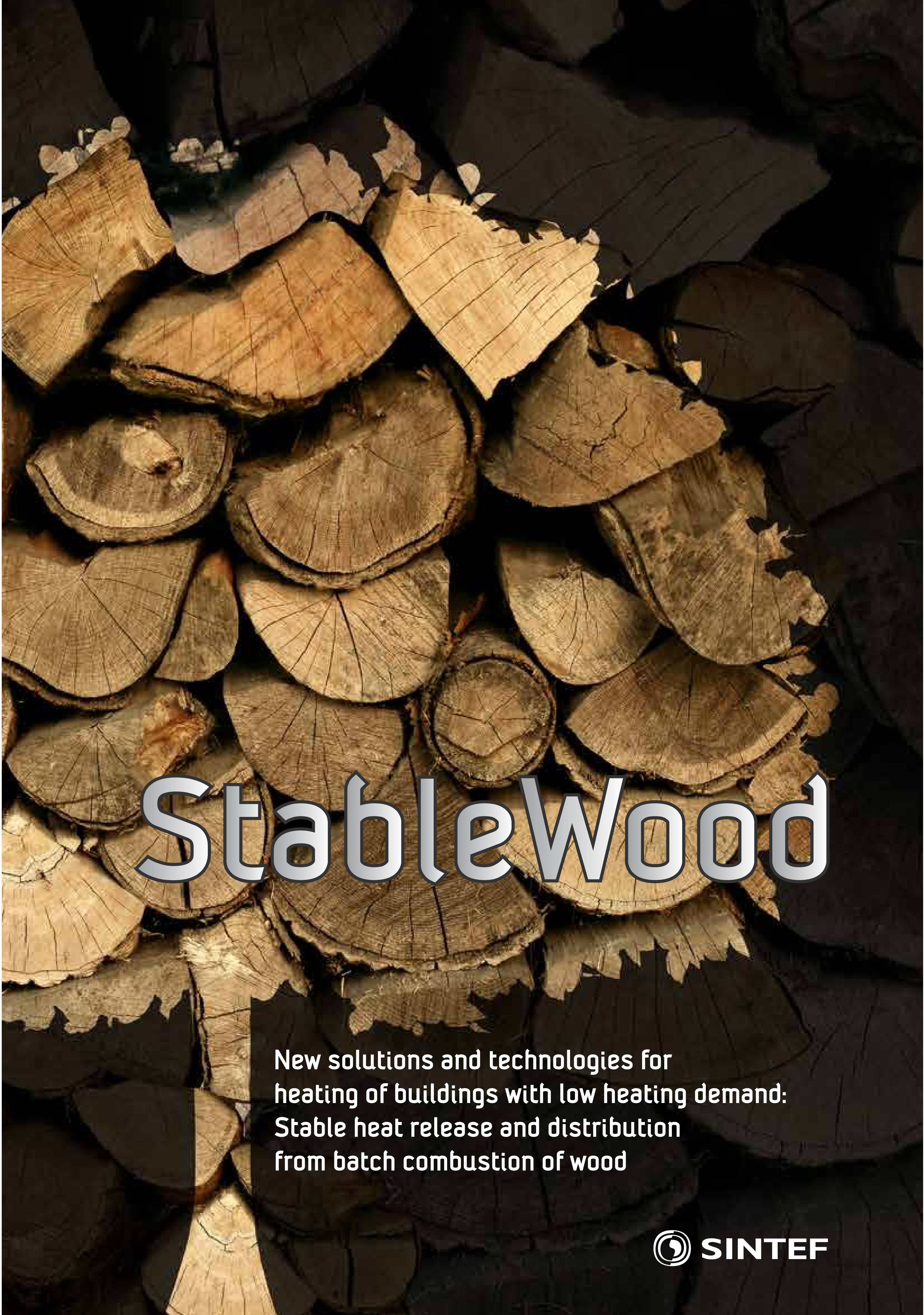

StableWood

New solutions and technologies for
heating of buildings with low heating demand:
Stable heat release and distribution
from batch combustion of wood

SINTEF

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New solutions and technologies for heating of buildings with low heating demand:
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Background

This handbook has been prepared by SINTEF Energy Research with the purpose to provide both partners of the StableWood project and others with a simple and easy to read guide on how the heating demand in the future low-energy and passive houses could be met using wood stoves.

The information in this handbook has mainly been obtained in studies performed throughout a 4-year project period in the competence building project entitled "StableWood – New solutions and technologies for heating of buildings with low heating demands: Stable heat release and distribution from batch combustion of wood". The project has been financed by the Research Council of Norway and four industry partners: Dovre AS, Jøtul AS, Morsø Jernstøberi AS and Norsk Kleber AS.

