SusWoodStoves – Sustainable wood stoves through stove, building integration and value chain optimisation

Newsletter 2-2023

Progress in 2023

In 2023 the focus has been on assessment of emissions and energy efficiency performance of the modern wood stoves and based on this establishing revised emission factors for this category of wood stoves. In addition, the effect of variations in different fuel and operational parameters (primary measures) have been investigated in additional experimental campaigns. The results show, after testing a representative selection of today's new wood stoves, that they are much better than the wood stoves that were new two decades ago. Also, primary emission reduction measures to further decrease the emission levels are possible as well as energy efficiency increase by improved operation and control. Further work has focused also on secondary emission reduction measures. The PhD study on advancing methods for climate change and air quality impacts in LCA is progressing well and the PhD study on data-driven analysis of the real building performance using wood stoves as well. Overall, the project activities are well on their way.

Main project findings so far

1) Today's new wood stoves are much better than the wood stoves that were new (and also based on the staged air combustion principle) two decades ago
2) Emissions of unburnt species have been much reduced, contributing to reduced climate impact and health effects of residential wood burning
3) At the same time the energy efficiency of today's wood stoves has increased, being typically 80%
4) Primary measures like automation of the air supply positively influence the performance of wood stoves, and reduces the possibility for the user to negatively influence the stove performance
5) Even though secondary emission reduction measures are possible, main focus should still be on improved primary measures and new stove designs and concepts, from a cost perspective
6) New stove concepts are also needed to significantly reduce black carbon emissions, and NOx emissions

SusWoodStoves workshop and Steering Committee meeting

The fifth workshop and SC meeting were arranged in Fredrikstad, 7-8 December 2023. This was the fourth physical consortium meeting in the project, with many interesting presentations and discussions on the workshop agenda, and the event was hosted by Jøtul, who also arranged a tour of their facilities.

Workshop participants looking at the new Jøtul Zensoric digital wood stove.

PhD work 1

The PhD position in data-driven analysis of the real building performance using wood stoves, filled by Abolfazl Mohammadabadi, is progressing well. The position is connected mainly to SusWoodStoves SP2. Associate Professor Laurent Georges at NTNU is his main supervisor, while Chief Scientist Øyvind Skreiberg at SINTEF Energy Research is co-supervisor. Abolfazl recently published a blog article

- a Knowledge-building Project for Industry (KSP-K) co-funded by the Research Council of Norway through the ENERGIX-programme.
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about his work: Wood Stoves for Cutting Electricity Costs and Preventing Unnecessary Expansions of the Electricity Grid (Bruk av vedovner for å redusere utgifter og forhindre utvidelse av strømnettet). He has now also published his first scientific article: Measurement of the Wood Stove Impact on the Electric Power Consumption of a Norwegian Detached House.

PhD work 2

The PhD position in advancing methods for climate change and air quality impacts in LCA, filled by Sofie Sødal Eiksund, is progressing well. The position is connected mainly to SusWoodStoves SP3. Professor Francesco Cherubini is her main supervisor, while Chief Scientist Øyvind Skreiberg at SINTEF Energy Research and Researcher Marcos Djun Barbosa at NTNU are co-supervisors. Sofie published a blog article about her work in 2022: From cozy woodstove to sustainable and healthy woodstove technology.

SusWoodStoves active in knowledge dissemination through blogs

Several SINTEF blogs have been published during the course of the SusWoodStoves project, for knowledge dissemination to the general public. The blog topics have covered the 1) proper wood stove selection for your house, 2) info on wood logs and why you should not use wood briquettes instead in your wood stove, 3) maintenance of wood stoves, including the chimney, and 4) emissions from wood stoves. These blogs have been published in Norwegian, but English versions of three of these are also available: (no. 1) How to choose the right wood-burning stove for your home, (no. 2) Everything you need to know about wood logs and wood briquettes, (no. 3) How to look after your wood-burning stove.

A blog in English, The 10 commandments of wood burning stoves (Vedfyringens 10 bud), that was first published before Christmas in 2021, was republished before Christmas in 2022, and received a lot of attention, especially from people in UK and Ireland. This big interest in wood stoves, which continues in 2023, is a clear signal that the European energy crisis was, and continues to be, economically very serious for many, and also that people consider energy security as more important now.

SusWoodStoves at Energy Informatics.Academy Conference 2023

A work entitled "Measurement of the Wood Stove Impact on the Electric Power Consumption of a Norwegian Detached House" was presented at Energy Informatics.Academy Conference 2023, 6-8 December 2023, Unicamp, Campinas, Brazil.

