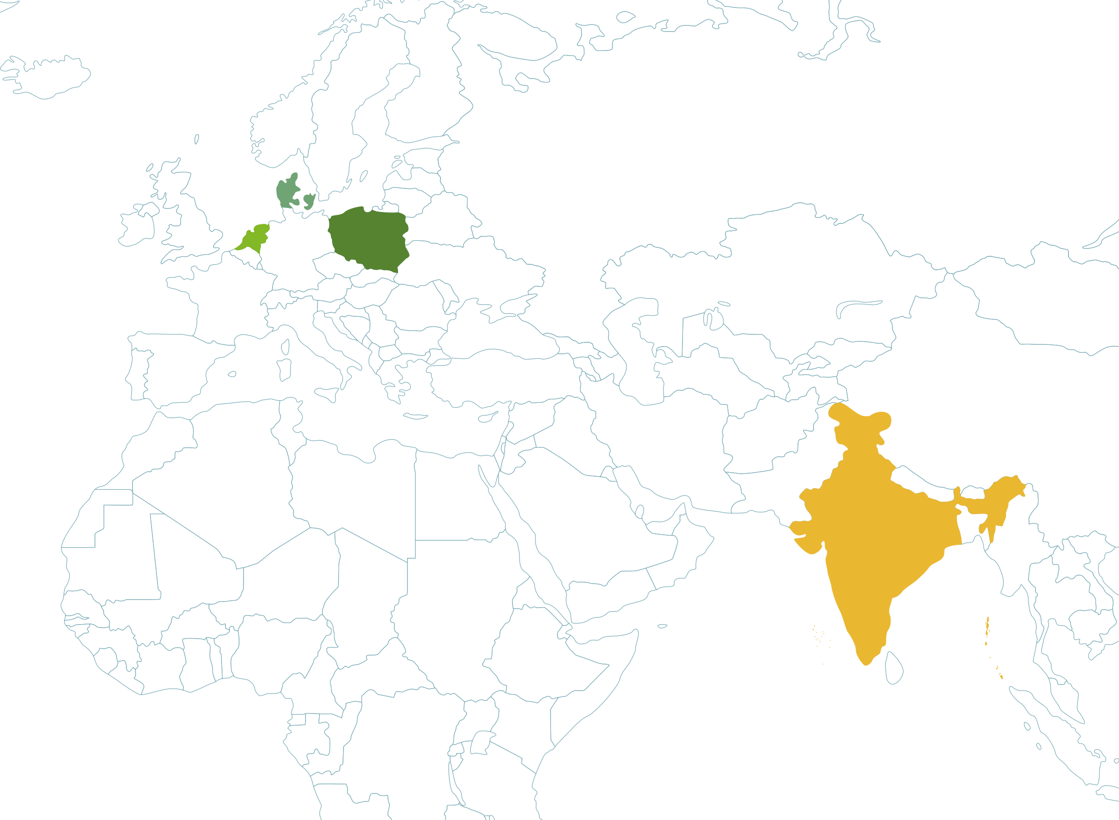

EDU MATERIALS

FINAL VERSION - NOVEMBER 2024

SUSTENANCE

SUSTENANCE introduces aspects of the energy transition

More info:
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Sustenance H2020 project

Total budget:
€3.8m of EU funds
Duration: 07.2021-12.2024

Project Coordinator:
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SUSTENANCE

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FUNDACJA KEZO

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DEPARTMENT OF SCIENCE & TECHNOLOGY
Ministry of Science and Technology
Government of India

List of contents:

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unique design helps swing the LSM_WTG horizontally using a hinge on one side and move it out of the wind when extremely high wind velocities are predicted, thereby keeping it safe.
Table 1 below presents the components and specifications of the Low Speed Micro Wind Turbine Generator prototype, developed in the Heat Pump laboratory of the Indian Institute of Technology in Bombay, within SUSTENANCE project.

Last but not least, it gives us pleasure to announce that the LSM_WTG prototype was recently patented (Patent No. IN201621017207A). ■

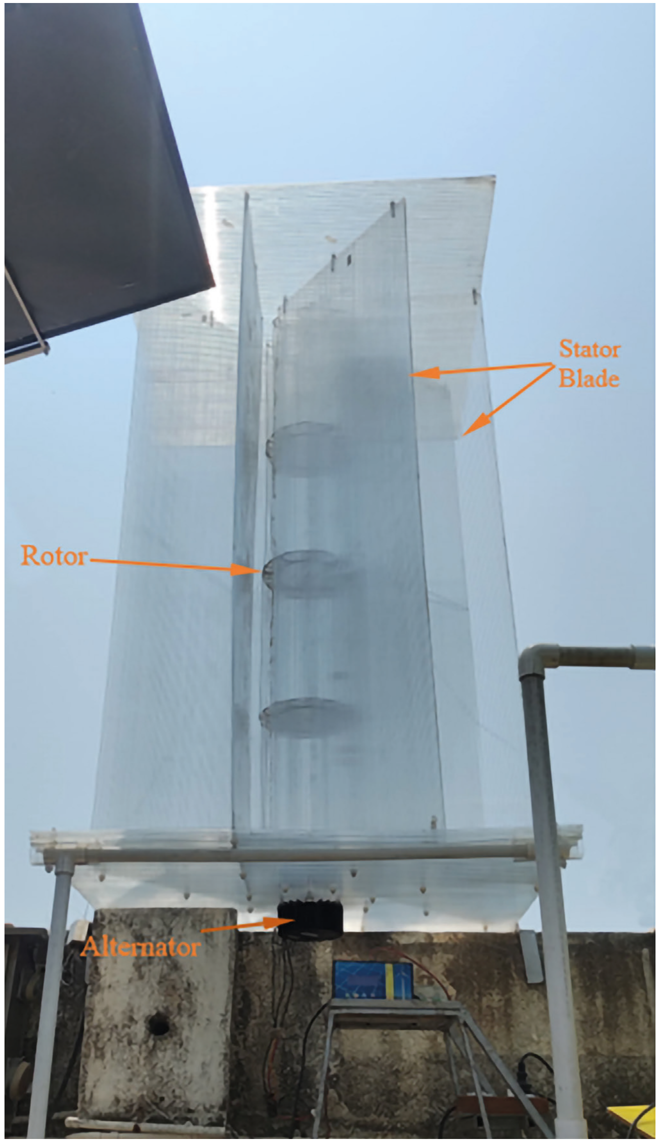
COMPONENTS	SPECIFICATION	UTILITIES
Rotor	Material: Polycarbonate Dimensions: OD 0.3 m x 2 m height Weight: 4.5 kg	Unique design for efficient air capturing with rotor blades cut at angles of 90 to 180°
Stator Blades	Material: Multi-wall polycarbonate Dimensions: 0.6 m x 2 m x 10 mm thickness Weight: 24 kg	The stator helps concentrate the wind on the rotor and support the rotor Unique design to utilize wind from all directions
Alternator	BLDC VDC Generator 58 frame Weight: 4.5 kg	Power generation at low rpm **3 m/s => 50 rpm, 5 V DC, 9 W** 100 rpm => 10 V DC, 21 W 200 rpm => 22.7 V DC, 45.4 W **6 m/s => 300 rpm => 34.1 V DC, 72 W** 400 rpm => 47.8 V DC, 95.6 W 500 rpm => 59.8 V DC, 119.6 W **12 m/s => 600 rpm => 72 V DC, 576 W**

Table 1: Low Speed Micro Wind Turbine Generator, LSM_WTG, Specification and Utilities

Author: Frans Coenen, Associate Professor, University of Twente

The role of citizens and local energy communities in the energy transition

Citizens are important players in the energy transition. They are the end-users of energy which they consume in their homes and through other activities like travelling. Their choices directly affect energy consumption through their energy use and energy-saving habits. They also indirectly influence energy consumption by buying energy-efficient appliances and equipment, which can help to reduce their energy consumption.