The overall objective of this project was:
Development of new strategies for improved heat production, storage and distribution from wood stoves and fireplaces through:

- Improved combustion control by increased understanding of the batch combustion process
- New heat storage solutions
- New heat distribution solutions

Through a combination of experimental activities, modelling and simulations, and feasibility studies, the research has focused on aspects that in the end are connected to emissions, efficiencies and the transient (a function of time) heat release from combustion of wood logs in wood stoves.

High efficiency stoves give colder flue gas

Wood stove history in Norway

When the first iron stoves came to Norway in the 1500's, these iron stoves connected to chimneys led to a new era within fireplaces and cooking, and the building tradition was significantly influenced. The production of iron stoves in Norway started in the 1600's, around the mid-1600's the demand for stoves was considerable, and during the 1700's the cast iron stove became the main heating source. The production of stoves is a very important chapter in Norwegian ironwork industry, and later also for the iron foundries. Iron stove reliefs are and have been an important contribution to Norwegian sculpture and applied art.

A short description of some major types of stoves from the very first iron stoves produced in Norway to today's stoves is given below.

Old buildings require wood stoves with high heat release

Box stoves

The first stoves were just a simple iron box, with a separate smoke pipe/tube. The stove was either fired through a stove door, similar to today's stoves or it was fired through the fireplace in the next room. The latter was commonly used until 1900.

Multiple hearth stoves came in the early 1700's for improved utilization of the wood and were very popular until around 1950. The stoves had a combustion chamber with one to four upper floors/chambers with gradually reduced sizes. A few models are still produced today.

Cylinder stoves for firing wood, coke or coal were introduced after 1850 and were produced for nearly 90 years. These stoves had the combustion chamber in the lower part with a door for lighting the fire, while there was a door for filling of solid fuel higher up.

Wood burning kitchen stoves with oven were introduced around 1850. The versions without oven were gradually developed with several common features with the multiple hearth stoves of the time.

In the 1930's the more simple wood stoves that could be used for combined heating and cooking gained popularity. They looked quite similar to the really old stoves. Some models were quite long in order to have more than one cooking plate, other models had multiple hearths.

In the late 1980's development of new concepts were addressed in order to make the wood stoves more environmentally friendly, user-friendly and cost-efficient. As a result, new stricter regulations on emissions from wood stoves were introduced 1 July 1998. In order to fulfil these regulations, most stoves are based on staged air combustion where the wood logs are gasified in the primary combustion zone and additional air is injected in a secondary combustion zone for complete combustion.

Residential buildings of the future

The introduction of low energy and passive houses is accelerating. This sets new requirements to future heating systems.

The term low energy building, or low energy house, is any type of house that from design, technologies and building products uses less energy, from any source, than a traditional or average contemporary house. In Europe it generally refers to a house that typically use 30 to 20 kWh/m² per year for space heating, but it also depends on the location. Below this the term ultra-low energy building or passive house is often used.

The term passive house refers to an ultra-low energy building that requires little energy for space heating or cooling. Its efficiency is based on the application of a super-insulated building envelope. For example, the passive house standard for central Europe requires that the building fulfills the following requirements:

- The building must be designed to have an annual (space) heating demand as calculated with the Passivhaus Planning Package of not more than 15 kWh/m² per year in heating and 15 kWh/m² per year cooling energy OR to be designed with a peak heat load of 10 W/m².