A corresponding article has been published in proceedings. The abstract is given below:

"Wood stoves are commonly used as space heating systems in Norwegian houses. However, the specific impact of wood stoves on electric power remains relatively unexplored and is investigated in our study. We also aim to reveal the coincidence between the wood stove operation and the use of electric appliances during the different hours of the day, as it directly impacts the total electric power of the dwelling. Detailed field measurements have been performed in a detached house equipped with a wood stove and electric radiators in the cold climate of Trondheim, Norway. As expected, the use of the wood stove leads to a significant reduction of the space-heating power. However, as wood stoves are operated manually, there are still periods when the electric radiators are operated at maximum power. Nevertheless, we discovered a positive correlation between the usage of the wood stove and electric appliances. It means that when occupants are active, they extensively use their electric appliances and are more likely to use the wood stove simultaneously. Consequently, the peak power of electric appliances does not coincide with the peak power of the electric radiators so that total electric power of the dwelling is reduced by using the stove."

SusWoodStoves at the 2nd International Conference on Energy, Environment & Digital Transition

A work entitled Emission levels and emission factors for modern wood stoves was presented at the 2nd International Conference on Energy, Environment & Digital Transition (E2DT), Palermo, Italy, 22-25 October 2023.

The measurements carried out in this work made it possible to provide emission factors for the modern wood stove category, for a wide range of emission compounds.

A corresponding article has been published in proceedings. The abstract is given below:

"The aim of this work is to recommend more correct emission factors for the modern wood stove category, based on extensive measurements carried out at SINTEF Energy Research in Norway for representative modern wood stoves. Today the best wood stoves outperform the staged air combustion wood stoves introduced in the 1990s, as further continuous improvements have been carried out and new and improved designs have been introduced. Hence, in national emission inventories this should be considered, so the mean emission factors used for the overall modern wood stove category reflect the continuous improvements over the last decades. The

measurements carried out in this work made it possible to provide such emission factors for the modern wood stove category, for a wide range of emission compounds. The results show that most emissions of unburnt have been much reduced the last decades. However, for black carbon and for emissions due to minor and trace elements in the wood, this is not the case. Further targeted development and/or new combustion concepts are needed to significantly reduce both black carbon and NOx emissions."

Comprehensive experimental results are now available from the SusWoodStoves project, showcasing the continuous technology improvements, resulting in reduced emissions and increased energy efficiency, that have been achieved by the wood stove producers the last decades, and additional improvements that can be achieved if operating the stoves correctly and by automating the combustion air supply.

SusWoodStoves at 16th International Conference on Chemical and Process Engineering

A work entitled "Energy Efficiency Increase by Improved Operation and Control in Wood Stoves" was presented at 16th International Conference on Chemical and Process Engineering (ICheaP16), 21-24 May, Naples, Italy.

The presentation highlighted the in general high energy performance of new wood stoves and pointed towards possible measures for further enhancement of the energy performance.

A corresponding article has been published in proceedings. The abstract is given below:

"The purpose and novelty of this work was to evaluate both the total and the transient energy efficiency of three types of modern wood stoves based on experimental results at different loads and elaborate on the level of energy efficiency increase that can be achieved by improved stove operation (user-controlled) and control (by design or automation). The experimental results show that the energy efficiency for modern wood stoves is around 80%, which is much higher than for old wood stoves due to improved stove designs and better combustion process conditions. This gives much reduced emission levels, contributing to a higher combustion efficiency, improved mixing conditions reducing the excess air need and improved heat exchanger designs reducing the chimney inlet temperature, both increasing the thermal efficiency. However, there is a significant improvement potential through further improved combustion control and stove operation, reducing the negative effects on emissions and efficiencies of the crucial period after igniting a new batch and in the final part of the char burnout. Improved heat exchanger designs and increased heat storage capacity will further increase the thermal efficiency. The total (stove) efficiency has the potential to approach the efficiency of pellets stoves."

SusWoodStoves at 16th International Conference on Chemical and Process Engineering

A work entitled "Reducing emissions from current clean-burn wood stove technology by automating the combustion air supply and improving the end-user interaction – two important primary measures" was presented at 16th International Conference on Chemical and Process Engineering (ICheaP16), 21-24 May, Naples, Italy.

The presentation highlighted that primary emission reduction measures to further decrease the emission levels are possible, such as automatic air-control, and that in general similar emission levels are found for emissions of unburnt independent of the wood species used.