Protectable from extreme weather by turn it horizontal, 1.22 m x 1.22 m x 2 m High LSM_WTG weighs 33 kg

Expected to generate 9 W at 3 m/s, 72 W at 6 m/s and 576 W at 12 m/s

Figure 1: LSM_WTG assembly on Heat Pump Laboratory at IITB Terrace with provision of a hinge.

Principle of operation

The wind gets directed towards the small diameter vertical rotor with the help of the stator blades. This increases the velocity of air encountered by the rotor blades. This increases the rotor rpm for the prevailing wind speed. A large number of magnetic poles in the alternator helps to increase the frequency of the flux variation through the stator pickup coils. The permanent magnets can be Alnico magnets of aluminium, cobalt, iron and nickel or rare earth magnets of barium ferrite (BaFe) or neodymium magnets (NdGeB). This induces an emf in the coils proportional to the rotational speed of the rotor responsive to the fluid force acting against the rotor blades. The induced emf varies depending on the wind velocity. The higher the wind velocity, the higher the rotor's rotation speed, the higher the change of magnetic flux across the cores, and the higher the induced emf. The voltage across the coils is tapped to generate electricity in a known manner.

Multiple modules can be deployed as required. Low wind speed often limits the potential to harness wind energy economically. The slow-speed wind turbines being deployed on a rooftop in specified positions could start generating power at a wind speed of 2.1 m/s. The usage of polycarbonate in the LSM_WTG lightweight and the cost of the LSM_WTG is cost compared to commercially available WTGs of similar rating.

Complementing PV and providing for both on-site and off-site need for electricity

The electric power generated by means of LSM_WTG prototype (Fig. 1) can be used to meet the on-site or off-site needs or stored and used to perform tasks later. Whenever the wind is available, power generation would complement electricity production from photovoltaics (PV). When the PV output is low during monsoon season, the windmill helps generate power.

It is recommended that the LSM_WTG be deployed on the edge of the roof or terrace to capture the enhanced wind velocity due to blockage of wind due to the building structure. The wind turbine's

In general, citizens can influence the energy transition in a democracy in their capacity as voters. They can for instance support political parties and policies that promote renewable energy. They are also economic market actors who can choose to buy renewable energy or invest in their own renewable energy production, like their own solar panels, or decide to invest in renewable energy projects, such as solar or wind farms. They can also influence the energy transition by contributing to decarbonization through green electrification of house heating and mobility by investing in batteries, heat pumps, and electric vehicles (EV).

Particularly the transition from a centralised to a more decentralised energy system involves a new role for citizens. Centralized energy supply involves the large-scale generation of electricity at a central power plant which is then transported over a distance to consumers through an electric power grid. In a decentralised local energy system, the role of citizens can change from mere consumers to active energy citizens that are more actively involved in producing energy or by organizing themselves in local community initiatives.

Besides making changes in their own lives, there are many ways for citizens to cooperate together in the energy transition. Citizens can join a local energy community (LEC), which is a group of people who come together to generate, share, and manage their own energy. These local energy communities can play a particularly important role in decentralised distributed energy systems (DES), that allow citizens to deploy their own energy systems like small-scale renewables and storage, which can complement grid-scale electricity decarbonisation. DES can help cut emissions, increase energy security and reduce the need to reinforce grids.

Such LEC’s can generate renewable energy by installing and operating renewable energy projects, such as solar panels or wind turbines. The investments in these projects would come from the community members. The LECs can also support individual members in producing their own renewable energy. Further, they can provide energy services, such as energy efficiency advice and web tools, that can help to reduce their member’s energy costs.

The European Union legislation introduced two definitions of the local energy community. The Citizen Energy Community (CEC), which is contained in Electricity Directive, and the Renewable Energy Community (REC), which is contained in the Renewable Energy Directive. They are similar but have some different characteristics. In the transposition of these directives to national legislation across the EU, we find several different labels, but some important common characteristics arethat they are open and voluntary and combine non-commercial aims with environmental and social community objectives. This means a particular form of governance with the participation of the members in the decision-making. Ownership and control are reserved for citizens, local authorities and smaller businesses whose primary economic activity is not the energy sector, and whose primary purpose is to generate social and environmental benefits rather than focus on financial profits

Authors: Milind V Rane, Professor; Ananthu Krishnan, Junior Research Fellow, Heat Pump Laboratory, Indian Institute of Technology Bombay, ranemv@iitb.ac.in

Low Speed Micro Wind Turbine Generator

Photovoltaics is being widely deployed to generate electricity in a decentralized manner. While cost-effective fluid power harnessers such as fluid motors and wind turbine generators can harness energy from water streams or wind sources and complement the electric power generated using photovolatics. Low wind speed often limits the potential to harness wind energy economically. However, researchers at the Heat Pump Laboratory of Indian Institute of Technology in Bombay (IITB) attempt to demonstrate a novel patented Low-Speed Micro Wind Turbine Generator (further referred to as LSM_WTG), capable of supplementing the renewable power generated using photovoltaics. The weight and cost of the LSM_WTG will be lower than the commercially available wind turbine generators of similar rating.

Table 1 below presents the components and specification of the prototype of the Multi Utility Pump prototype developed at the Indian Institute of Technology in Bombay within SUSTENANCE project.

Last but not least, we are pleased to announce that the Multi-Utility Heat Pump for Rural Application for Agro Produce Drying developed at the Indian Institute of Technology in Bombay was patented (Patent No. IN200300613I3). ■

COMPONENTS (SEE FIG. 1 FOR REFERENCE)	SPECIFICATION	UTILITIES
Condenser Dryer (CND.Dryer)	Moderate-temperature agro-produce dryer using condenser heat	45°C low-temperature drying, Tube-Tube Heat Exchanger, Storage space of 330 L. Tray arrangement (Scalable)
Evaporator Cold Box (EVP.CB)	Storage of agro-produce, Milk and other commodities	Maintains temperature of 3°C to 6°C. Storage Space of 750 L. Inbuilt thermal storage (Scalable)
Hot Water Outlet (HWo)	Unique Tube-Tube Heat Exchanger	Water heating from 30°C to 50°C
Cold Water Outlet (CWo)	Unique design for Instant water chilling	Water cooling from 30°C to 15°C
Compressor (CMP)	Nominal capacity of 0.75 TR & 1.5 TR (Scalable)	Catering for multiple utilities using compressor using power input 0.9 kW for 0.75 TR & 1.8 kW for 1.5 TR

Table 1: Multi Utility Heat Pump Specification and Utilities

A particular form of local energy communities is the juridical form of a cooperative. Like other cooperatives, energy cooperatives follow a number of the basic principles set by the International Cooperative Alliance (ICA). Next to the general local energy community elements of voluntary and open membership and democratic member control, particular ways of proceeding for energy cooperatives' are economic participation by members, autonomy and independence and concern for the community.

