management) should be taken into consideration. However, one can still assume, that during the life cycle of the appliances the environmental impact caused by the use phase is the most dominant. Emissions from transportation may negligible over the whole lifetime of the devices. The end-of-life phase could have high impacts, but thanks to recycling it could be negligible as well. Therefore, the electricity mix, the central element of the use phase should be improved, completed with imported electricity, as the emission of electricity generation highly depends on the actual energy mix.

ACKNOWLEDGEMENTS

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54

THERMAL ANALYSIS OF BRANDY DISTILLATION BY USING THERMAL CAMERA

Ádám Virág, Zsolt Csendes, Tamás Laza

Abstract: *Laboratory (manufactured Duran glass) distillation (prepared as brandy) were carried out by using distillation equipment, during which the distillation column and the dephlegmator thermal conditions as well as the cooling water inlet and outlet temperature deference was monitored by using measuring instruments and thermographic shooting at the same time. Important factors affecting the quality of the finished brandy are the dephlegmator temperature conditions. By altering these, three distinct thermal relationships could be distinguished: basic, less cooled and super cooled state which were measured by us one by one. In the process of distillation, we pre- obtained 1500 ml of starting substance (made from Stanley plum mash) and then we measured the volume and alcohol content of the pre-, middle-, and after distillates, we measured the volume and the alcohol content. The theoretical values have been determinate and the thermal camera record combined results made the cooling variables well analysable, making new opportunities to optimize the distillation process.*

1 THEORETICAL BASIS

Alcoholic drinks accompany the history of mankind, sometimes it was a blessing, and sometimes a curse for the living population. It was not until the14th century when alchemists obtained the first distillates by using distillation techniques that were initially used as medicinal products. Aqua Vitae sold under the name "water of life" is the first produce that we have written records about. These products (in the 14th century) were first taken by Charles Robert's wife, Elizabeth to cure her gout. The name brandy (which is of Slavic origin) was initially used for all products made by distillation in the 17th century, but later this term was exclusively used for spirits made of fruits.

With the use of industrial steam distillation, the amount of spirits increased, quality has improved, thereby enabling the spread of distillates as luxury goods for the broad community. In the 20th century, as an influence of the Slavic alcohol culture, the original values of brandy (proper scent, flavour and alcohol content) declined in importance, it was gradually replaced by spirits that were enriched with flavours and contained fruits only to certain extent. Today, brandies characterized by fragrance and fruity flavours has begun to penetrate gastronomy and trade, ie., spirits are undergoing a renaissance again. [1]

With the development of technology, there was a need to explore and learn more about the closed extraction equipment processes during distillation [2], thereby optimizing the distillation process. Recognizing these demands, we carried out thermal measurement and recorded thermal images of the distillation process.

The modern, one-step column distillery devices operate based on the rectification principle. During the two-way rectification, heat and mass transfer – due to imbalances – takes place between the vapour and liquid phases. The temperature of the phases differs and show reverse flow relative to each other [3].

Our measurements were performed by a distillation apparatus that was manufactured from duran bottle and that was suitable for batch rectification. The distillation was carried out by a so-called amplifier "topping" distillation apparatus, which is shown in Fig. 1:
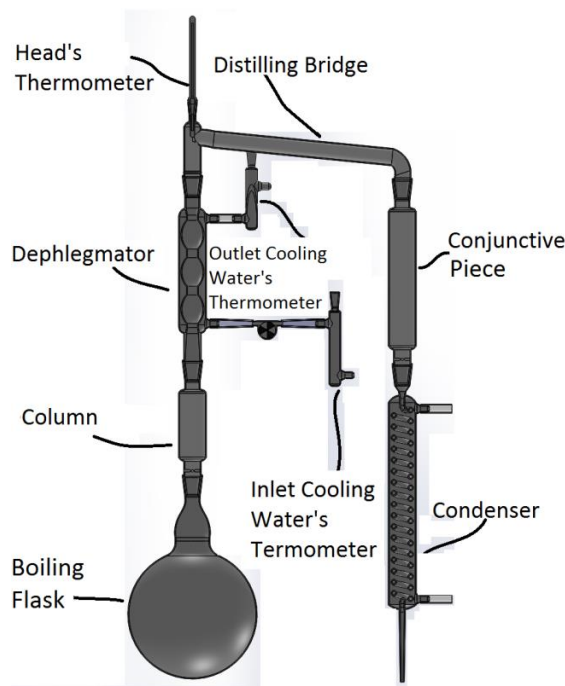
Fig.1. *Figure Structure Measuring equipment*

The pan was heated with an infrared heater which provides a constant heat input, and after the substance has reached the boiling temperature, it keeps it at a constant temperature.

The contact phase takes place in the column (the amplifier is required). The copper column filled cylindrical cartridge (Figure 2) in which the continuous phase is in contact. The amplified "topping" distillation in one step makes and refines the sub-alcohol. Furthermore, another advantage is that it provides for richer aromatic (in taste and odour) components, leads to energy saving, fine separation and a good yield. Flowing through the dephlegmator (which is a partial condenser), the reflux ratio and therefore the quality of the distillation can be controlled by the amount of the cooling water. Therefore, it is required to control the amount of cooling water and the entry and exit temperature of it. The distillation bridge and the connecting element is used to convey the steam flow, this phase does not change the characteristic of the distillate, instead the distillate cool gradually, thus the taste and scent in it is not lost. The capacitor will carry the vapour through a liquid phase. The final element in the distillation device is the head thermometer which is used to monitor the distillation process, there are obtainable information on the start of the distillation, when the temperature reached 78.3 °C, alcohol reached its boiling point and the distillation ends when it reaches 100 °C, the temperature when also water starts to boil.