A corresponding article has been published in proceedings. The abstract is given below:

"The current work concerns two of the most important primary measures to reduce emissions from small scale appliances for space heating; improvement and optimization of current technology and user behavior, where the latter is related to the effects of the ignition procedure, fuel quality and type, and amount of wood when loading and re-loading. Air-control both concerns user behavior and technology improvement. A recently developed in-house automatic air-control system was compared to manual operation. The ignition procedure is important and affects the quality of the combustion, not only for the ignition period itself but also for the subsequent burning periods. Two self-defined categories of primary measures were studied, primary measure A and B, as PMA (automated air flow) and PMB (manual operation varying the ignition procedure, wood specie, amount of fuel, log size and moisture content), respectively. Woodstove testing in our laboratory showed that for emissions related to primary measures, PMA, automating the combustion air reduced the particulate matter (PM) with 66% applying the Norwegian test method. Using the European test method, automation increased the efficiency with 8% and decreased PM, CO, and Organic gaseous compounds (OGC), with 12%, 34% and 55%, respectively. Comparing nominal and high fuel loads with birch, at low burn rates, automation reduced PM and CO with 4% and 61%, respectively, for a fuel load of 1.2 kg. For a 1.8 kg fuel load, automation resulted in even higher reductions in PM,

CO and OGC of 68%, 52% and 82%, respectively. Automation also substantially decreased CO (70%) emissions when burning briquette presses. The effect of end-user operation as for the ignition from cold stove, and use of fuel with varying properties, as in PMB, showed significant variation in emissions over the ignition period. Good ignition, when firing according to the Norwegian standard, can be achieved repeatedly by assuring that the fuel catches fire before closing the door and/or reduce the primary/secondary air flows. Bad ignition due to over-/under firing and dense stacking, can produce at least twice as much PM and CO and 3-4 times the OGC, compared to correct ignition. No significant differences in emissions were found when comparing birch, spruce, and pine, for wood with equal moisture content. However, burning pine, showed higher emissions of total carbon particles, as elemental and organic carbon, on the same level as with poor ignition."

Other news

Standardisation work

In November, the standard series EN-16510 was finally harmonized for roomheaters fired by solid fuels. That includes a two-year transition period between the new and old standards. Work on this standard started more than ten years ago. Its major drawback is that it includes the EN-PME methods that only samples solid particles, which are only a fraction of the total particulate emissions. It also only tests a single heat output in contrast to the previous Norwegian method which measured also condensed particles and at different heat outputs. The same emission limits as in Ecodesign are included in EN-16510. The gain of the standard series is that it requires testing by an accredited test laboratory in opposite of Ecodesign. Ecodesign for local space heaters fired with solid fuels started also its revision this year. A report about the situation of wood heaters in Europe was made by a Danish consultant addressing disadvantages of EN-16510, such as testing with little fuel and only testing one single heat output.

Experts from Switzerland have started the process of establishing a new project to develop the "Next Generation Particle Measurement method (NG-PMM)" gathering several researchers from all over Europe. The focus is on emissions from wood heaters regarding health relevance and comparability with ambient air measurements. The second workshop was arranged in September with experts both on small scale wood combustion and emissions to air. The project start is planned in 2024/25 depending on national funding.

Franziska Kausch and Morten Seljeskog at SINTEF Energy Research are representing Norway in wood stove testing standardisation work.

Wood stoves sales are normalising

High energy and electricity prices due to the unrest in Europe led to a boom in the sale of wood stoves in Norway, and the wood stove producers faced the challenge of producing stoves fast enough, and on average there was a significant waiting time for those wanting to buy a modern clean burning and energy effective wood stove. The wood stoves sales are now normalising.

In addition to being the main heat source for many, wood stoves are an important security of supply backup for many more. When the electricity price goes through the roof, as it more frequently does in parts of Norway since we are part of the European electricity market, people tend for economic reasons to use more wood logs and less electricity for heating. This also results in a higher demand for wood logs and the suppliers have problems satisfying the demand, even if also the wood log price becomes higher. With heating oil being banned for space heating in Norway, the only real alternative to electricity for houses not connected to a district heating grid, is in fact wood stoves, which are completely dominating when it comes to non-electricity based space heating in Norway.