CECs and RECs can undertake similar activities includingenergy generation, storage, energy distribution and energy sharing. However local energy communities and community members must comply with the same obligations as other market participants. This means that for instance energy sharing by members or grid distribution by the community is only possible when there are explicit legal provisions. ■

> **BESIDES MAKING CHANGES IN THEIR OWN LIVES, THERE ARE MANY WAYS FOR CITIZENS TO COOPERATE TOGETHER IN THE ENERGY TRANSITION.**

Authors: Rakesh Sinha, Postdoc; Birgitte Bak-Jensen, Professor;
Jayakrishnan R. Pillai, Associate Professor, Aalborg University

Power system flexibility and its potential/ advantages

A large share of electricity production from variable renewable energy sources in electric power systems requires flexibility. Power system flexibility refers to the ability of the electricity system to always balance the fluctuation in generation and consumption of electricity in real-time, while maintaining the security of supply and efficient utilisation of existing grid infrastructure.

The MUHP_RA prototype (Fig. 1, Table 1) consists of four main components:

1) The refrigerant evaporator integrated with an ice bank storage inside the cold box

- It is used to preserve the agro-produce or milk at low temperatures in the range of 3°C to 6°C
- Provision to cool water from 30°C to 15°C is also available, up to removal 37 kg/h for 0.75 TR & 75 kg/h for 1.5 TR

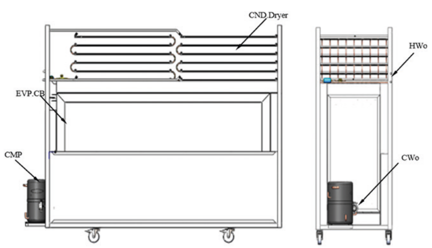
2) The compressor, which compresses the low-pressure refrigerant vapour from the evaporator outlet to the high-pressure in the condenser inlet

- R-290 is the environment-friendly refrigerant used in the system
- Power input 0.9 kW for 0.75 TR system & 1.8 kW for 1.5 TR system

3) The condenser integrated as a dryer cum water heater

- It is used to dry the agro-produce using the condenser heat, moisture removal 3 kg/h for 0.75 TR & 6 kg/h for 1.5 TR
- Drying is enabled at moderate temperatures in the range of 36°C to 45°C
- Provision to heat water from 30°C to 50°C is also available, up to removal 30 to 36 kg/h for 0.75 TR & 60 to 72 kg/h for 1.5 TR

4) The expansion valve regulates the flow of the refrigerant from the condenser outlet to the evaporator inlet.



Dryer volume 330 L with a moisture removal rate of 6 kg/h, water heating from 30°C to 50°C.

Cold box storage volume 750 L with agro-produce and milk cooling between 3°C to 6°C, water cooling from 30°C to 15°C

Figure 1: MUHP_RA Field Prototype of 1.5 TR Using R-290 Refrigerant (Indian Institute of Technology Bombay)

Heat pump dryers enhance microbial safety

The deterioration of quality caused by microorganisms poses a commercial challenge due to its impact on shelf-life and overall quality. Drying emerges as a solution to mitigate potential microbial damage. Heat pump drying minimises the risk of microbial contamination by ensuring that raw materials meet established preparation standards. Heat pump dryers contribute to enhancing microbial safety in food products by maintaining optimal low levels of relative humidity. Further, low-temperature drying helps retain the nutrition and aroma in the dried products and increases the system's performance.

Principle of operation

The Multi-Utility Heat Pump for Rural Application (further referred to as MUHP_RA, Fig. 1) operates on the Vapour Compression Refrigeration (VCR) cycle. A unique condenser design aids in drying the agro-produce at a rate of 6 kg/h moisture for a 1.5 TR at a moderate temperature of around 45°C. Water heating from 30°C to 50°C is also a utility provided on the condenser side. It can be tapped as and when required while the compressor is on. Fruits and vegetables are available in ample quantities in the villages and the surrounding forest. Small dryers and water chillers can be used by the villagers to precool the fruits and vegetables to remove the field heat before being transported to the markets, and the condenser heat of the MUHP_RA can be used for drying various agro-produce, like Jack Fruits, Mango, etc.

“ SURPLUS AGRO-PRODUCE IS AVAILABLE AFTER LOCAL CONSUMPTION. THEREFORE, IT CAN BE DRIED FOR STORAGE, AND ITS VALUE CAN BE ENHANCED

The illustration of the balance between generation and consumption is shown in Figure 1. To achieve power system flexibility for system balance, the electricity market structure and electricity grid operation play a crucial role. Flexible power systems promote sector coupling of renewable generation and consumption, allowing accommodation of variable renewable energy sources, such as solar and wind. Sector coupling is defined as the integration of various energy systems (electricity, heat, gas, and transportation), with the objective to gain mutual benefits to support their stable and secure operation.Flexibility in the power system is a critical aspect for transforming the energy system into carbon neutral economies.

To attain flexibility, the electricity market is considered as a key driver. Global market structure allows flexibility in import and export of renewable energy, between countries, during its shortage and excessive production respectively. The market structure is based

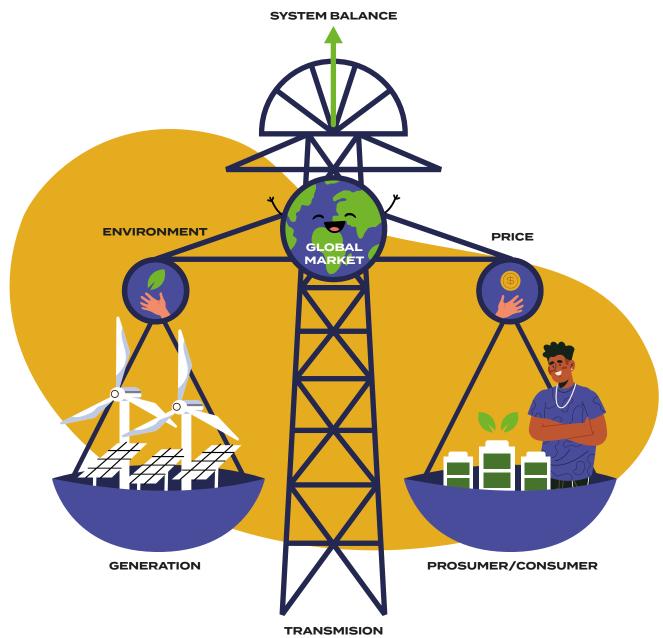


Figure 1: Synergies between generation technologies, market structure, transmission system, and loads (Power System Flexibility) (R.Sinha, 2023)

on the system's requirement to balance and maintain a secure supply of electricity. This requirement is achieved through flexible price signals to end-consumers as an economic incentive for participation, to effect demand-side flexibility.