***Fig.2.*** *Figure Structure Measuring equipment*

2 THEORETICAL DISTILLATION

Before the actual brandy production, a theoretical distillation is carried out in a known ethanol - water mixture (10-90% V / V). In this distillation process, the parameters of the measuring equipment's could be determined: the number of theoretical plates and the average reflux ratio.

In the case of packed columns, we cannot speak about the physical plate, since the liquid and vapour phases are present in the column in their full scope rather than on the preformed trays. It is therefore important to know how may physical plates the column corresponds to. The theoretical plate is a plate, of which the average composition of all the exhaust gas is in equilibrium with the average composition of the effluent [4]. The number of these plates is the *theoretical plates* (ne). The recycled liquid is named reflux, the quantitative ratio of the recycle liquid and the discharged distillate is defined as reflux ratio [4].

The batch rectification can be done two ways: by constant reflux ratio or by constant distillate composition. During the measurements we sought to reach constant composition of the distillate. As a result, reflux ratio has been constantly changing, so we determined a mean reflux ratio calculation for future simplification of calculations.

For the measuring of the average reflux rate, we took the amount (ml) and alcohol content of the distillate and the residue (1. Table, and Graph 1). The alcohol degrees are measured on an Anton Paar Snap 40 type based on oscillating U-tube density measurement principle.

R [-]

$$R = -7{,}879*10^{-8}V^3 + 6{,}338*10^{-5}V^2 - 5{,}092*10^{-3}V + 6{,}223*10^{-1}$$

V [ml]
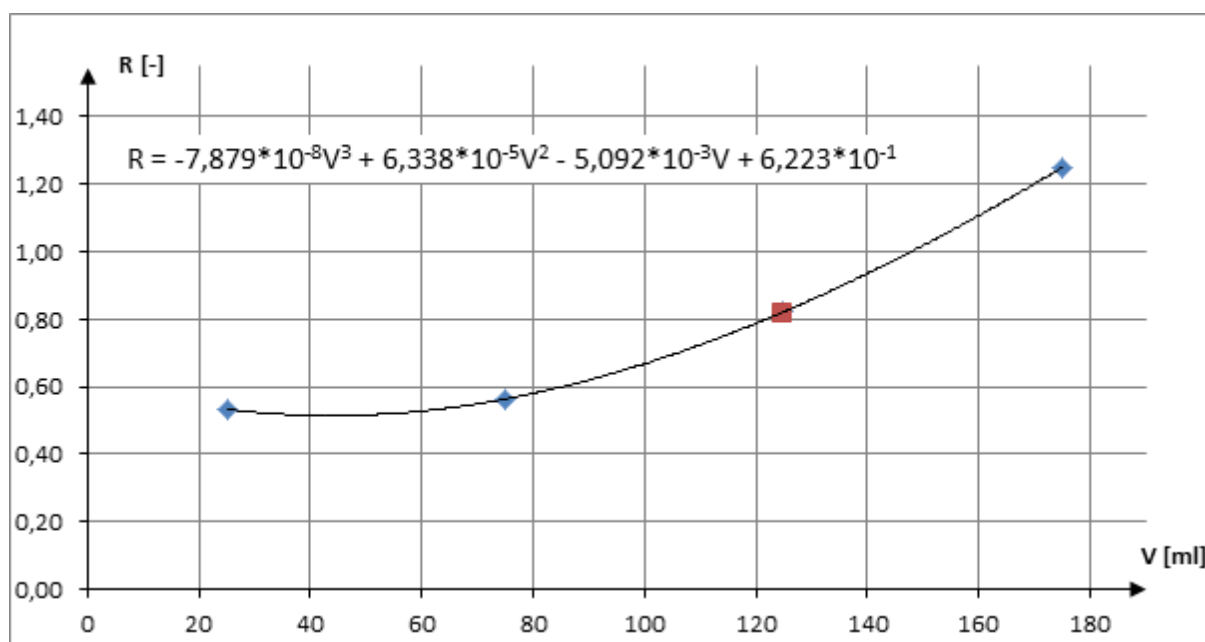
Graph.2. *Average reflux ratio determination*

During the distillation the reflux ratio increased more and more, which means that for the sake of constant distillate yield we had to increase the input "performance". The calculation of the average reflux ratio using cubic equation is shown in chart 1, on the basis of the proportions of each area:

$$R_{á} = \frac{R_1 \cdot A_1 + R_2 \cdot A_2 + R_3 \cdot A_3}{A_1 + A_2 + A_3} \tag{1}$$

Where $R_{á}$ [-] of the average reflux ratio

                 A_n [ml] Area under the curve

                 $R_{án}$ [-] Average value between the reflux

Based on equation (1), the value of the average reflux ratio is 0.82 [-].