IEA Task 32 Biomass Combustion

A new IEA triennium (2022-24) has now started, and a number of new activities were planned in Task 32. There will be a focus on wood stoves also in this new triennium. Planned activities are:

- Substitution of fossil fuels in industry – case stories
- Overview of carbon capture connected to biomass combustion: technical options including small scale, systems and case stories
- CO_2-neutrality and sustainability of biomass combustion
- State-of-the-art of low emission biomass combustion for district heating plants
- The nitrogen cycle for biomass combustion plants
- State-of-the-art of residential biomass boiler systems
- Workshop on residential biomass combustion
- Strategies for reducing the impact on air quality from small scale wood combustion

The main activities in the previous triennium (2019-21) were:

- Workshop on improved combustion in stoves and small biomass boilers

Finalized or to be finalized in the new triennium:

- Advanced test methods for pellet stoves

- Technical guidelines for the design of low emission wood stoves
- Inventory of national strategies for reducing the impact on air quality from residential wood combustion
- Biomass for process heat in industry

Moved to the new triennium:
- Workshop on experiences with combustion of pulverised non-woody solid biofuels
- Workshop on experiences with wood chips for large scale CHP production

Earlier, relevant deliverables were:
- Aerosols from biomass combustion
- Advanced test methods for firewood stoves
- Particle emission measurement techniques
- State of the art on innovative CHP concepts
- Strategic study for renewable heat
- Bioenergy for heat - the Hot Cases
- Workshop on Solid Recovered Fuels
- Workshop on Biomass Combustion Generated Nanoparticles
- Workshop on New Emission Measurement Methods

One recent and interesting task event regarding wood stoves was a webinar entitled "Residential Wood Combustion – Towards Low Emission Systems" arranged for presenting the upcoming task report (now published) with the title "Technical guidelines for the design of low emission wood stoves".

For information about IEA Bioenergy Task 32 activities, see the webpage and newsletters, and for IEA Bioenergy news, see the newsletters. Øyvind Skreiberg from SINTEF Energy Research is the Norwegian participant in IEA Bioenergy Task 32.

IEA Bioenergy publications/resources

Some recent publications:
2021 country reports on implementation of bioenergy, here, including for Norway.
Approaches to sustainability compliance and verification for forest biomass, here.
WS27 Summary Report: Bioenergy and Sustainable Development – Climate Change Mitigation and Opportunities for Sustainability Co-Benefits, here.
Land use for bioenergy: synergies and trade-offs between Sustainable Development Goals, here.
How can biomass supply for bioenergy deliver multiple benefits and contribute to sustainable development goals?, here.
IEA Tracking Clean Energy Progress – biofuels/bioenergy, here.
Sustainability governance of bioenergy and the broader bioeconomy, here.
Applying a science-based systems perspective to dispel misconceptions about climate effects of forest bioenergy, here.
Bioenergy for climate change mitigation: Scale and sustainability, here,
The role of bioenergy for climate and sustainable development targets, here.
Campaigns questioning the use of woody biomass for energy are missing key facts, here.

IEA publications

Some recent publications:
Net Zero Roadmap - A Global Pathway to Keep the 1.5 °C Goal in Reach - 2023 Update, here.
How bioenergy contributes to a sustainable future, here.
Net Zero by 2050 - A Roadmap for the Global Energy Sector, here.
Energy Technology Perspectives 2023, here.

EERA Bioenergy – SP4 Stationary Bioenergy

In 2020 an updated Strategic Research and Innovation Agenda (SRIA) was made for the whole EERA Bioenergy, and it serves as a guiding document for the EERA Bioenergy activities. For more info on EERA Bioenergy, visit the website, and see the newsletters. Berend Vreugdenhil from TNO in The Netherlands is the leader of SP4 Stationary Bioenergy in EERA Bioenergy.

RHC technology and innovation platform

The European Technology and Innovation Platform on Renewable Heating & Cooling (RHC-ETIP) brings together stakeholders from the biomass, geothermal and solar thermal sector - including related industries such as District Heating and Cooling, Thermal Energy Storage, Hybrid Systems and Heat Pumps - to define a common Research, Development and Innovation strategy for increasing the use of renewable energy technologies for heating and cooling. Previously concrete work has been carried out by the Biomass Panel in the RHC-ETIP connected to giving input to the SET-plan issues paper on renewable fuels and bioenergy, as well as work connected to the Implementation of the biomass technology roadmap of the Biomass Panel. The aim of the latter was to update the progress in R&I priorities identified by the Biomass technology roadmap. This work continues through different efforts. Øyvind Skreiberg from SINTEF Energy Research is a member of the Biomass Panel Steering Committee.
For the three years period 2019-21 there has been a special focus on work to be carried out in horizontal working groups (HWG) that focus on contributing to 1) vision (finalized in 2019), 2) research and innovation priorities (finalized in 2020) and 3) deployment and implementation strategy (in 2021) documents. Øyvind Skreiberg has chaired the HWG 100% Renewable Buildings, where a number of members from the different RHC-ETIP panels have contributed to the

