ASSESSMENT REPORT OF
RENEWABLE ENERGY AND ENERGY EFFICIENCY SOLUTION
FOR RURAL WATER SUPPLIES IN VIET NAM

HA NOI, 09/2023

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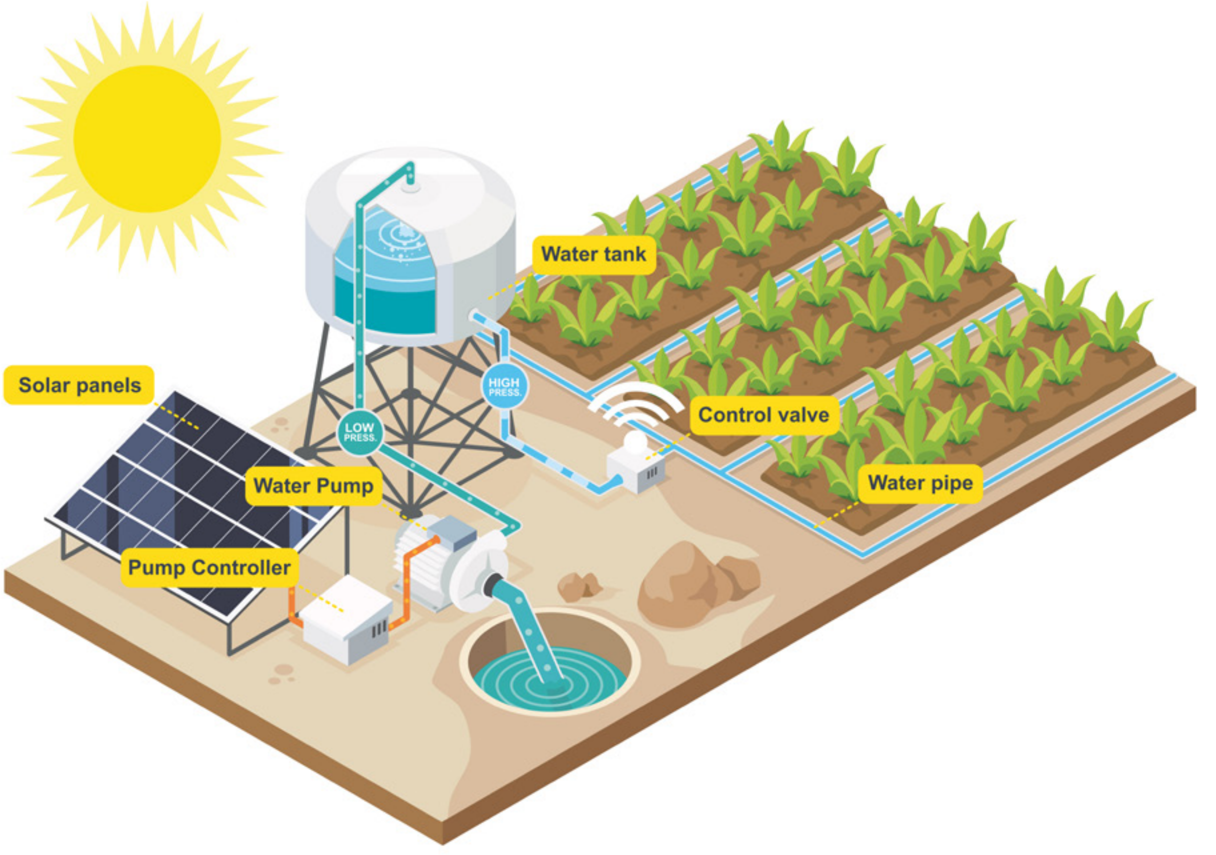
ACRONYMS