Determining the number of theoretical plates McCabe - Thiele [5] method was used, which is most commonly used graphical method for determining the number of theoretical plates (for each of colours designated measurement data from different time: blue 1, red 2, green 3 and 4, the purple measuring point).We used the representative equilibrium curve taught by the Szent István University Faculty of Food Industry, Beer & Spirits Industry Department, Brandy master teachings, and work lines up on the basis of measurements taken. The method resulted in all cases that the number of theoretical plates is four. (see Fig. 3).
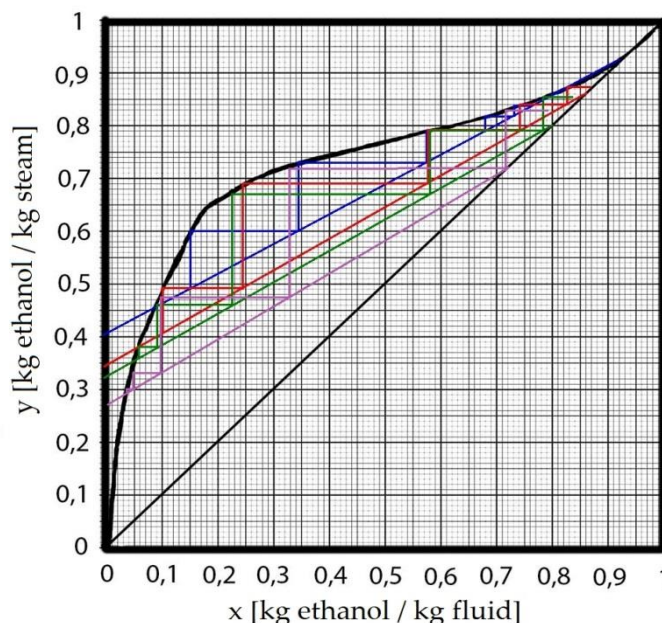

Fig.3. *Theoretical Determination plates*

Because the real distillation is done on the same equipment, we carried out in similar circumstances, a good approximation to assume that the number of theoretical plates and reflux ratio is equal to the average value of the theoretical calculations.

3 REAL DISTILLATION

Between the theoretical and the actual distillation, the main difference is that, while there are only two components of the theory (ethanol and water), while the actual case is a complex compound containing an unknown number of components and aromatics which the main component in the water and ethanol. Between theory and real distillation, further difference is that while in case of theoretical distillation, the total distillate can be utilized, while in the real case we must be separate pre-, mid- and after- distillation, which differ in content and also in aromatics and alcohol content. (A useful yield of the amount of distillate and the alcohol content is the product of, units ml·alkohol%.) Only the middle-distillation is suitable for consumption, so this is the only yields considered as useful.

The real distillation was performed with Stanley plum mash with three different distillation settings. The three options are, in the dephlegmator cooling of various regulations. First we set the dephlegmator at 60 °C, which is the basic setting in our equipment under measurement experiences. After that, we did undercooling, then finally, we used super-cooling. (In the process of undercooling, we extracted less heat compared to the baseline cooling conditions, however, during super-cooling, we applied much more cooling compared to the baseline cooling conditions.) In the distillation processes, three sections can be distinguished based on the aromatic features of the distillate components: pre-, mid- and after distillation sections.

During the distillation, we measured the head, the vessel and the cooling water inlet and outlet temperature, the cooling water flow rate at different distillation sections and the volumes of and alcohol concentration of the distillate.

In the base condition, the distillation showed similar results as expected in the theory of distillation. This is because the initial mash's alcohol content (9.2% v / v) were used in nearly identical to the theoretical distillation - a mixture of water and ethanol (10% v / v). With the measuring device, and with optionally stabilized distillation the useful yield compared to the theoretical distillation that resulted in a 1:2.49 ratio. This was compared with the values observed in the industry (1: 5; 1: 5.5) from which one can conclude that an individual fruits distillation setup can be determined in distillation, which is able to optimize industrial conditions [6]. (And their evaluation results of the measurements are shown in Table 1 and Chart 1).

In the case of under-cooled distillation, the useful yield compared to the theoretical yield had a ratio of 1:2,88, this is 16% less than the normal powered distillation. Compared to the base distillation, in the circumstances of under-cooling, the pre-distillate was less and it has less alcohol content too, in opposite of that, the after-distillate was likely the same amount, and had a significantly higher alcohol content. This is because in the middle-distil, the residuum (the mash during the distillation process) could not give appropriate amount and quality of alcohol, and that the alcohol appeared only during the after-distil.