The market is further enhanced by the engagement of energy communities. The application of demand side flexibility enhances active participation of energy communities in balancing the system with local energy production, consumption, storage and aggregation. This demand side flexibility is attained by shifting the operation of flexible loads (dishwasher, washing machine, dryer, heat pump, electric vehicle charging, energy storage systems etc.) and storing energy (battery, thermal storage, etc.) to match the electricity generation in the grid (Figure 2). An electric

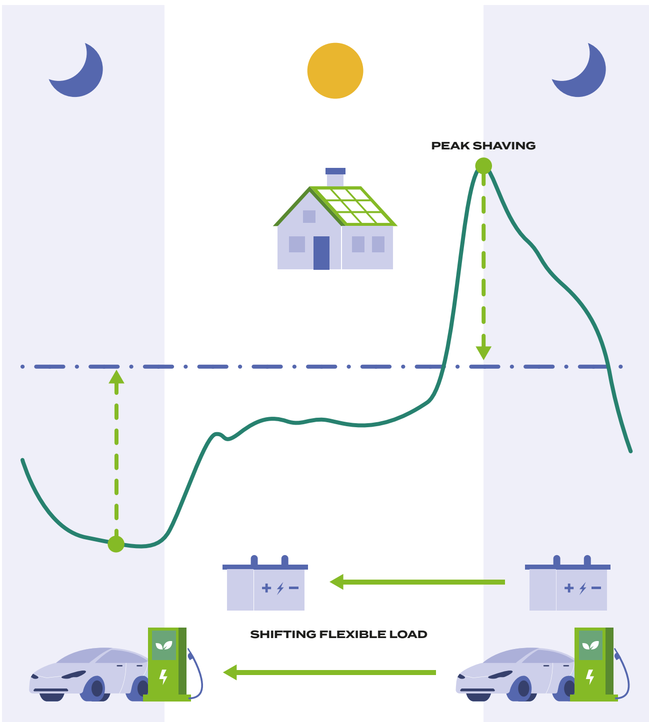


Figure 2: Demand Side Flexibility (Source: R.Sinha, 2023)

Authors: Milind V Rane, Professor; Ananthu Krishnan, Junior Research Fellow, Heat Pump Laboratory, Indian Institute of Technology Bombay, ranemv@iitb.ac.in

Multi-Utility Heat Pump for Rural Application for Agro Produce Drying

In the context of rural development and sustainable energy access, the enhancement of rural livelihoods takes centre stage. Rural areas, often reliant on agriculture, face persistent agricultural produce wastage post-consumption, indicating inadequate post-harvest management. Introducing technology solutions is imperative to address this challenge and support rural economies. Drying machines, for instance, offer an efficient means to reduce moisture content in agricultural produce, extending shelf life and market value. Additionally, improved short-term storage facilities for fresh produce can enable aggregation, reduce transportation costs and empower farmers to engage in bulk sales, fostering economic resilience and stability in rural communities. These interventions are pivotal for rural development, contributing to local economies and sustainable progress.

PROJECT/ DEVELOPER	LOCATION	CAPACITY	NO. OF VILLAGES
Dharnai solar city	Dharnai, Bihar	100 kW	1
Sagar Island microgrid	Sagar Island, Sundarbans	26 kW	1
Palm Meadows project (urban)	Hyderabad	30 kW	1
CREDA	Chhattisgarh	500 PV systems	6
DESI Power	Bihar (4), Madhya Pradesh (1)	260-kW PV systems	4
HPS microgrids	Bihar	82 systems (32 kW each)	48
OREDA	Orissa	2-4.5 kW each	27
WBREDA	West Bengal	25-500 kW each	22
UPNEDA	Uttar Pradesh	1.2 kWp	27 districts
MGP	Uttar Pradesh	240 Wp systems	8
SREDA	Sikkim	10-25 kW systems	-
Garam Oorja Projects	Maharashtra, Karnataka	5-30 kWp systems	30-40
Alamprabhu Pathar: MEDA	Maharashtra	12,000 kW	50 households + 40 commercials
SELCO foundation microgrids	Karnataka	1-14 kWp systems	5
Amrita self-reliant villages	Kerala	8 kW mini hydro	1
Biomass energy for rural India project	Karnataka	500 kW	3

Table II: Details of some Indian microgrid projects [3]

vehicle can be charged during the night when electricity demand and the electricity price are low and heat pumps can be operated during day time, to store thermal energy, when PV generation is high. Demand-side flexibility ensures power system reliability and optimal cost of electricity consumption benefiting both the energy utilities and end-consumers.

Potential advantages of power system flexibility :

- Ability to accommodate greater share of variable renewable energy sources.

- Increased requirement for sector coupling, (in the form of Power-to-X, where X stands for: heat/cool, hydrogen, and/or vehicles-to-grid, etc.) is relevant to the utilisation of renewable energy in various energy sectors and promotion of a carbon neutral society.

- Reduction in power loss, secure supply of power, and cost effectiveness is achieved from decentralised power system. Such advantages stem from the use of decentralised power generation rather than conventional and centralised fossil fuel based power units for power system balancing. This is realised by active participation and aggregation of decentralised energy production and local demand side flexibility.

- Efficient utilisation of existing grid infrastructure can be ensured with the support of demand response. Also, it facilitates congestion management and postponement of grid reinforcement in the present transmission and distribution network to accommodate increased renewable generation and new sizeable loads (EVs, HPs, etc) through shifting peak demand. As a consequence, reliability and quality of electricity supply and economic benefits are supported.

- Possibility of self-sustainable mode (island mode) of electricity grid operation: during the event of faults, power system can be divided into smaller self-sustainable and flexible islanded systems, operating independently, ensuring energy security. ■

Author: Gerwin Hoogsteen, Researcher, University of Twente

Smart charging of electric vehicles to support the sustainable power grid

Day by day, we see more electric vehicles entering the roads with the promise that this means of transport is much more sustainable. Without the noise, it is a convenient and comfortable method of mobility. However, this growing group of electric vehicles need to charge somewhere in our electric grid. It is often overlooked how much energy is required to fully charge an electric vehicle with a range of say 385km (70kWh of energy). The battery can hold enough energy to power an average European household for more than a week! Furthermore, current home chargers draw an amount of power from the grid that is roughly equal to 10 households. Fast chargers along the highway are even more crazy, with the equivalent of more than 100 households per charger.

“SOLAR ENERGY-BASED GENERATION HAS MADE A VISIBLE IMPACT ON THE LIVES OF RESIDENTS IN THE RURAL AREAS IN RECENT YEARS, BY HELPING THEM MEET THEIR LIGHTNING, COOKING AND OTHER NEEDS IN AN ECOFRIENDLY MANNER.

Under the solar power application program of Ministry of New and Renewable Energy, till 30 November 2022, end-use applications such as solar pumps, lamps, streetlights, and home lightnings are installed as per the number mentioned in Table I. The details of the few installed microgrids with their capacity are presented in Table II [3].