HWG. The work progressed well and HWG 100% Renewable Buildings submitted in 2019 their contribution to HWG Vision 2050, which finalized the Vision 2050 based on input from all the HWGs, including also 100% Renewable Districts, 100% Renewable Cities and 100% Renewable Industry. In 2020, focus was on defining research and innovation priorities, and a Strategic Research and Innovation Agenda (SRIA) was finalized. In 2021, the focus was on developing an Implementation and deployment strategy, where a co-creation workshop was arranged dedicated to industry and research experts as well as public authorities, to identify and verify research & innovation trends and priorities of renewable heating and cooling sectors recently. The Implementation and deployment strategy has been finalized.

A three year continuation project financed by the EU started in 2022, enabling a continued effort led by the RHC-ETIP secretariat, assisted by the technology panels and the horizontal working groups, towards increased use of renewable heating and cooling in Europe. The first HWG 100% Renewable Buildings meeting of the continuation project was arranged May 3 via Teams, and the second meeting was arranged September 11. A link towards the SET-Plan Action 5 has now been established.
As a continuation of the SET-Plan work, workgroups were established to provide specific input to the SET-Plan work, e.g. Action 5 Energy Efficiency in Buildings with the sub-action 5.2 Heating and Cooling Technologies for Buildings and Action 8 Renewable Fuels and Bioenergy. The work and an endorsed implementation plan were finalized. Øyvind Skreiberg was involved in the Action 5 work, representing the Biomass Panel. The work is now continued, focusing on the implementation of the SET-Plan, both for Action 5 and 8.
Recently, a website was established for the Action 5 on buildings.

See the RHC-ETIP news webpage for other news.

Recent events

ICheap16, 21-24 May 2023, Naples, Italy. https://www.aidic.it/icheap16/

31st European Biomass Conference & Exhibition, 5-8 June 2023, Bologna, Italy. + e-conference
http://www.eubce.com/

E2DT, 22-25 October 2023, Palermo, Italy. https://www.aidic.it/e2dt2023/

Ren Luft Konference 2023, 2 November, Aarhus, Denmark, https://www.teknologisk.dk/kurser/ren-luft-konference/k91208

Energy Informatics.Academy Conference 2023, 6-8 December 2023, Unicamp, Campinas, Brazil, https://www.energyinformatics.academy/eia-2023-conference

Upcoming events

IConBM2024, International Conference on BIOMASS 19-22 May 2024 Palermo, Italy, https://www.aidic.it/iconbm2024/

IEA Bioenergy events.
https://www.ieabioenergy.com/iea-bioenergy-task-events/

32nd European Biomass Conference & Exhibition, 24-27 June 2024, Marseille, France.
http://www.eubce.com/

Links (click on the links or logos to get there)

WoodCFD
SKOG22
Energi21
Renewable Heating and Cooling ETIP
EERA Bioenergy
IEA Task32 Biomass Combustion
IEA Task45 Climate and Sustainability Effects of Bioenergy within the broader Bioeconomy

Project information and past achievements

About the project

The overall objective is sustainable wood stoves through stove, building integration and value chain optimisation.

The sub-objectives are:

1. Speciation and quantification of particulate and gaseous emission levels from wood stoves for representative stove technologies and operating conditions
2. Reduction of climate and health related emission levels through emission reduction and energy efficiency measures
3. Optimum building integration of stoves
4. Assessment of value chain performance of existing and improved stove technologies and connected systems for different stove-building configurations in Norway
5. Techno- and socio-economic assessments of the current and future role of wood stoves in the Norwegian energy market
6. Development of a roadmap for sustainable wood stoves in Norway
7. Education of highly skilled candidates within this area and training of industry partners
8. Monitoring of activities and state-of-the-art within this area and dissemination of knowledge to the industry partners, and other interested parties when applicable