In the case of over-cooled distillation, the useful yield compared to the theoretical yield had a ratio of 1:2.11, and it is 15% more than the base distillation process. Moreover, comparing the two distillation process we can say that the pre-distillate is less in volume and alcohol content, however, the after-distillates alcohol content was nearly the same. As a consequence, the useful yield, which depends on the alcoholic strength and volume of the middle distillate, is higher than in the case of distillation in the basic state.
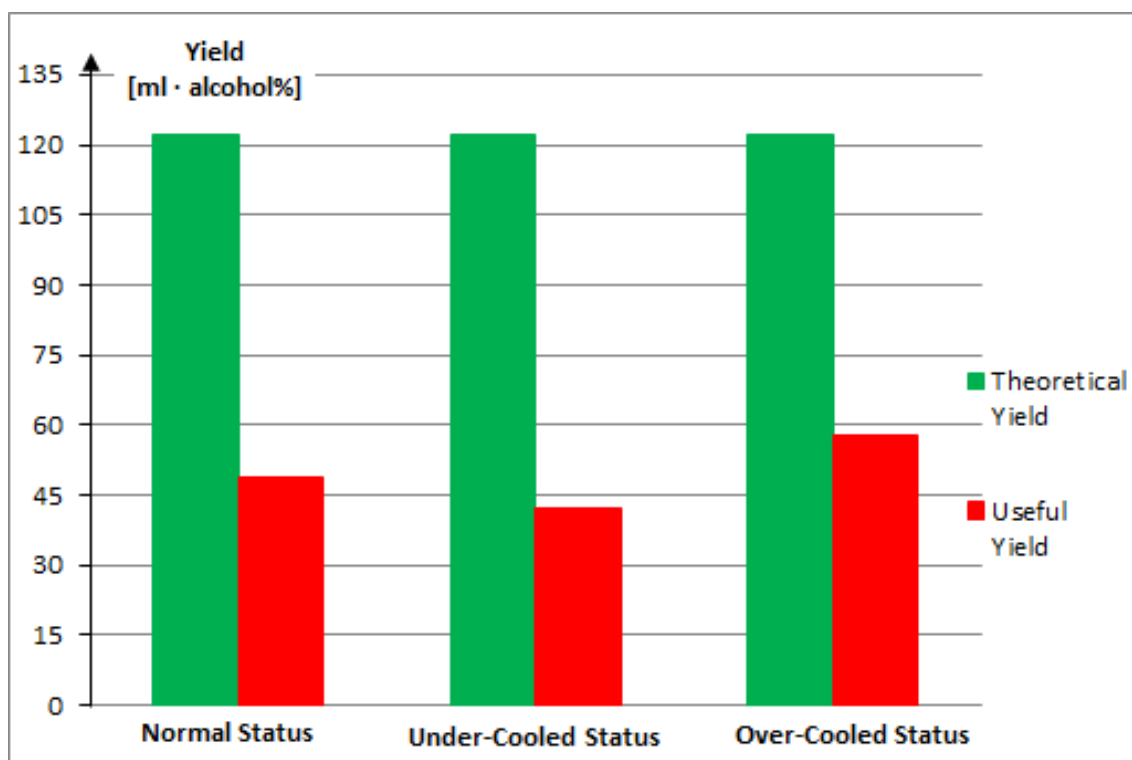

Chart 1. *The usefulness of theory and under different cooling options*

Table 1. *Measured data and recovery rates*

	Quantity	alcohol content	useful yield	theoretical yield	theoretical amount
	ml	V / V%	ml · alcohol%	ml · alcohol%	ml
Normal Status					
Mash	1500	9.2%	138.0	-	-
Pre-distillate	35	86.9%	30.2	-	-
Mid-distillate	58	84.1%	49.0	122.0	136.5
After-distillate	141	37.3%	52.4	-	-
The rest	1254	0.0%	0.0	-	-
Comparing to the theory: 2.49		2.49-to-1 ratio			
Under-cooled status					
Mash	1500	9.2%	138.0	-	-
Pre-distillate	29	72.0%	20.9	-	-
Mid-distillate	49	87.2%	42.3	122.0	141.5
After-distillate	134	48.0%	64.3	-	-
the rest	1276	0.0%	0.0	-	-
Compare this theory: 2.88		2.88-to-1 ratio			
Over-cooled status					
Mash	1500	9.2%	138.0	-	-
Pre-distillate	30	78.0%	23.0	-	-
Mid-distillate	656	88.2%	57.7	122.0	113.01
After-distillate	126	40.4%	50.7	-	-
The rest	1267	0.0%	0.0	-	-
Compare this theory: 2.11		2.11-to-1 ratio			

In our measurement we can say that the over-cooled state results in the highest yield, but that yield was not enough for us if the distillates quality is not right. Because of that, the middle-distillate has been criticized by official Brandy juries, and the results was written in the 2ⁿᵈ, 3ʳᵈ and 4ᵗʰ Table has.

The sensory test has five main categories:
- Fragrances purity (3 points)
- Fragrance characteristic (5 points)
- Purity taste (3 points)
- Taste characteristic (5 points)
- Overall impression (4 points).

The juries first test the purity and fragrance of the distillate, after that they form an opinion on the sample after tasting it and based on their overall impression. All samples were judged by a jury of three members. The members first judge the sample alone, and in consultation with each other, seeking consensus establish proper corporate evaluation by the jury score. Based on the jointly formed scores, brandies are classified into the following categories: gold (18 to 20 points), silver (16 - 17 points) and bronze (14-15 points). The selection of the winners of the gold medal – known as Champion - is based on the opinion of all judges at the end of the competition.

Table 2. Table: Baseline Quality criticism

name:		The main groups: Stone fruit			Sub-group: Stanley Plum	
scent purity (0-3)	fragrance character (0-5)	taste purity (0-3)	taste characters (0-5)	overall impression (0-4)	Result (0-20)	number of judges
3	4	3	3	3	**16**	8
3	4	3	4	2	**16**	12
3	5	3	4	3	**18**	13
Consensus results:		**16 (Silver)** On the nose, intense inch a kind of character, feeling short post, Crisp fresh shares outstanding character, nice sleek.				
3	4	3	4	3	**17**	2
3	5	3	3	3	**17**	7
3	4	3	3	3	**16**	10
Consensus results:		**17 (Silver)** Its taste, smell kind of error-free ticket bears the scent is fresh and strong floral notes, fresh plum flavour characteristics make flat aftertaste, silky short overall effect of ingratiating.				
3	4	3	3	3	**16**	12
Consensus results:		There is no consensus result.				