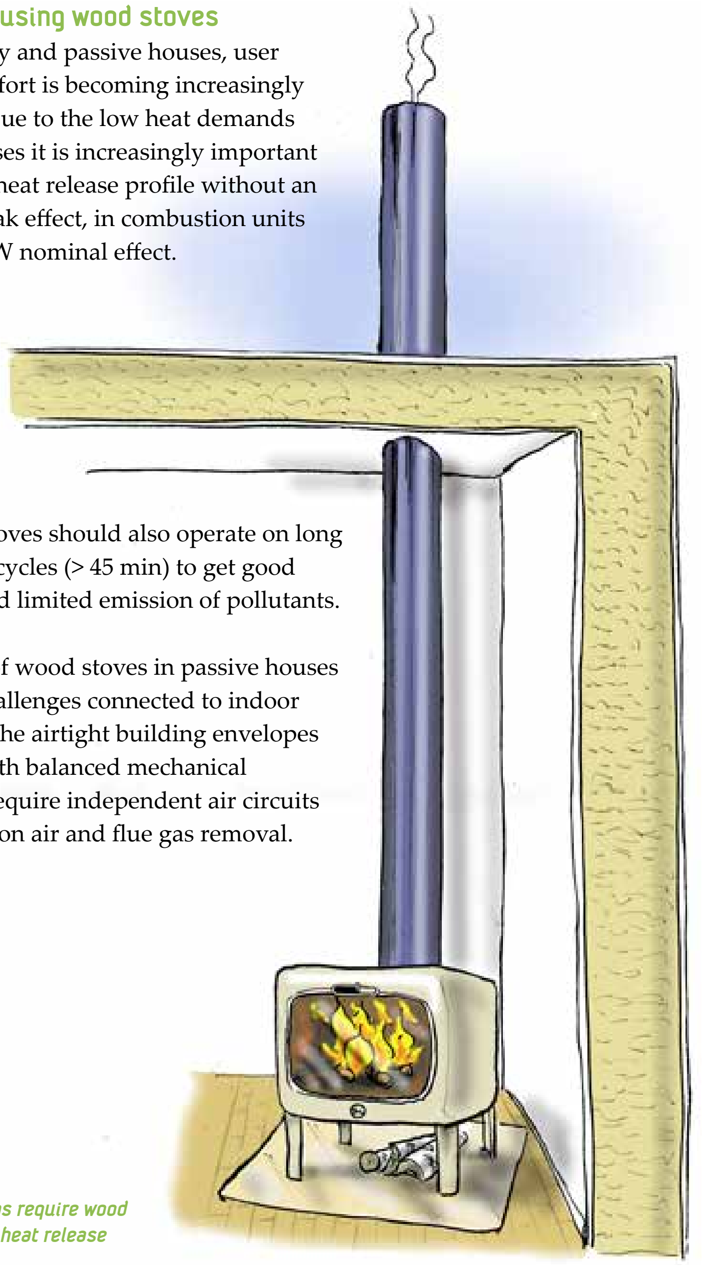
  An annual heating demand of 15 kWh/m² corresponds to 1500, 3000 and 4500 kWh for 100, 200 and 300 m², respectively. A peak heat load of 10 W/m² corresponds to 1, 2 and 3 kW for 100, 200 and 300 m², respectively.
- Total primary energy consumption (primary energy for heating, hot water and electricity) must not be more than 120 kWh/m² per year. This corresponds to 12000, 24000 and 36000 kWh for 100, 200 and 300 m², respectively.
- The building must not leak more air than 0.6 times the house volume per hour (n50 ≤ 0.6 / hour) at 50 Pa (N/m²) as tested by a blower door.

Challenges using wood stoves

In low energy and passive houses, user thermal comfort is becoming increasingly important. Due to the low heat demands of these houses it is increasingly important to achieve a heat release profile without an excessive peak effect, in combustion units down to 2 kW nominal effect.

The wood stoves should also operate on long combustion cycles (> 45 min) to get good efficiency and limited emission of pollutants.

Integration of wood stoves in passive houses also faces challenges connected to indoor air quality. The airtight building envelopes equipped with balanced mechanical ventilation require independent air circuits for combustion air and flue gas removal.



Modern buildings require wood stoves with low heat release

Emissions and efficiencies

Standardization progress & new requirements

Several standards and regulations setting emission measurement methods are currently aiming at significantly stricter emission limits for point source heating applications like wood stoves. The most important among these are the Ecodesign Directive, the European standard (CEN), The German DIN (Deutsches Institut für Normung) and DINPlus method, the German BImSchG (Bundes-Immissionsschutzgesetz) regulations as well as the Nordic Ecolabelling of stoves. A working group (LOT20) has been given a mandate to assess whether it is appropriate to set stricter Ecodesign requirements for energy efficiency and for emissions of particulate matter (PM), organic gaseous compounds (OGC), CO and nitrogen oxides (NOx). The Ecodesign requirements were recently approved in September 2014. The new requirements will be operative from 1 January 2022.

The new requirements for seasonal space heating energy efficiency for typical solid fuel wood stoves shall be no less than 65 %. The seasonal space heating energy efficiency shall be calculated as the seasonal space heating energy efficiency in active mode (based on the net calorific value of the fuel at nominal heat output) corrected by contributions accounting for heat output control, auxiliary electricity consumption and permanent pilot flame energy con-sumption.

When it comes to emissions of PM from closed fronted solid fuel local space heaters, these shall not exceed 20 mg/Nm^3 at 13% O_2 when measured with a heated filter (first meth-od/current European method) at nominal load as well as at part load if appropriate. When measured by the second method (Norwegian method), i.e. over the full burn cycle using natu-ral draft and a full flow dilution tunnel with particle sampling filter at ambient temperature, the requirements are 5 g/kg (dry matter). When measured by the third method (English meth-od), i.e. PM sampling over a 30 minutes period, using a fixed draft of 12 Pa and a full flow dilution tunnel as well as either a particle filter at ambient temperature or an electrostatic pre-cipitator, the requirements are 2.5 g/kg (dry matter). For OGC, CO and NOx the requirements are 120 mgC/Nm^3, 1500 mg/Nm^3 and 200 mgN/m^3 expressed as NO_2, all values taken at 13% O_2. Additional requirements for product information/ technical documentation have also been formulated.

The German DIN and DINPlus method and the BImSchG regulations are also currently being updated with significantly lower emission limits. The current particle and CO emission limits according to the BImSchG regulations is 75 mg/Nm^3 and 2000 mg/Nm^3, respectively. In 2015 the emission limits will be decreased to 40 mg/Nm^3 and 1250 mg/Nm^3, respectively. This means that stoves for the German market, although measured with a heated filter, must be able to cope with particle emissions of maximum 0.46 g/kg.