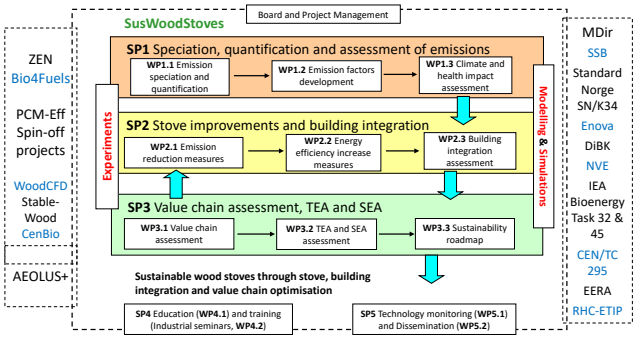
Previous projects have increased significantly the knowledge about wood log combustion in stoves to enable improving wood stoves with respect to emissions and energy efficiency, as well as combustion stability and optimum room and building integration. However, to ensure a sustainable wood stove future both in the existing building stock and the residential buildings of the future, further knowledge building within emission reduction, energy efficiency increase, proper building integration, and value chain, techno-economic and socio-economic assessments is needed. This will secure the continued use of wood stoves as an important, comfortable and sustainable heat source in the existing building stock (replacing old/poor stoves) and the residential buildings of the future, providing also substantial socioeconomic benefits. Therefore, SusWoodStoves is established, and is working according to the following hypotheses:

1. The best wood stoves today are much better than some emission factors for new wood stoves in the Norwegian emission inventory indicates - still, they can be significantly further improved (reduced emissions, increased efficiency) by better understanding and controlling the wood log combustion process
2. Proper wood stove design and material choices can much reduce the influence of the typical heat production peak on thermal comfort
3. Wood stoves have the potential to be suitable for heating any kind of residential building if properly designed, sized, selected, installed and operated
4. The best wood stoves have a natural place in a sustainable future
5. Further improvements can be shaped in such a way to maximize benefits for climate change and health, increase the overall sustainability performance of the wood stove value chain in Norway, and make a quantifiable step forward in the country transition to a sustainable bioeconomy

The methodology chosen to address the project objectives and hypotheses are based on:

1. Collection and assessment of existing data
2. Laboratory experiments to provide additional needed data
3. Field measurements and questionnaires to collect end-user behaviour data
4. Use of the derived knowledge combined with modelling and simulations for improvement of wood stoves with respect to energy efficiency, emissions (climate and health focus) and satisfying thermal comfort
5. Simulations based on advanced and up-to-date climate and sustainability impact models, with feedback to the stove improvements activities.

The Work Breakdown Structure of SusWoodStoves is:



SusWoodStoves management and work break down structure and project links and information flow.

SusWoodStoves will run for four years (2021-2024) and has a total cash budget of 18.6 million NOK, which is 80% financed by the Research Council of Norway through the ENERGIX program and 20% financed by the industrial partners.

The SusWoodStoves consortium

The project consortium covers all the necessary aspects and includes large and central industrial players in the wood stove area in Norway.

SINTEF Energy Research leads the project and focus on speciation and quantification of particulate and gaseous emission levels and reduction of climate and health related emission levels. **NTNU** (Norwegian University of Science and Technology) supervise two PhD candidates and Master candidates, with the main focus being building integration of stoves, assessment of value chain performance of stoves and techno- and socio-economic assessments.

The industrial partners contribute with finances as well as stoves and their extensive industrial knowledge generated through their commercial activities within the wood stove area: Jøtul AS, Nordpeis AS, Norsk Kleber AS and Norsk Varme.

The constellation of project partners is very strong, bringing together leading research organisations within the field and major industrial players.

Project background

SusWoodStoves, with its focus on sustainable wood stoves, is a response to the open Research Council of Norway KSP call and the topic Environment-friendly energy and its focus on the long term, sustainable development of the energy system, that enhance the competitiveness of Norwegian trade and industry and accelerate the transition to a low-emission society, including reducing anthropogenic greenhouse gas emissions. It is also directed towards the ENERGIX program plan and its focus on sustainable utilisation and consumption of renewable energy resources - as biomass, reduction of Norwegian and global emissions of greenhouse gases - from bioenergy, enhancement of Norway's security of supply - through increased use of domestic biomass resources, strengthened innovation in Norwegian trade and industry and the public sector - for the wood stove value chain, further development of Norwegian research and educational institutions - to be able to support innovation efforts in the wood stove industry.

Bioenergy is important in Norway and the current national bioenergy strategy is influenced by e.g. Klimakur 2030, Klimameldingen, Bioøkonomistrategien, Energi21 and Skog22. Wood log combustion has long traditions in Norway, constituting above 40% of the total use of biomass for stationary energy purposes, and accounting for about 12% of the domestic heating.