With the ongoing research on improving the efficiency of the PV modules, battery storage and inverter controllers, along with the incentives provided by Governmental policies, every remote location in the country is expected to be electrified very soon. The SUSTENANCE project in this regard focuses on development of smart technology concepts enabling a “green transition” of the energy systems, thereby aiming to provide clean energy to the regional communities to meet their local needs. Additionally, the project goes beyond just helping in the electricity sector. Other aspects such as local transportation, energy, heating and cooling are being locally integrated into “energy islands” or “integrated community energy systems”. The collective effort will enhance the local economy, create new employment and business, and bring about positive environmental changes, such as improving air quality. Besides, community empowerment and capacity development for smart solutions along with improved infrastructure in both the energy and transport sectors are some of the added advantages. ■

Solar energy-based generation has made a visible impact on the lives of residents in the rural areas in recent years, by helping them meet their lightning, cooking and other needs in an eco-friendly manner. The solar based microgrids were pioneered in India in the 1990s by the West Bengal Renewable Energy Development Agency (WBREDA) in the Sundarban delta region with an installation of a 25-kWp solar PV system [6]. Subsequently, various microgrids have been installed all over the country under the Government of India initiatives including the Remote Village Electrification Program (RVEP), Decentralized Distributed generation (DDG) scheme, Village Energy Security Program (VESP) etc. The Government issued a National Electricity Policy (NEP) in 2021, emphasizing the promotion of RES-based mini and microgrids and establishing up to500 MW of generation with around 10,000 microgrid projects [7]. In February 2021, a team of Global Himalayan Expedition introduced electricity to a village in the union territory of Ladakh by harnessing solar energy, which had no access to it for the last 60 years [8]. Globally, India stands as 4th in cumulative installed solar power capacity with 61.97 GW of active installations at the end of 2022 [9].

SYSTEM	NO. OF UNITS \ CAPACITY INSTALLED
Solar Lamps/Lanterns	75,29,365
Solar Pumps	2,56,156
Solar Street Lights	7,15,029
Solar Home Lightning Systems	17,21,343
Solar Power Plants	214.57 MW

Table I: Application-wise status of the installations under Solar PV Applications Program till November 2022 [9]

Many of the electric grids in our neighbourhood were never designed to supply these amounts of power. Furthermore, it is hard to get a feeling for electricity use, but it can be compared to water pipes. Now imagine, that many water (electric) vehicles are charging in your neighbourhood, the amount of water (electricity) that needs to flow is so high that the pipes would burst. In an electricity grid, this is no different: too much power flow will lead to circuit breakers tripping and a local blackout is the result.

In some areas, the electric grid will be overloaded already nowadays if many electric vehicles charge at full capacity. The solution to this is Smart Charging (Figure 1). In essence, this means that charging stations communicate and negotiate with each other over who gets how much power at which time to avoid a grid overload. And yes, this means that cars will charge a little bit slower and will be completely "topped off" later as well. This is what you also will experience in the (near) future. But look at it from the positive side, if all cars would be charging at full power, then you would suffer a power outtage, which also results in your car not being charged, but even worse, all other devices such as your fridge, would not receive power. It is also not such a significant problem since cars are generally parked for 95% of the time!

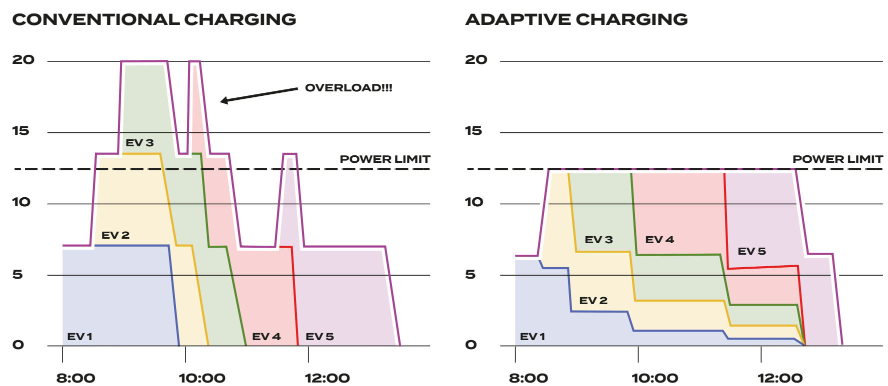


Figure 1: Resolving grid overload through smart charging (adapted from ev.caltech.edu/info).

Looking at it from the sunny side, this 95% means that, even with smart charging, we still have a lot of flexibility left. Which means we could delay the charging even further, which opens up a lot of possibilities to use electric vehicles to support the grid by providing demand response. Demand response is the act of changing the power draw of a load to assist the grid. This could for instance be to provide balancing services to ensure the security of power supply. Consider a moment when the electricity production from a large wind farm suddenly steeply reduces. Normally, another power plant, such as a gas or coal fired power plant will take over to balance the production. Instead, electric vehicles could now reduce their power consumption to balance the grid until the wind comes back again. This way, the vehicles can increase the use of renewables and reduce the emissions of greenhouse gases. Next to this, flexibility also has an economic value, since the electricity bill can also be signifcantly reduced.

Figure 2: Smart charging app showing charging schedule (University of Twente, 2023).

In addition, blackouts have been observed in many areas and several villages around the country continue to experience power cuts for long periods. Also, villages in India face problems like low voltages at their supply terminal, flickers, and other power quality issues due to their location being almost at the end of feeders. With most Indians living in villages, the primary requirement lies in providing access to a reliable and round-the-clock electricity supply for households as well as for cultivation purposes.

To mitigate these issues, several microgrids are in the process of being installed [3]. A microgrid is defined as [4] the group of controllable sources (typically renewable energy sources), loads and energy storage systems, which can collectively operate either in a grid connected or isolated mode (Figure 1).

One of the first instances of a microgrid in India was a 65-kW hydropower plant commissioned in 1897 at 3600 ft. above sea level at the base of Arya tea Estate, around 12 km from Darjeeling, West Bengal [5]. However, with the current shift in focus towards integrating more renewable energy sources (RES) in the generation mix, especially solar and wind, due to their abundance and environment-friendly nature, the concept of microgrids is especially beneficial for villages which are sparsely connected to the main grid, experience frequent power cuts and irregular power supply.

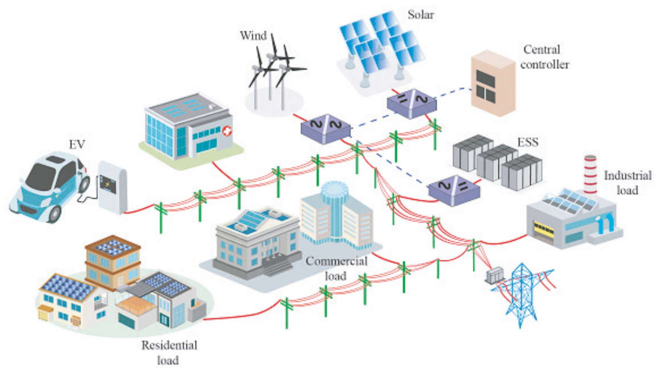


Figure 1: Diagram of a Sample Microgrid

> **“ THE BATTERY CAN HOLD ENOUGH ENERGY TO POWER AN AVERAGE EUROPEAN HOUSEHOLD FOR MORE THAN A WEEK!**

Another option is to synchronize the charging with the production of sustainable energy from solar panels and wind turbines. Preferably, these are local sources of electricity, which means that the electrons do not need to travel vast distances. By directly using local energy, for example from your own PV panels or those of your neighbours, you can also reduce the load on the grid.