Table 3. The operating status of super cooled quality criticism

name:		The main groups: Stone fruit			Sub-group: Stanley Plum	
scent purity (0-3)	fragrance character (0-5)	taste purity (0-3)	taste characters (0-5)	overall impression (0-4)	Result (0-20)	number of judges
2	3	2	3	3	**13**	21
2	2	2	2	2	**10**	7
2	3	2	3	3	**13**	11
Consensus results:		**for 14 (-)** On the nose, barely recognizable characters inch a kind of intense, alcoholic sensation dominates the long hot utóérzett, alcohol overweight.				

Table 4. Table: The operating status of quality undercooling criticism

name:		The main groups: Stone fruit			Sub-group: Stanley Plum	
scent purity (0-3)	fragrance character (0-5)	taste purity (0-3)	taste characters (0-5)	overall impression (0-4)	Result (0-20)	number of judges
3	3	3	3	3	**15**	28
3	4	3	4	2	**16**	12
3	4	3	4	3	**17**	3
Consensus results:		**16 (Silver)** On the nose, fruity kind of characters gives its flavor notes of cooked jam, jelly post sense, deep waxy, spicy long finish plum dumplings, plum bag feel.				

The results are shown in the illustrative diagram web (see Chart 2).

The larger the enclosed space, the greater the aroma characteristics of the brandy is. Based on the review by the jury, we can say that the quality of normal distillation is also excellent. The difference from the gold grade was only due to the lack of decades of experience of brandy masters. In contrast, the quality of the overcooled state does not even reach the bronze grade, so it can be stated that its quality is inadequate. So, in this state, the best yield is in this state, because its quality is almost inadequate. The quality of the undercooled state also reached the silver grade, but it is worth observing the consensus result as well. On the basis of this, it can be said that the quality according to the rating category would be acceptable in itself, but its scent is more like the "plum dumplings" shifted towards the deeper broader character, rather

than the quality of the brandy, which is the fresh fruity notes and the capital, would be a balanced harmony of jam. As well as its high yield, this state of operation is not suitable for producing quality and optimal yield of brandy.
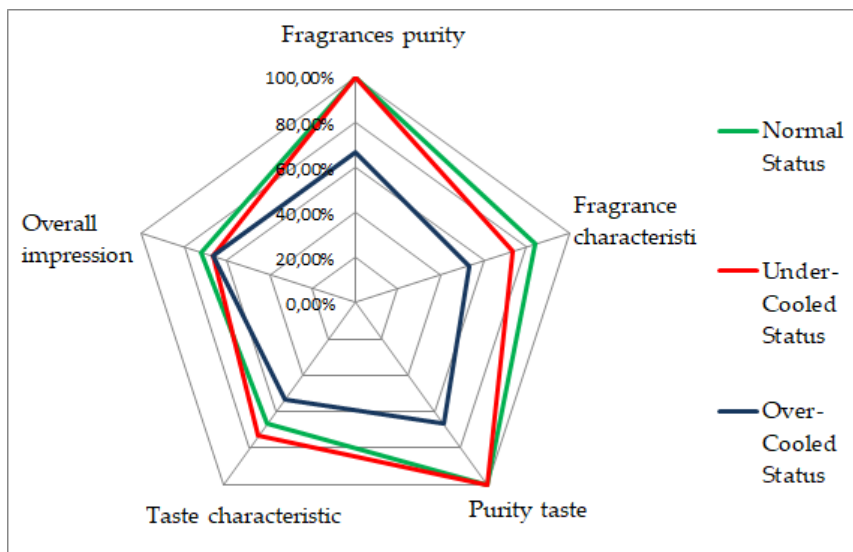

Chart 2. *spider web diagram of average quality Distillation of criticism*

Taking into account the results, the ideal brandy distillation, which is optimal in both the taste world and the yield, was achieved with the normal state, which was achieved by the proper cooling ratio of the deflator. In order to continuously monitor this cooling relationship, all measurements were taken with a thermal imaging camera, which clearly illustrates the temperature change in the device as a function of time.

4 THERMAL CAMERA RECORDING

Infrared thermal imaging cameras belong to a group of so-called non-contact infrared thermometers, which have the advantage of speed, lack of interference, safe measurement and ability to measure at high temperatures (3000 °C) [7]. Its principle of operation is similar to the human eye. The lens represents the optics through which the radiation (photon flow) from the surface of the body to be measured reaches the photosensitive surface (retina). Here it turns into a signal that can be also interpreted by a computer. The radiation emitted by the body is proportional to the movement of the molecules inside the body, which depends on the temperature of the object (this is called typical or characteristic radiation). This radiation moves within a wavelength of 0.7-1000 μm, which falls within the red range within the visible light range, so it is called infrared light.