Using wood logs is important for security of supply in Norway, where we today rely heavily on the electricity grid to deliver the needed space-heating for our houses, which are typically wooden (with relatively low thermal mass). With a high nominal power, wood stoves can significantly reduce power peaks in the electricity grid, prevent blackouts and act as backup heating system. In a context of increasing electricity use in households, including electric cars, reducing peak electric power is strategic as it enables to prevent or postpone large investments to reinforce the distribution grid. New houses, as well as retrofit/upgrading of old houses, have increasingly focused on improved energy efficiency (e.g. the Norwegian passive house standard, the TEK17 regulation and nearly-zero energy buildings from 2020, NZEB). The space-heating effect (power) required for these highly-insulated buildings is drastically reduced, which means that wood stoves for these buildings should be able to deliver a close to constant heating effect to the building as low as ~1 kW, which is much lower than for a new stove in an old house.

Combining heat production, storage and distribution in an optimum way, would make it possible to achieve a substantially more stable heat release and distribution, and with lower heating effect. This was a key focus of the knowledge-building projects StableWood (2011-14) and WoodCFD (2015-18), the predecessors to SusWoodStoves. The StableWood studies confirmed that wood stoves have a place in future's buildings, while WoodCFD progressed the knowledge and especially modelling tools significantly, to enable improving wood stoves with respect to emissions and energy efficiency, as well as combustion stability and optimum room and building integration. Additionally, FME CenBio (2009-17) made a first effort to assess the wood stove value chain, comparing old and new wood stoves, at nominal and part load operation.

SusWoodStoves builds on the previous work, and will through further knowledge building within emission reduction, energy efficiency increase, proper building integration, and value chain, techno- and socio-economic assessments, contribute to ensuring a sustainable wood stove future both in the existing building stock and the residential buildings of the future.

Project overview

The project is divided into 5 subprojects (SP), each subproject is itself divided into several work packages (WP).

- Speciation, quantification and assessment of emissions - SP1
- Stove improvements and buildings integration - SP2
- Value chain assessment, TEA and SEA - SP3
- Education and training - SP4
- Technology monitoring and dissemination - SP5

Speciation, quantification and assessment of emissions - SP1
Addressing sub-objective 1 (Speciation and quantification of particulate and gaseous emission levels from wood stoves for representative stove technologies and operating conditions) and hypothesis 1 (the best wood stoves today are much better than some emission factors for new wood stoves in the Norwegian emission inventory indicates - still, they can be significantly further improved (reduced emissions, increased efficiency) by better understanding and controlling the wood log combustion process).
SP1 leader: Chief Scientist Øyvind Skreiberg, SINTEF Energy Research

Stove improvements and buildings integration - SP2
Addressing sub-objective 2 (Reduction of climate and health related emission levels through emission reduction and energy efficiency measures) and 3 (Optimum building integration of stoves) and hypothesis 1-3 (1) the best wood stoves today are much better than some emission factors for new wood stoves in the Norwegian emission inventory indicates - still, they can be significantly further improved (reduced emissions, increased efficiency) by better understanding and controlling the wood log combustion process, 2) proper wood stove design and material choices can much reduce the influence of the typical heat production peak on thermal comfort, 3) wood stoves have the potential to be suitable for heating any kind of residential building if properly designed, sized, selected, installed and operated)
SP2 leader: Associate Professor Laurent Georges, NTNU

Value chain assessment, TEA and SEA - SP3
Addressing sub-objective 4 (Assessment of value chain performance of existing and improved stove technologies and connected systems for different stove-building configurations in Norway), 5 (Techno- and socio-economic assessments of the current and future role of wood stoves in the Norwegian energy market) and 6 (Development of a roadmap for sustainable wood stoves in Norway) and hypothesis 4 (the best wood stoves have a natural place in a sustainable future) and 5 (further improvements can be shaped in such a way to maximize benefits for climate change and health, increase the overall sustainability performance of the wood stove value chain in Norway, and make a quantifiable step forward in the country transition to a sustainable bioeconomy).
SP3 leader: Professor Francesco Cherubini, NTNU

Education and training - SP4
Addressing sub-objective 7 (Education of highly skilled candidates within this area and training of industry partners).
SP4 leader: Professor Francesco Cherubini, NTNU

Technology monitoring and dissemination - SP5
Addressing sub-objective 8 (Monitoring of activities and state-of-the-art within this area and dissemination of knowledge to the industry partners, and other interested parties when applicable).
SP5 leader: Chief Scientist Øyvind Skreiberg, SINTEF Energy Research, who also is the SusWoodStoves project leader

Earlier publications

SusWoodStoves in EERA Bioenergy Newsletter

An article entitled "Emission factors, their reliability and needs for improvement – The case of wood stoves" presents a summary of and conclusions from a SusWoodStoves critical review in EERA (European Energy Research Alliance) Bioenergy Newsletter, Issue 17.