The Nordic Ecolabelling of stoves is a prominent label which normally also have separate emission limits incorporated from several standards/regulations and normally more stringent than the criteria given by these standards; Norwegian NS 3058-59 (particles), CEN/TS 15883:2009 (OGC) and EN 13240/13229 (CO). The emission limits for OGC, CO and particles are 100 mg/Nm^3, 1250 mg/Nm^3 and a weighted value based on 4 burn rates of maximum 2 g/kg and never higher than 5 g/kg for each individual test, respectively. The increased strin-gency of these European standards will at some point have to be reflected in the Norwegian standard. It is therefore expected that the Norwegian standard, NS3059, which have had the same emission limits since 1998, will have to tighten up its current weighted emission limit of 10 g/kg, possibly down to 2-5 g/kg. The maximum allowed emission of 20 g/kg will also probably have to be reduced with at least 50% or more, down to 5-10 g/kg. Emission limits for OGC and CO will also probably be included as provided by the new Ecodesign requirements.

Stoves approved for the Norwegian market, 1998-2014

The figure, illustrating the evolution of particle emissions from wood stoves approved for the Norwegian market, shows what has been achieved over the years, thanks to the close re-search/industry collaboration, in terms of wood stove emissions due to incomplete combustion in general. During the last 15 years, continuous improvements have resulted in wood stoves with much reduced particle emission levels, approaching 80-85% particle emission reduction compared to the current 10 g/kg dry fuel emission limit in NS3059.

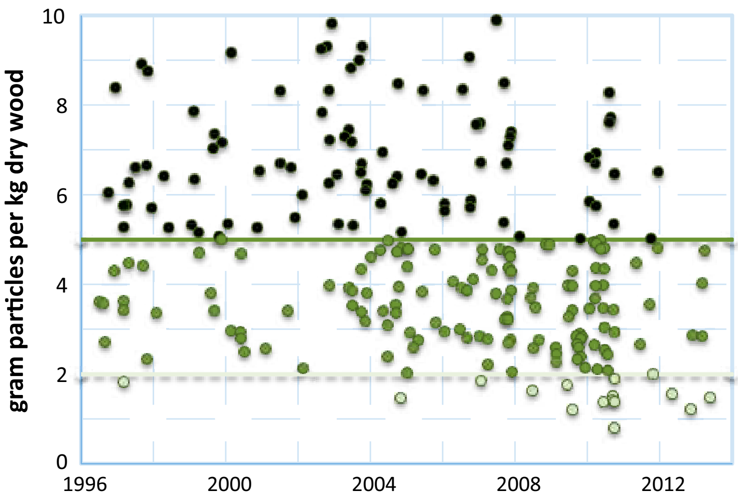
Due to increased stringency for both emissions and heat demand, new wood stoves must be developed that are able to operate at a significantly lower heating effect, with a much more constant heat release. Emissions must be reduced and stoves must be able to operate with a separate air intake and flue gas evacuation system with no risks of indoor smoke leakage.

Efficiency

The most important factors which affect the efficiency of a stove are the excess air ratio, the flue gas temperature and chemical losses due to incomplete combustion. Thermal efficiency will increase with decreasing chimney inlet temperature and excess air ratio. This means that at part load operation, i.e. below nominal effect and assuming an optimum amount of air, the efficiency will increase.

There seems to be a common misunderstanding regarding part load operation where it is believed that such conditions always leads to lower efficiencies. One example of this can be found in the latest Nordic Ecodesign 2014 guidelines where it stated that "low air intake can lead to poor combustion, high emissions and poor efficiency". That part load operation leads to higher particle emissions as compared to nominal operation has been known for decades. However, the negative effect on the efficiency, due to the chemical losses from poor combustion, is significantly smaller than the positive effect of lower part load flue gas temperatures for approved stoves; hence, an efficiency increase will occur for most wood stove configurations currently available on the market.

Evolution of particle emissions from wood stoves approved for the Norwegian market