Figure 4 shows the temperatures and changes in the base distillation. (We used maximum condenser cooling for the entire duration of the measurement, so its temperature change is so small that the thermal imager could not detect.) In the first picture ("a"), the Stanley plum mash in the cauldron begins to reach its boiling point of 100 °C (the cauldron is white), the dephlegmator is then fully cooled. In the "b" image, the so-called standing column is displayed. (As a standing column we call the state when rectification takes place on the columns and on the dephlegmator.) This is the point when the control of the dephlegmator cooling is started. In the "c" image, the pre-distillation reaches the distillation bridge and increases the temperature of the distillation wall. Image "d" shows the increasing warming of the cooling water leaving the dephlegmator (the wires on the passing branch have become yellow), this is the beginning of the middle evaporation stage, which has to be checked by sensory examination (fragrance, taste). Image e shows the middle distillation stage. At this point, the temperature of the column is equal to the temperature of the cauldron under the influence of the flowing steam, whereas

the temperature of the cooling water at the bottom of the deflator is significantly lower. As the cooling water heats up, the surface of the dephlegmator heats up. The "f" image shows a distillation phase, confirmed by sensory analysis. At this time, due to the increasing warming of the deflector, the column, the distillation bridge and the connecting element, their thermal image is white. The reason for this is that after the end of the middle distillation we do not need the work of the dephlegmator at the after-distillation (because we would like to extract the remaining alcohol in the mash), therefore we stopped the cooling. After the head thermometer reached 99 °C (only water was evaporated) we stopped the heating of the cauldron and returned the cooling to the dephlegmator, which can be seen in the picture "g", where the dephlegmator cooled down within a short period of time due to the cooling water passing through the deflator. The last image ("h") shows the state at the end of the measurement, where no distillation components can be distilled off, condensation has stopped at the end cooler, and the heated distillation bridge and connecting element also start to cool down.
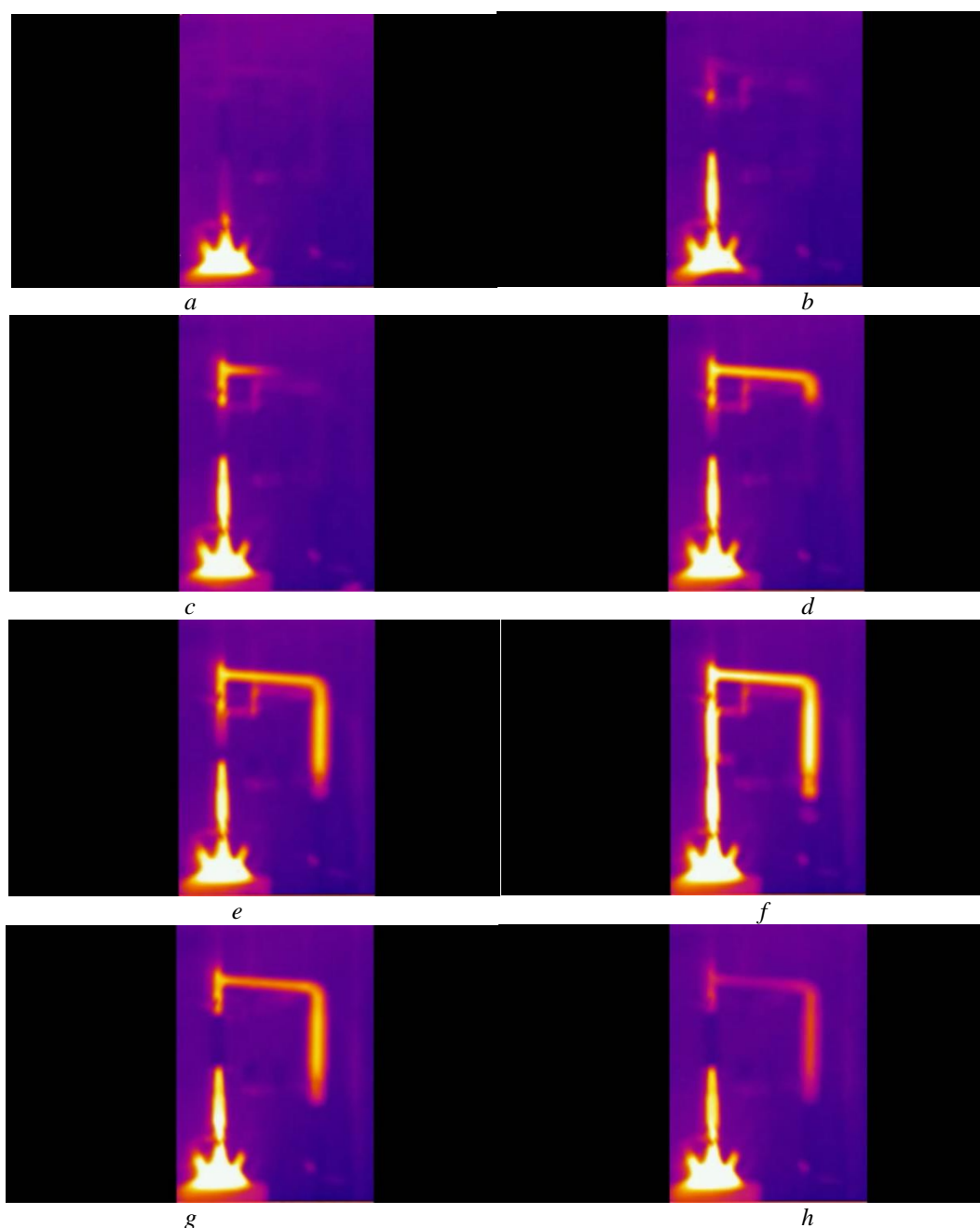