Still, it is important to make sure that an electric vehicle is charged on time. This can be done through an app, in which departure time, energy requirement, and prefered mode of charging can be selected (Figure 2). In the future, such information screens will also be displayed in the vehicles themselves and directly communicated to the charging station. In this way, the charging system knows exactly how you would like to charge your car. More and more charging operators willl offer the option to charge differently. Of course, by knowing your preferences, they can provide you a better service, but also at a lower price through electricity market integration.

So, let go of the petrol-head mindset of recharging an electric vehicle as fast as possible. Instead, make use of offered smart charging solutions and the fact that the car is parked for 95% of the time and help the grid. You will be rewarded with a lower charging bill and a battery that is mostly, if not completely, filled up with sustainable energy. And, don’t forget to smile when you’re driving on sunshine! ■

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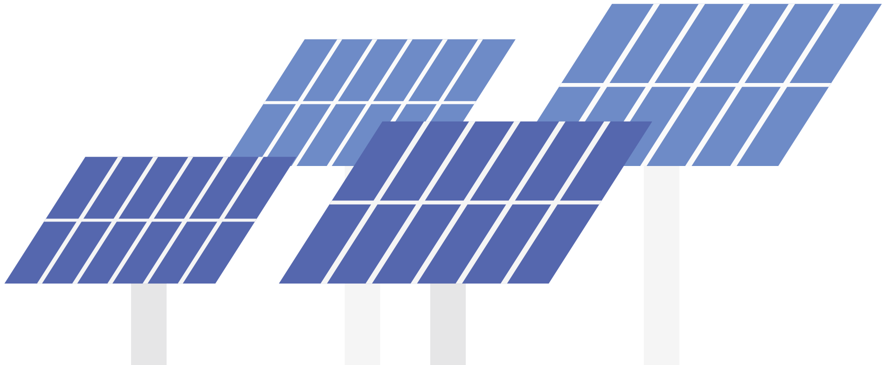
Microgrids for rural villages in India



India is a growing country with a population of around 1.4 billion [1], which has an ever-increasing demand for energy. In this regard, the grid has evolved significantly over the years to enhance its installed capacity. However, we are still facing a few challenges, as it is impractical and uneconomical to expand the main grid to some of the remotely located regions of India. Even though it is asserted that India has achieved 100% electrification, a village is declared to be 100% electrified even if only 10% of all homes and public offices have access to electricity. In that regard, around 15% of the population is still devoid of access to electricity [2].

SUSTENANCE

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iEMS – intelligent Energy Management System

Local energy systems can get complicated as the amount of resources available grows. The efficient generation and usage of energy in such systems requires the use of dedicated control systems. In general, an Energy Management System (EMS) consists of hardware and software which is designed, installed and programmed to:

In the example in figure 1 we can see the load profile of the heatpump shown in the graph, with the optimizer schedule indicated in the grey/green/red area above.

Conclusion

NEOGRID's heat pump control system exemplifies how integrating energy management solutions can optimize electricity consumption, reduce peak loads on the grid, and promote the use of renewable energy. By leveraging dynamic pricing and real-time scheduling, this system enables communities to take full advantage of their local energy resources, creating a more sustainable and cost-effective energy future. ■

Heat pump operation and cost

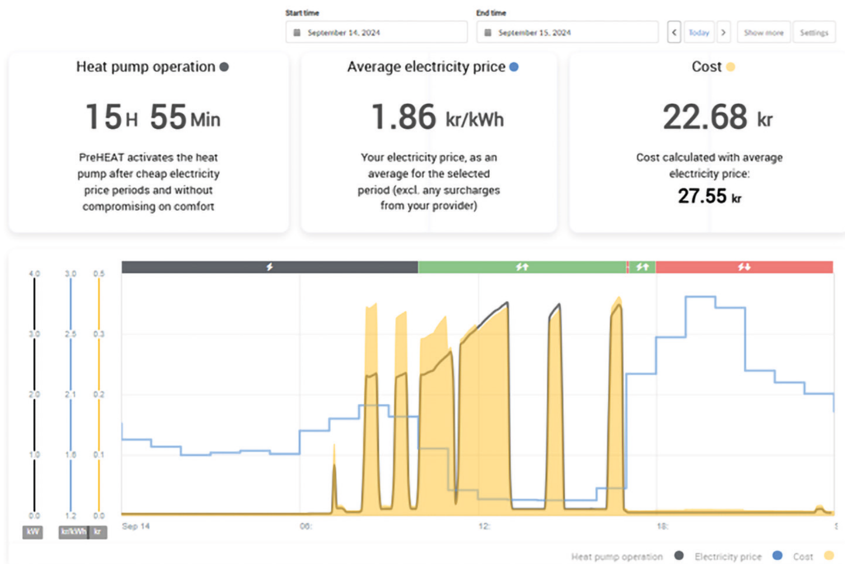

Figure 1: NEOGRID Heat pump dashboard.

2. Neighbour-Consumption: This price is applicable when there is excess electricity production from neighbouring PV systems within the community. In this scenario, the local energy community can negotiate a reduced tariff with the Distribution System Operator (DSO), making it cheaper to use surplus energy generated locally rather than drawing from the grid.

3. Grid-Consumption: This is the price of purchasing electricity from the main grid. It usually represents the highest cost, incentivizing the use of local and self-generated electricity whenever possible.

Optimizing Schedules with NEOGRID's Cloud-Based System

Using the dynamic pricing model, NEOGRID's optimization engine creates an optimized schedule for the connected energy assets in the community over a 24-hour period. The goal is to reduce peak loads and ensure that the most cost-effective and sustainable energy sources are utilized first.

- Heat Pumps: Given their predictable nature and continuous operation, heat pumps can be scheduled to operate during periods when electricity is cheapest (e.g., when local PV production is high or when the neighbor-consumption tariff is low).

- Electric Vehicles (EVs): Since EVs are not always connected, the system must adapt its schedule dynamically. Every time an EV arrives home and is plugged into the charger, the system triggers a new iteration of the schedule to incorporate the EV's charging needs in the most efficient way possible.

User Interaction and System Monitoring

All scheduling activities occur in the NEOGRID Cloud. Users can monitor and follow the optimized operation of their heat pumps and EVs through an intuitive dashboard. This platform provides a simple overview of the schedule, as well as access to historical data, enabling users to understand their energy consumption patterns and the impact of the optimization.

- Communicate and gather data from the devices in the energy system such as power grid meter/analyser, PV installation, EV charging stations, energy storage system (ESS) including battery management system (BMS), heat pumps
- provide an overview of the system performance for the user,
- actively manage the operation of flexible devices in the energy system (e.g. schedule ESS operation, dynamically limit EV charging power),
- integrate with external systems (e.g. building management system, SCADA, distribution system operators, grid services aggregator)

EMS algorithms can have multiple goals such as to:

- optimize the cost of energy by exploiting dynamic prices,
- increase system independence and decrease emissions by maximizing the self-consumption of local renewable generation,
- prolong the life of the components (e.g. use ESS in optimal conditions),
- provide auxiliary services for the power grid (e.g. Demand Side Response and other flexibility services)
- improve power quality (perform peak shaving and reactive power compensation),
- increase energy security.