The aim and content of the StableWood project

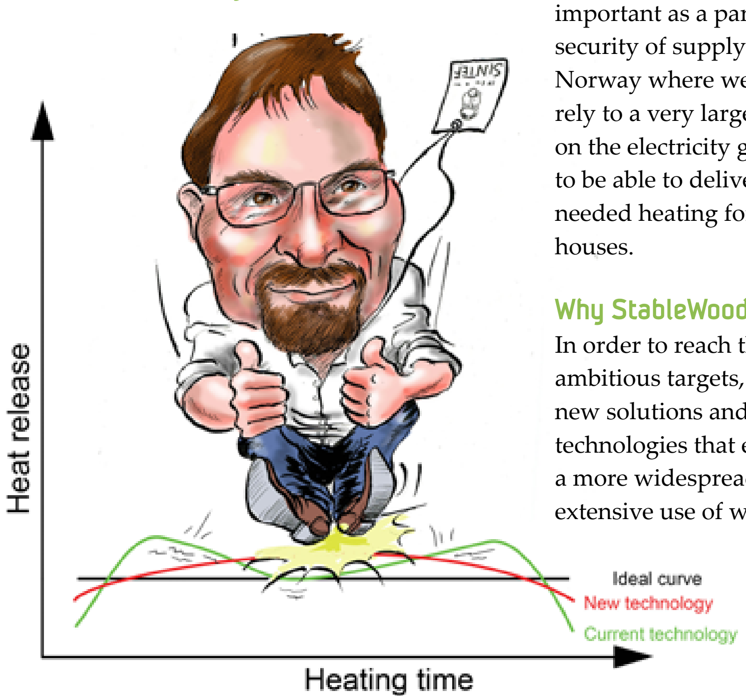
Why bioenergy

Several national strategies points out the importance of bioenergy in the future energy supply for Norway. The most important one is the ”Strategy for increased expansion of bioenergy (2008)” which states that Norway shall double the bioenergy production from 14 TWh (2008) to 28 TWh in 2020.

Why wood stoves

Wood log combustion has long traditions in Norway and constitutes as much as 50% of the current use of biomass for energy purposes. The national strategy mentioned, states that the major single contributor of new bioenergy production shall come from bioenergy use in small-scale heating appliances for space heating, meaning in practice the use of wood log combustion in wood stoves and fireplaces.

Stable heat release is the goal



Using wood logs is also important as a part of security of supply in Norway where we today rely to a very large extent on the electricity grid to be able to deliver the needed heating for our houses.

Why StableWood

In order to reach these ambitious targets, new solutions and technologies that enable a more widespread and extensive use of wood log combustion are clearly necessary. The heat released during combustion of one batch of wood varies significantly, and measures to flatten the heat release from wood stoves are required.

New houses as well as retrofit/upgrading of old houses have increasingly focused on improved insulation due to new regulations like the Norwegian passive house standard, the future TEK15 regulation and nearly-zero energy buildings in 2020. And hence, the heat release effect needed is reduced.

This call for new solutions and technologies that provide a stable heat release and distribution from wood log combustion at a heat release effect down to as low as 1 kW. These issues have been addressed in the StableWood project through focus on:

- Improved heat production concepts through improved combustion control (by increased understanding of the batch combustion process)
- New or improved heat storage concepts by optimum material location and choice, including phase transition and change options, and through room integration
- New or improved heat distribution concepts through optimum passive and active methods and through building integration

An optimum combination of these will give increased heat comfort and a more stable heat release at a lower heating effect, enabling the implementation in low energy and passive houses as well as extending the wood log heating season. This will be an important contribution to the national target; doubling of the bioenergy use in 2020.

Project achievements

State-of-the-art and initial evaluations

Initially, studies were carried out to establish the state-of-the-art related especially to aspects that in the end are connected to emissions, efficiencies and the transient (a function of time) heat release from combustion of wood logs in wood stoves. Additionally, principles and methods to ensure the thermal comfort of the user when relying on wood stoves as the primary space heating source in modern types of buildings were investigated.

Wood stoves for modern energy efficient buildings as low-energy and passive houses will benefit from a combination of improvements that satisfies the user's and building's need in the optimum way. Specifically, fuel properties and their influence on the batch combustion process, choice and use of wood stove materials and their thermal properties, passive and active heat distribution methods, as well as room and building integration options were investigated.

Research methods

Experimental activities

Experimental activities have been carried out to establish the performance of current state-of-the-art technologies and to further improve upon these, as well as investigate aspects connected to the operation of wood stoves in low-energy and passive houses, regarding both thermal comfort and indoor air quality.

Modelling and simulations

Combining the traditional experimentally based development with modelling for an improved understanding of the special wood log batch combustion process gives the possibility to accelerate the development speed in a cost-efficient manner. Therefore, StableWood has also had a focus on modelling of the wood log batch combustion process and its transient heat production and subsequent heat release to a room, and through that additionally contributing to the understanding of this special combustion process and how to control it in the best possible way. This provides guidelines for the industry in their efforts to produce improved wood stoves as well as how to operate them in an optimum (environmental, energetic, heat comfort) way.

Feasibility studies

Feasibility studies have been an integrated part of the work carried out in StableWood with respect to evaluating the feasibility of using phase change material (PCM), different material configurations, and applying different passive and active heat distribution solutions, as well as considering constraints imposed by building regulations. In the end both technical and economical feasibility are necessary.

Combustion performance of state-of-the-art wood stoves

During the last two decades, the combustion performance of wood stoves has been improved significantly, leading to substantially reduced emissions due to incomplete combustion and also improved thermal efficiency. This continuous development has primarily been experimentally based. Combining experiments with modelling in the effort of designing the downscaled wood stoves of the future and their stable operating conditions has a great potential.