Fig.4. During the distillation, the temperature changes on the equipment

4.1 OPTIMIZATION

The recordings made with the thermal imager do not only serve as an illustrative tool, but also help to control the distillation process. The essence of optimization is that every distillation has an optimum dephlegmator cooling curve that ensures high quality of the middle distillate at maximum yield. The thermal imaging recording helps to keep the temperature of the distillation at an optimum value while keeping a constant eye on the distillation during the distillation, which greatly impairs the quality of the middle distillate. To do this, it is first necessary to determine the temperature conditions that the equipment develops in the middle distillation stage for the different fruits. For Stanley plum, these temperature conditions were determined using several test evaporations (this is the basic distillation state). By comparing the images taken in the three operating states, we were able to compare not only the distillates but also the thermal processes of the total distillations. In the following parts, we only deal with the analysis of middle distillates, as the taste of the pre- and post-distillation is inadequate. Images cut out of the middle distillation stages of each operating state are shown in Fig. 5, Fig. 6 and Fig. 7.
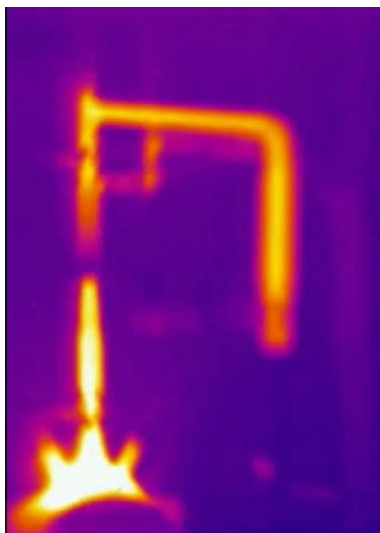

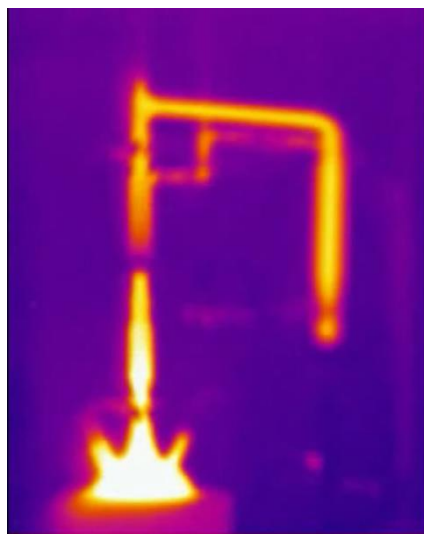*Fig.5. Heat-camera shoots middle distillate phase of Baseline*

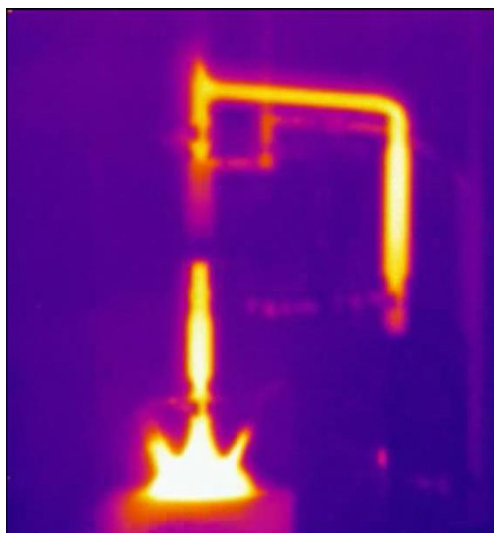*Fig.6. Heat-camera shoots under cooled state middle distillate phase*

Fig.7. *Under-cooled thermal camera shoots status section of middle distillate*

As shown in Fig. 5, in the baseline condition, the dephlegmator warmed up to the upper half of the dephlegmator, thereby allowing the reflux to form on the lower half to form aroma and alcohol. In contrast, in the undercover state, almost the entire dephlegmator was overheated, resulting in a dramatic decrease in reflux formation, resulting in lower aroma formation compared to baseline. In the over-cooled state, only the part of the dephlegmator warmed up, where the cooling water had gone away, thus reflux formation on the entire surface of the dephlegmator resulted in excessive alcohol formation, which prevented the formation of flavor. These processes were well-traceable on the thermal imaging camera, so it can be used to further fine-tune (even optimize) other fruits. desztillátum

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PROGRAM OF THE CONFERENCE

MONDAY, 27. MAY

PLENARY SESSION

Potential Impact of Digitalisation to Energy Sector
Einari Kisel

Energetic and Environmental Adequacy of Biomass Thermal Insulation Materials
Dragi Antonievic

Simulation in the Design of renewable Energy Systems with Storages
Walter Commerell

Integrated approach for Waste to Energy or Resources Recovery
Yves Andres

Alternative models for the new electricity market
Zsolt Bertalan

SESSION I – POWER GRID and ELECTRICITY MARKET

Effects of decreasing synchronous inertia on power system dynamics - review of country specific experiences and possible solutions
István Táczi, István Vokony, Bálint Hartmann

New wholesale market with flexibility services
István Vokony, Bálint Hartmann, Dániel Divényi, Péter Sőrés, Beáta Polgári

Smart power laboratory and real time simulator - tools for investigation of GRID integration issues
László Prikler

Mass 0.5 MW PV plant forecast
Bálint Olaszi

Development of a simulation framework for microgrid control algorithms
Bálint Hartmann, János Csatár, József Kiss, Bálint Sinkovics, Beáta Polgári