The designated overarching goal can differ, but usually it is to optimize the overall operational costs of the energy system or to decrease its environmental impact. The goal might also be a combination of the above. Typically, a time-of-use strategy is applied to minimize the cost of energy drawn from the grid and maximize profit from selling surplus energy from renewable sources. This is done by controlling flexible devices having characteristics of an energy buffer (energy storage systems, EV battery charging, heat pump or electric boiler with its storage tank).

EMS can be applied to individual resources or sites as well as to whole communities.

Figure 1: Screenshots from the iEMS user interface

The Role of Heat Pumps and EVs in Energy Management

Heat pumps and EVs are significant electricity consumers. However, their energy consumption patterns differ significantly:

- Electric Vehicles (EVs): EVs consume large amounts of electricity sporadically, usually a few times per week when they need to be charged. This sporadic consumption can create peak loads on the electricity grid, especially when multiple EVs charge simultaneously.

- Heat Pumps: In contrast, heat pumps operate almost continuously throughout the heating season, consuming energy in a more predictable and steady manner. This predictability makes heat pumps an advantageous asset for optimizing energy usage within a community.

Integrating Renewable Energy Sources

To build a comprehensive understanding of a community's energy landscape, the system developed by NEOGRID also incorporates data from local photovoltaic (PV) systems and the main electricity meters of the utility. By combining historical data with weather forecasts, the system can predict and optimize energy consumption patterns.

Dynamic Electricity Pricing for Optimization

The system uses a dynamic pricing model to guide the operation of heat pumps and EVs. Three different electricity prices are calculated to reflect the various sources of electricity available within the community:

1. Self-Consumption: This price applies to individuals who generate their own electricity using PV systems. The price is calculated in real-time and reflects the income that would have been earned if the electricity were sold back to the grid. This rate is usually very low since selling surplus electricity to the grid often yields minimal returns.

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Heat Pump Control System

Modern energy management requires innovative solutions to optimize electricity consumption and reduce strain on the grid. In this context, NEOGRID TECHNOLOGIES, as part of the SUSTENANCE project, has developed an advanced system that controls various energy assets, primarily focusing on heat pumps and electric vehicles (EVs). This control system aims to minimize the peak load on the electricity grid while efficiently managing energy use within communities.

> **FURTHERMORE, CLEAR VISUALIZATION OF ENERGY USAGE, GENERATION AND PRICE PROFILES ALLOWS USERS TO ADJUST THEIR BEHAVIOUR TO OPTIMIZE ENERGY COST**

The iEMS (which stands for intelligent EMS), developed by STAY-ON within SUSTENANCE, is an energy management system dedicated to monitor and coordinate energy assets in the communities, as well as commercial and industrial sites with a focus on energy storage systems and EV charging infrastructure. iEMS enables communication between installation nodes to manage energy flows between energy sources, storage and loads according to predefined objective (i.e. to maximize renewable self consumption or minimize energy cost). iEMS combines edge devices and cloud service to integrate different types of assets and combine multiple sites in a single system.

If local business models are applicable, EMS governs energy flows to satisfy common goals such as an increase in local RES self-consumption or decrease in peak load/generation. It includes the option to operate in an off-grid mode, i.e. to operate independent from the larger energy grid.

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Self-Organizing Energy Management System

Within the SUSTENANCE project, Saxion University of Applied Sciences and the University of Twente have jointly developed a novel self-organizing energy management system. The aim of this system is to provide an easy to use, plug-and-play energy management system (EMS) for end-users in energy communities. In the future energy system, and thus also for local energy communities, such a system is of utmost importance to be able to share locally sourced energy, provide grid balancing services, and reduce both costs and carbon emissions that result from energy usage. Without such coordination, overloading due to simultaneous power draw may still occur as devices do not know what the intentions of other devices are.

> **“ HOWEVER, MANY NEW APPS AND DEVICE DRIVERS STILL NEED TO BE ADDED, ESPECIALLY FOR DEVICES THAT ARE NOT IN THE DUTCH DEMONSTRATOR**

Next to an EMS app, the IECON platform allows for the connection of user interfaces. The most important aspect is a smartphone app and dashboard that displays the most important information of the system and tips and tricks on how the user can assist in reducing carbon emissions, as shown in Figure 3.

How to use the developed system

The foundation of IECON has been developed such that it works in its core essence. Software developers can develop and add their own apps, which are written in Python, to enrich the complete ecosystem.

For normal users, such as citizens in an energy community, the developed system should be as easy as other digital devices, such as computers. This is the plug-and-play character as it should be as easy as plugging in a power plug in the socket and the device should work as expected. ■

After an application has been installed, it can be started on the IECON edge node. Upon starting it will communicate a birth certificate to the system. This certificate provides information about what kind of device it is (e.g., a battery), the data it provides (e.g., state of charge of a battery), and what functions it can execute (e.g., charging with a specific maximum power). Other applications can obtain these birth certificates such that they know exactly what other devices are available.

These birth certificates thereby also resolve the issue seen with many current EMSs: The need for manual configuration. Through the use of these certificates, the DEMKit EMS is able to automatically detect new devices and adds these to the energy management framework. The configuration of new algorithms is done automatically as vital information of the flexibility is embedded in the certificate information. Such automatic addition can be done as the DEMKit EMS is built around a self-organising algorithm called Profile Steering. Within the algorithm new devices can be added as the mathematical algorithm describes how devices must together come to an agreement about their energy use. They all communicate their desired profile and then collectively decide which devices help to stabilize the power system best.

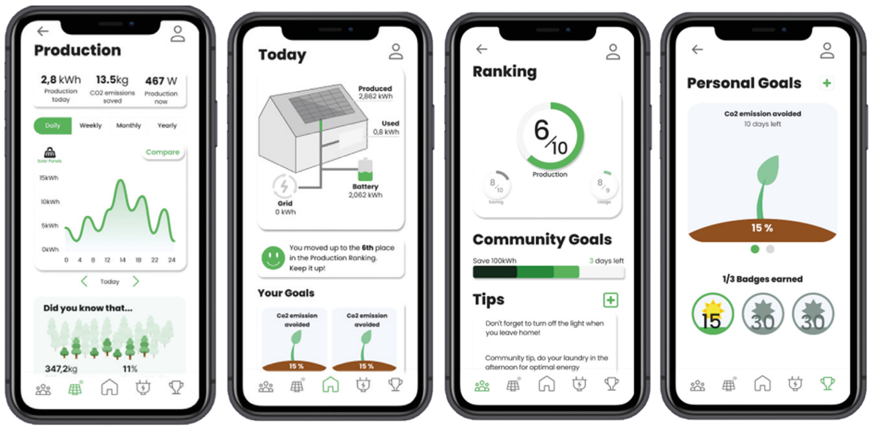

Figure 3: Dashboard in an app with different depths of detail are provided based on the needs of the users

In general, an EMS is a combination of physical hardware and advanced software that allow for the automated management of energy streams within a system. An EMS provides the means for wider system integration of different devices in an energy system, such that the joint energy usage is coordinated. The problem with many existing EMS solutions is that these are comprised of only a few components that still require custom configuration by an expert. Furthermore, many platforms only support a single or limited selection of brands. Current solutions therefore pose barriers for broad adoption in many energy communities.