Indoor air quality

In cooperation with a Danish research group, the indoor air quality (IAQ) performance of different wood log heating appliances installed in different low-energy and passive houses in Denmark and Norway have been investigated. Emissions into a room from the operation of a wood stove will to some degree happen, especially in a start-up-phase and when the stove is refilled. The goal is to minimize these emissions to ensure an optimum IAQ. Parameters of importance are the wood stove design, proper selection/ sizing and installation of the wood stove, and the operator of the wood stove.

Test standards for wood stoves

During the course of the StableWood project SINTEF Energy Research has as part of a continuous activity connected to standardization of approval tests for wood stoves participated in international standardization work as wells a in the development and testing of measurements methods to be introduced in updated standards.

A main focus from the Norwegian side is the preservation also in future standards of testing the part load performance. At part load operation, which is a common way of operating a wood stove in Norway due to a low heat storage capacity both for the typical cast iron or plate steel stoves and wooden buildings, emissions rapidly (exponentially) increase for poor wood stove designs, even if they are sufficiently clean burning at nominal load operation. Hence, it is essential to ensure a robust wood stove design that works well also at part load operation. This will also be a requirement for future's wood stoves in low-energy and passive houses, as a means to achieve a higher operational flexibility for covering the heat demand at a wide range throughout the heating season.

Transient conversion of wood logs

Modelling has been carried out with respect to the transient thermal decomposition of a single wood log and a batch of wood logs, as well as the transient combustion of a batch of wood logs. In such a modelling approach it is essential to establish with sufficient reliability the sub-models necessary (drying, volatiles release and char oxidation/ gasification) to describe the thermal decomposition and the combustion process at the various relevant operating conditions. Modelling of a wood log, which is a very thermally thick particle (with large internal gradients, e.g. temperature) is challenging, and modelling of a batch of wood logs even more so. However, this is important work in the development of future's cost efficient modelling tools for optimal design and operation of wood stoves.

Heat transfer and storage in composite walls

The heat released from the transient combustion process, the heat production profile, will to a large extent be transferred through the wood stove walls, giving a heat release profile to the room. Depending on the walls' properties, this will be a time-delayed heat release profile compared to the heat production profile. As the heat release profile in the end heavily influences the thermal comfort in a building, it becomes essential to investigate methods to both dampen the typical heat production peak effect and prolong the heat release time. In StableWood a composite wall model was established, where the effect of a heat production profile on the heat release profile could be studied for different material configurations, including the use of PCM (Phase Change Materials).

A PhD candidate has been financed by the StableWood project, with the specific task of investigating the applicability of using PCM

Thermal comfort depends on the choice of wood stove

to optimally control the heat release from wood stoves. A PCM has, through its phase change, the ability to store a large amount of heat at a constant temperature during the combustion process, when typically changing phase from solid to liquid. Many PCMs exist, but a number of factors, as the phase change temperature and heat storage capacity, need to be considered.

The phase change heat will be released at the same temperature when the stove is cooling down. This enables a very stable and significantly prolonged heat release, i.e. more controlled and reduced heat release.

It is a challenge to design solutions that work well at varying operating conditions as well as to ensure an optimum heat transfer to, and homogeneous heat storage in, the PCM. A PCM will irreversibly degrade when heated to a too high temperature. Hence, a key issue in the PhD study is to ensure that this will never happen, while optimally utilizing the installed heat storage capacity by phase change. The artificial sweetener Erythritol, a sugar alcohol, is maybe the most promising candidate tested for use in wood stoves.

Buildings integration simulations and experiments

In cooperation with FME Zero Emission Buildings, the effect of wood stoves in low-energy and passive houses on their thermal comfort was investigated through building integration simulations for various stove and building properties configurations, covering a wide range of stove-building configurations in different climate zones. The work clearly showed how wrong stove-building configurations would lead to unacceptable thermal comfort. However, it also showed that the proper configurations would lead to satisfactorily thermal comfort even in low-energy and passive houses.

Experiments have been carried out for verification of buildings integration simulations where the influence of different heat release profiles for stoves with different nominal effects operated at nominal and part load operation and applying different heat storage measures have been investigated. An electric wood stove was designed and constructed, with the aim of accurately following a pre-programmed temperature profile on each of its surfaces, simulating the actual temperature profiles during operation of a real stove. The electric stove was placed in a passive house and a measurement campaign was carried out where the thermal and flow conditions in the building were mapped for a large number of stove operating conditions. The buildings integration simulations carried out conformed well with the experimentally mapped thermal comfort picture.

CFD modelling

Computational fluid dynamics (CFD) simulations have the potential to incorporate all necessary physical and chemical processes going on in a wood stove during combustion of a batch of wood logs. In a CFD model the sub-models for the fuel can be combined with modelling of the gas phase combustion process involving the volatiles released from the fuel and their mixing with combustion air. In order to have reliable results, modelling of chemical kinetics and turbulence and their interaction, radiative heat transfer as well defining appropriate boundary conditions are essential. The chemical kinetics needs to be detailed enough to realistically represent the real combustion process. Especially if the goal is also to reduce NOx emissions, quite comprehensive detailed chemical kinetics is needed.