Integration of fuel cells with energy systems
Albin Zsebik

SESSION II - THERMODYNAMICS

How can thermodynamics contribute to numerical methods
Tamás Fülöp, Róbert Kovács, Mercédesz Vass, Mohammad Fawaier, Alex Szaller, Mátyás Szücs

Internal variables and phase fields
Péter Ván

A simple method to find new dry and isentropic working fluids for Organic Rankine Cycle
Attila Imre

Challenges in modeling of rarefied gases
Róbert Kovács

Irreversible thermodynamics in the GENERIC framework
Mátyás Szücs, Tamás Fülöp

TUESDAY, 28. MAY - MORNING

SESSION III – SUSTAINABLE PROCESSES I

Energy consumption and environmental impacts of primary aluminium production
László I. Kiss, Viktória B. Kovács

Economic load dispatch model of a Biomass Power plant
Axel Groniewsky

Analyses of waste heat generated through bioethanol separation process
Réka Kustán

Environmental assesment of wet biomass utilization for the product of renewable energy carriers
Dániel Fózer, Péter Mizsey

Improvement of the energy efficiency of acetone-butanol-ethanol distillation process
Ferenc Dénes, Paula Losa-Zapico

SESSION IV – SUSATAINABLE PROCESSES II

Alternative Mobility - Drive and Supply Concepts of the Future
Bodo Groß

Sustainability assessment of renewable energy in the European union with special attention to Hungary
Edit Cséfalvay, István T. Horváth

Identification and technical analysis of synergy potential of an innovative biocatalitic methanation process
Botond Sinoros-Szabó, Zoltán Csedő, Máté Zavarkó

A review on the applications of nanotechnology in solar energy: from mechanical and chemical engineering perspective
Samrand Saeidi, Gyula Gróf

Development of a flame image and deep learning based monitoring system for optimizing industrial scale, moving step grate biomass combustion
Attila Garami

SESSION V - IC ENGINES

Influence of increased pressure for over-expanded engine performance
Karol Grab-Rogalinski

Stability of deisel/ethanol combustion in dual fuel engine
Wojciech Tutak, Lukasz Nowak

R&D collaboration between industry and academic sector on combustion engines under the project Knocky-H2020-MSCA-RISE-2015
Stanislaw Swaja

Utilisation n-buthanol in compression ignition engines
Ákos Bereczky

SESSION VI – RENEWABLE ENERGY SOURCES

Ejector cooling machines powered by solar heat
Michal Masaryk, Peter Mlynar

Modelling of photovoltaic power plants
Martin Mayer, Gyula Gróf

The Future of Geothermal Energy
Gábor Molnár

Experiences of heat tranfer intensification in solar thermal collectors
Mahmoud Sharafeldin, Gyula Gróf

Thermal Performance simulation of the Parabolic Trough Collector under Radiation
Otabei Al Oran, Ferenc Lezsovits

TUESDAY, 28. MAY - AFTERNOON

SESSION VII – COMBUSTION TECHNOLOGY

Co-fluidization of biomass and waste particles with sand – an experimental study
Botond Szücs, Pál Szentannai

Designing a laboratory turbulent swirl burner for alternative gaseous and liquid fuels
Gyöngyvér Hidegh, Attila Kun-Balog, Krisztián Sztankó, Viktor Józsa

Approaches for Modeling Fluidized Beds of Energy Industrial Relevance – an Analytical Review
Mohamed Sobhi Alagha, Pál Szentannai

Environmental implications of a second MSW incineration plant in Budapest
Artúr Szilágyi

Surrogate mixture for modelling the vaporization process of multicomponent liquid fuel
Dávid Csemány, Viktor Józsa

SESSION VIII – HEAT TRANSPORT

Thermal transport properties of semiconductor superlattices: experiments and theory
Federico Vazquez

Numerical methods for heat conduction
Ágnes Rieth

Effect of the nanoparticles on boyling process
Mohammed Saad Kamel

Implementation of an excess Renewable Electricity to Heat Methodology using Raspberry Pi in an Energy System Demonstrator
Muthalagappan Narayanan, Walter Commerell

PLENARY SESSION (HUNGARIAN)

Innovációk finanszírozási és nemzetközi lehetőségei az energetikában
Dervalics Ákos

SESSION IX - LCA STUDIES

Comparative Eco-design Analysis of Old and New Generation Products in Terms of Energy Efficiency
Mónika Godó

Life Cycle Analysis of Wine Bottle
Zsuzsanna Bogóné Tóth

Environmental impacts of fresh milk processing: a LCA case study in Hungary
Júlia Gájer, Viktória Barbara Kovács

Life cycle assessment of household appliances in aspect of energy efficiency
Nóra Varga, Viktória Barbara Kovács

Carbon footprint analysis for the production of cooked eggs from different keeping
Viktória Kruppa

SESSION X - POSTER SESSION

Optimalization of a given dephlegmator by measurements, using thermal camera and simulation models, in the case of a pálinka distillation equipment
Ádám Virág, Zsolt Csendes, Tamás Laza

Time dependence of Thermodynamics
Mátyás Szücs

Effect of the nanoparticles on boiling process
Mohammed Saad Kamel, Ferenc Lezsovits

Loss of coolant accidents in the supercritical water loops of various Generation IV nuclear reactor types
Gábor Györke, Attila R. Imre