SusWoodStoves at IConBM2022

A work entitled "A critical review and discussion on emission factors for wood stoves" was presented at IConBM2022, 5-8 June, Naples, Italy.

The presentation highlighted the need for continuous revision of emission factors for new wood stoves in national emission inventories and recommended that the typical modern wood stove category should be divided into sub-categories reflecting the continuous improvement of wood stoves with respect to decreasing emission levels.

A corresponding article has been published in proceedings. The abstract is given below:

"Small scale heating appliances such as wood stoves, significantly contribute to domestic heating and energy security in many European countries. However, emissions from wood stoves remain a significant concern, even though modern wood stoves are continuously improved to reduce emissions due to incomplete combustion. Most State-Of-The-Art (SOTA) stoves after the 1990s, achieve significantly lower emissions than stoves produced in the period 1940-1990. The main reason being the introduction of emission limits and test standards both in Norway and other European countries. SOTA stoves today, including catalyst stoves and the more recent downdraft concepts, all apply a strategic and more or less optimized staged air supply. In stoves without catalyst, optimized air supply and combustion

chamber geometry as well as combustion chamber insulation, are the main reasons modern stoves achieve better burnout. When comparing national emission inventories, we find unacceptable large variations in emission factors for most reported compounds in all official stove categories. There are in some cases plausible reasons for such differences, but for some cases the differences can hardly be justified. Both stove categories, old and new, suffers from differences of up to two magnitudes, when comparing emission factors used in the national emission inventories in the Nordic countries. Hence, there is a real need to correct and align these for inclusion in national emission inventories, which should be reflecting real-life emissions as accurately as possible. As stoves are continuously being improved, we also suggest yearly updates accounting for such improvements, in the annual national emission inventories reports."

In addition, main findings of this study have been disseminated in EERA Bioenergy Newsletter, Issue 17.

SusWoodStoves at EERA Bioenergy webinar

A presentation entitled "Norwegian WtE and wood stoves research for the European future" was presented at an EERA Bioenergy webinar (arranged by SP4 Stationary Bioenergy), 16 November 2021, and highlighted the continued importance of these two traditional bioenergy sectors in the European renewable energy future.

SusWoodStoves in EERA Bioenergy Newsletter

An article entitled "Sustainable wood stoves through stove, building integration and value chain optimisation" presents SusWoodStoves in a EERA (European Energy Research Alliance) Bioenergy newsletter, Issue 15 June 2021.

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SusWoodStoves

Increased sustainability for the wood stove value chain

Background

Wood log combustion is important in and for Norway and contributes much to residential space heating and relieves the pressure on the electricity grid, as well as provides energy security when the electricity grid goes down. However, wood log combustion contributes also to air pollution, and there is a need to increase the sustainability through stove, building integration and value chain optimization, which is the main project focus.

Goals

1) Speciation and quantification of particulate and gaseous emission levels from wood stoves for representative stove technologies and operating conditions,
2) Reduction of climate and health related emission levels through emission reduction and energy efficiency measures,
3) Optimum building integration of stoves,
4) Assessment of value chain performance of existing and improved stove technologies and connected systems for different stove-building configurations in Norway,
5) Techno- and socio-economic assessments of the current and future role of wood stoves in the Norwegian energy market,
6) Development of a roadmap for sustainable wood stoves in Norway,
7) Education of highly skilled candidates within this area and training of industry partners,
8) Monitoring of activities and state-of-the-art within this area and dissemination of knowledge to the industry partners, and other interested parties when applicable.

Project title: Sustainable wood stoves through stove, building integration and value chain optimization (SusWoodStoves)

Project leader: SINTEF Energy Research

Partners: NTNU, Jøtul AS, Nordpeis AS, Norsk Kleber AS, Norsk Varme

Project period: 2021-2024

Type: Knowledge building project for the industry

Financing: 18.6 mill. kroner (15.1 from Research Council of Norway)

Project number: 319600