In StableWood an initial work on stationary CFD modelling of wood stoves has been carried out, where a full detailed chemical kinetics mechanism has been used, as well as reduced, yet detailed, chemical kinetics mechanisms derived from the full mechanism. An appropriate reduction level gave similar results as the full mechanism, making it possible to significantly reduce the computational time without significantly sacrificing accuracy of the results. For NOx emissions, the CFD simulations showed significant reduction of fuel nitrogen, released from the fuel as NH_3 and HCN, to molecular nitrogen, when applying staged air combustion. An optimum primary excess air ratio exists, giving the highest NOx emission reduction.

Recommendations

Based on the broad and comprehensive work carried out in StableWood the following recommendations can be given and conclusions can be drawn:

- Wood stoves for low-energy and passive houses needs to be downscaled (typically to 4 kW nominal effect and below) compared to today's typical wood stoves (of typically 8 kW nominal effect), without sacrificing environmental performance, but rather improving it.
- The StableWood project has generated a broad knowledge base and established guidelines and simplified tools to aid in the development of future's wood stoves for low-energy and passive houses.
- The negative effects of the unsteady and transient heat production profile in wood stoves can be reduced by applying the proper materials and material configurations to ensure a flattened heat release profile to the room.
- Also building architectonic measures should be sought to further improve the thermal comfort performance of wood stoves in low-energy and passive houses.
- Particle emission levels from wood stoves have continuously decreased after the introduction of a Norwegian test standard for approval testing of wood stoves. These levels will need to decrease further to improve the environmental performance of wood log combustion in stoves and conform to future's expected increasingly stricter environmental regulations.
- NOx emission reduction by staged air combustion can be applied also for wood stoves, however, the air distribution needs to be optimised to maximise the NOx reduction.
- An increased understanding of the transient combustion process in wood stoves should be sought, and should in the end be applied in a comprehensive CFD modelling tool for simulation of the combustion process, both transient and stationary simulations.
- A more concentrated effort is needed in the future on developing advanced modelling tools that together with targeted experimental work can be used effectively to design optimum environmental, energetic and user-friendly wood stoves that satisfies the thermal comfort demand of the user.
- In the end, wood stoves are not only a renewable space heating solution, but part of the Norwegian soul, and the flame picture and the crackling sound when the wood logs are burning are an important part of that. To be able to enjoy this and the heat comfort that wood stoves provide a chimney is essential!

The four industry partners,
their products and strategies

Norsk Kleber

Norsk Kleber builds upon centuries of experience in the development and production of genuine soapstone stoves and fireplaces. The company itself was founded in 1893, as a result of a professionalization / industrialization in which several small independent handcrafters merged into one company. Our goal is to keep alive and further improve century old and thoroughly tested traditions in the use of soapstone, and to combine these with modern Scandinavian design. We combine tradition and innovation with an eye towards functionality, quality and good design. Our products are exported to a number of European countries.

The future of genuine soapstone furnaces

The industry is facing strict regulations from the authorities at the one hand and needs for low energy output from end customers at the other hand. Our products are naturally optimally suited to satisfy these demands, since we develop and produce soapstone furnaces without iron or steel inserts. In this manner, the soapstone captures maximal heat from the fire in the most effective way. Consequently, the heat will be dissipated by convection and infrared radiation from the soapstone long after the fire is extinguished. This heat is experienced in much the same way as the warmth from the early morning – or late evening sun. Our stoves deliver warmth, because of their rather moderate size, rather quickly, and continue to do so for a considerable time. In other words: with our genuine soapstone stoves you generate warmth quickly, but not more than you need!

Cooperation with leading research institutions

Norsk Kleber only produces stoves and fireplaces that fulfill the strictest regulations regarding safety, environment and clean combustion. We continuously seek to improve the efficiency and the emissions of our stoves in close cooperation with qualified research partners, both nationally and internationally, in order to be able to maintain our position as one of the leading manufacturers of wood burning stoves in the world. Our participation in the StableWood project is central to this aim.

Morsø

The history of Morsø dates all the way back to 1853, and the company early became one of the leading iron foundries in Denmark. For generations, Morsø has supplied high quality wood-burning stoves made of cast iron. In 1915 the company was bestowed the prestigious title of Purveyor to the Royal Danish Court. The subsidiary company – Morsø UK was established in 2004 in Rugby, the United Kingdom. Today Morsø UK and the Danish mother company employ 93 people. In addition to the main markets in Denmark and the United Kingdom, Morsø exports to 32 different countries worldwide.

Main products

Over the years, Morsø has developed a broad range of products, which comprises both classical and modern stoves of cast iron or steel. Furthermore, Morsø distributes a diverse range of accessories, including fire tools and hearth plates.