The developed system

The developed system (see Figure 1) consists of a few already existing elements that have been integrated. The first element is the DEMKit EMS as developed by the University of Twente. This piece of software contains the algorithms to coordinate energy usage and therefore can be seen as the brain. The next element is the IECON computer platform developed by Saxion UAS. This consists of an operating system that allows for the integration of different energy applications in a so-called edge node. An edge-node is a small and energy efficient computer, such as a Raspberry pi, that hosts various applications, such as the EMS. Lastly, the platform uses SparkPlug-B as a communication interface to sure that different apps, devices and IECON edge nodes can work together as a system.

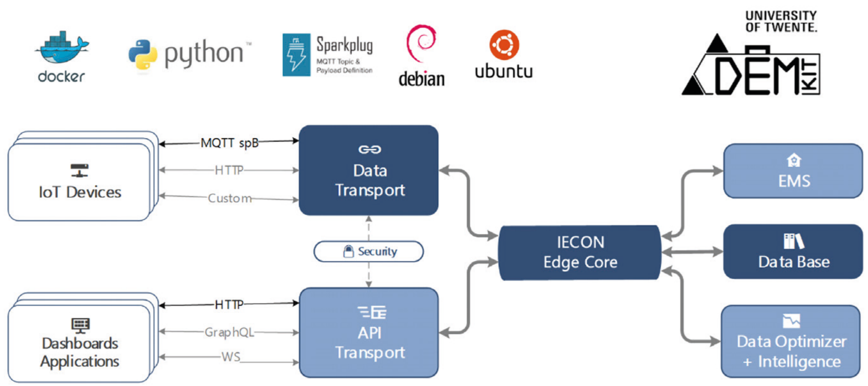

Figure 1: IECON Framework architecture diagram

CURRENT SOLUTIONS THEREFORE POSE BARRIERS FOR BROAD ADOPTION IN MANY ENERGY COMMUNITIES

How does it work

The IECON operating system forms the basis of the system, which allows to run applications. In a similar manner to smartphones, new apps can be downloaded and installed in the IECON system. These apps are various and contain services (e.g., weather and electricity price forecasting apps), devices (e.g., smart meters and electric vehicle charging stations), and an EMS. For devices, the accompanying apps can be best seen as a device driver such that an EMS knows how it works and how it must be controlled.

All installed apps communicate with each other automatically through the SparkPlug-B interface. Herein it is important that they all speak the same language. For this, we make use of the SAREF data standard which prescribes how certain information should be communicated using uniform names and units. This standardization allows the platform to be extended in the future too.

A local database is running as an app in an IECON edge node (See Figure 2). This database collects all the communicated data and stores it locally on the machine instead of in the cloud. This way, an IECON edge node can operate stand-alone, even when the internet connection is lost for some period of time. Important information is still communicated to the cloud for e.g., access to overviews in a smartphone dashboard. Furthermore, the highest standards regarding encryption and authentication are implemented to make sure the data is safe and correct.

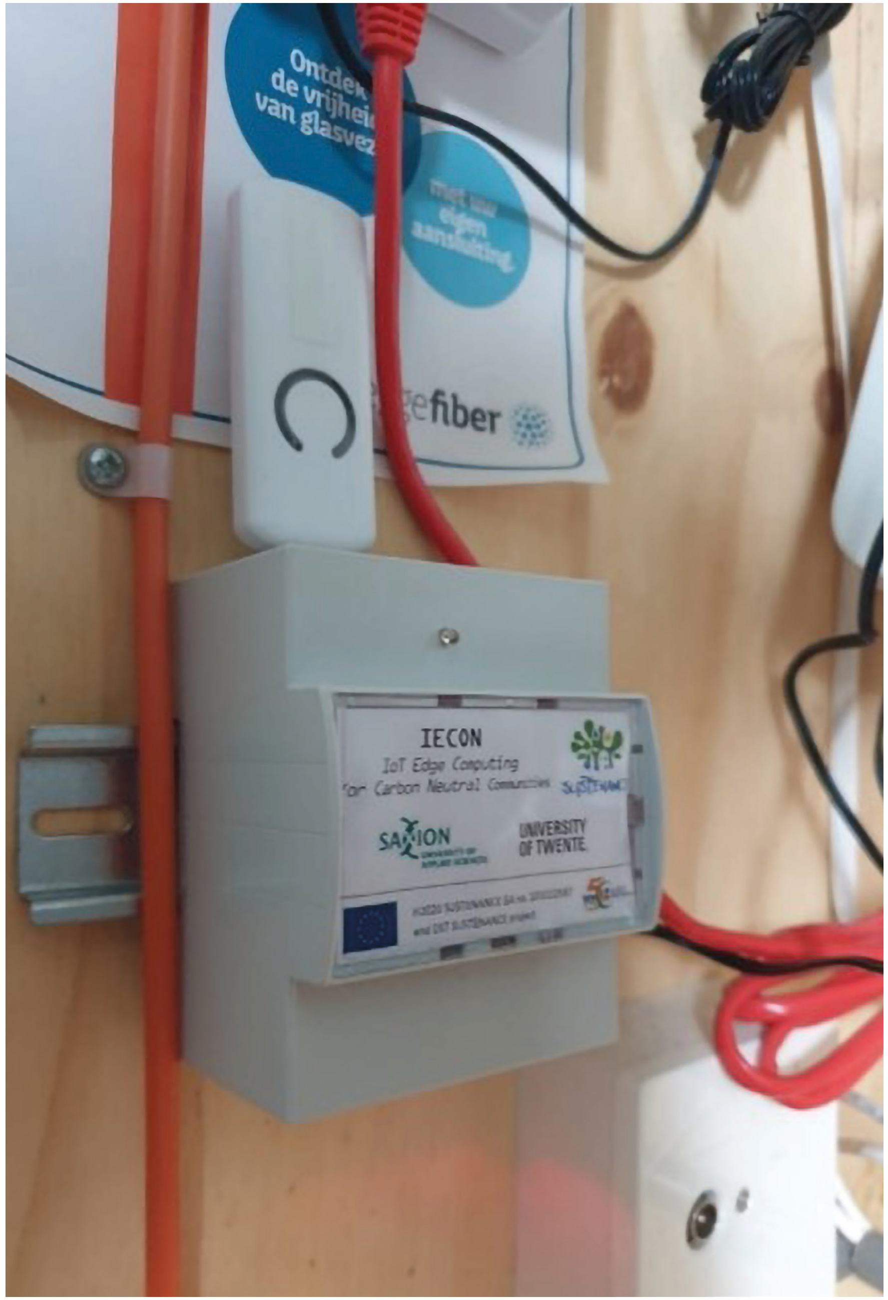

Figure 2: Installed IECON dge computer at Vriendenerf