In 2011 Morsø increased its product range and included a new outdoor concept, which consists of outdoor ovens, grills and cast iron cookware bringing comfort into the garden.

Morsø has always led the way in both new designs and new ways of combining form and function with environmental awareness. The wood-burning stoves developed meet some of the strictest environmental standards in the world. In particular, they meet the Norwegian Standard, which sets out stringent requirements on minimising particle emissions. Most Morsø wood burning stoves are certified by the Nordic Swan Eco-label. This does not only prove the stove's minimal impact on the environment when operating, it also highlights the minimal environmental impact caused by the actual production and packaging.

Future development

Morsø has always been at the forefront when it comes to environmentally friendly combustion, especially in the field of low emissions. Morsø constantly seek to improve its knowledge in order to develop high quality wood burning stoves with the best possible combustion systems providing use-value to the consumer.

For Morsø the StableWood project has been inspiring and proved constructive, particularly due to the composition of its member including both researchers and professionals from recognized companies. The StableWood project has taken concrete steps in order to meet the most stringent requirements of future wood log combustion.

By appointment to The Royal Danish Court

morsø

Dovre

Dovre is the world's oldest manufacturer of fireplaces, established in Ulefoss, Norway, in 1933. Dovrepeisen obtained 50 years world wide patent for the unique convection heating system which gave a completely different and significantly improved distribution of the heat. The principle is still used by several manufacturers all over the world. Dovrepeisen was a success both in Norway and in Europe.

In 1981 the capacity at Ulefoss became too small and the production was moved to Weelde in Belgium, and Dovre has developed into a large and modern manufacturing company with one of Europe's largest foundries. Products made by Dovre are sold all over Europe, in the Far-East and Asia.

In 1991, Dovre introduced a new generation of stoves - the clean burning system. This double combustion system ensured a substantial increase in the energy efficiency and a reduction in wood consumption of almost 40% could be achieved, compared to the old stoves.

Development of new products

Dovre is continuously working on product development, in order to be in the forefront regarding further development of existing and new internal combustion systems as well as new solutions for heat storage and heat distribution, which have been research topics in the StableWood project. The fact that we have been a leading supplier and a driving force of combustion technology since 1933 both inspires and commits our work.

Dovre's vision is to be a leading supplier of new technology. The goal is that the new technology is in the forefront of environmental requirements given by national and international authorities, ensuring that we are a driving force in the development of combustion systems. We are also a prime mover (pushing) for more stringent environmental requirements in general.

Todays and future houses need less energy than before. In order for Dovre being a fireplace and wood stove supplier to these houses, development of fireplaces and wood stoves that provide less effect directly to the rooms, as well as store any excess heat that can be utilized later, are needed.

The collaboration with SINTEF Energy Research and the support from the Research Council of Norway has contributed to a more cost efficient and less labor intensive development of new combustion systems. We are proud of the results we have achieved together, the collaboration has given motivation, inspiration and new knowledge in our development of new combustion systems.

Jøtul

Jøtul has a more than 160-year-long history. In 1853 Oluf Onsum founded Kværner Jernstøberi at Loelva east of Kristiania, now Oslo. Kværner started as a manufacturer of cast-iron goods, where cast-iron stoves were one of the most important products. In the years leading up to 1900, the company established one of the largest stove foundries in Norway. In 1916 the stove production was sectioned out from Kværner Brug. The company received its present name, Jøtul, in 1935.

A new era, with international focus, started in 1977 when the company was sold to Norcem. In the 1980s, additional steps were taken to expand globally through a number of acquisitions of foundries and import companies in the US and Europe. Today Jøtul has the world's largest distribution network for stoves and fireplaces, 43 countries, and is one of the highest sought after brands in the stove and fireplace industry.

The Jøtul Group today

Jøtul develop, manufacture, market and sell our products under brand names Jøtul, Scan, Atra, Warm and Ild. Our products are based on Nordic heritage and expertise focusing on environmentally conscious processes during production and daily use. Jøtul Group has approximately 640 employees and an annual turnover of approximately 838 MNOK. The production takes mainly place in Fredrikstad, Odense and Portland.

New challenges

In the last years there has been an increasing demand for stoves with low output due to better insulated buildings with very low air leakage and low heating needs. The focus on particle emissions is also increased, and there have generally been higher demands for stoves with high efficiency and low emissions.

New combustion technology and new ways to store and distribute the heat are required in order to meet these new challenges. Our involvement in the StableWood project was a result of these needs.

The StableWood project has brought us closer to a realistic computer simulation of the batch combustion process, which will be a very effective tool for optimizing the stoves. The project has also given very important knowledge on heat storage and distribution in modern buildings. New stoves in development already take advantage of some of the knowledge aquired in the StableWood project.

Publications

Journal publications

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StableWood

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Research partners: SINTEF and NTNU

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