AC	Alternating Current
BAU	Business as usual
DANIDA	Danish International Development Agency
DC	Direct Current
EE	Energy efficiency
ESCO	Energy service company
EVN	Viet Nam Electricity
GHG	Greenhouse gas
GSO	General Statistics Office
IRR	Internal Rate of Return
Kwh	Kilowatt hour
Kwp	Kilowatt Peak
LEEC	Law of Energy Efficiency and Conservation
MARD	Ministry of Agriculture and Rural Development
MOIT	Ministry of Industry and Trade
MW	Megawatt
NCERWASS	National Centre for Rural Water Supply and Environmental Sanitation
NCEF	National Clean Energy Fund
NPV	Net Present Value
NRDWP	National Rural Drinking Water Programme
NRW	Non-Revenue Water
PCERWASS	Provincial Centre for Rural Water Supply and Environmental Sanitation
PDP VIII	Power Development Plan VIII
PV	Solar photovoltaic
RE	Renewable energy
RWSSs	Rural water supply systems
SCADA	Supervisory Control And Data Acquisition
TCO2	Tonne of CO2
UNICEF	United Nations Children's Fund
WASH	Water, sanitation, and hygiene
VEPF	Viet Nam Environmental Protection Fund
VND	Viet Nam Dong
VNEEP3	Viet Nam National Energy Efficiency Programme 2019-2030
VNEEP	Viet Nam - National energy efficiency programme



EXECUTIVE SUMMARY

This report is the outcome of research conducted from March to July 2023 as part of a five-year partnership between Viet Nam's Ministry of Agriculture and Rural Development (MARD) and United Nations Children's Fund (UNICEF) that is exploring the applications of renewable energy (RE) and energy efficiency (EE) for rural water supplies in the country. The primary objective of this study, commissioned by UNICEF, National Centre for Rural Water Supply and Environmental Sanitation (NCERWASS) and conducted by the Green Development Centre (GreenDC), was to assess the current status and potential of EE and RE solutions for rural water supply systems (RWSSs), to promote the use of clean energy and reduce the cost of clean water production and operations in rural areas. In response to the complex and ever-changing challenges, against the backdrop of evolving climate crisis, UNICEF is committed to supporting Viet Nam in strengthening its water and sanitation sector through a holistic approach that ensures effective, innovative and sustainable responses at scale.

The primary methodology employed for this study involved a combination of qualitative and quantitative research approaches. The main sources of information were gathered from: 1) a review of existing documents (legal texts, reports, relevant materials from domestic and international organizations and agencies), 2) interviews with representatives from central and local agencies of MARD and the Ministry of Industry and Trade (MOIT) across six provinces/cities, RE-EE service providers, financial institutions and banks, and expert consultants and 3) on-site surveys with representatives of 25 RWSSs. A consultative workshop to present the survey findings and solicit feedback from relevant stakeholders was also held on 6 April 2023 in Ha Noi.

The main findings of the study are summarized as follows:

VIET NAM'S RURAL WATER SUPPLY SECTOR

Viet Nam has a substantial number of rural water supply systems (RWSSs) spanning across all 63 provinces and cities nationwide. According to statistics from the NCERWASS, by the end of 2022, there were 18,109 RWSSs in Viet Nam. Most RSWWs (94 percent) are medium, small and micro-sized, supplying less than 500m^3 of water per day.

In terms of water supply technology, approximately 61percent of RWSSs (more than 11,000 RWSSs), are gravity (self-flowing) water supply systems, while the remaining 39 percent, nearly 7,000 systems, rely on mechanical pumping entirely dependent on electricity for operation. Most such systems, more than 91percent, are micro, small and medium-sized that provide less than 500m^3/day. These latter systems use electricity to operate pumps throughout various stages, including raw water extraction, water treatment, supply to end-users, lighting systems and other related activities. Pumps constitute the primary electricity consuming equipment in these systems, contributing to 95-98 percent of total electricity consumption.

CURRENT APPLICATIONS OF RE-EE IN RURAL WATER SUPPLIES

Applications of RE in RWSSs

Despite having the potential to harness various RE sources such as wind, tidal energy, hydropower, biomass and solar power, the most common RE resource used by RWSSs to generate electricity is solar power systems. The first solar power systems for rural clean water projects were introduced during 2013-2015. However, the pace of development has slowed. As of 2022, only 40 solar power systems had been installed in RWSS projects nationwide.

These installed solar power systems are predominantly of small capacity, typically less than 12kWp. All were funded through foreign grants or State budget allocations as pilot projects to assess the technical feasibility and financial viability of solar energy systems in RWSSs.

There are two types of solar power systems installed in RWSSs: off-grid and on-grid. Prior to 2016, off-grid solar power sources were utilized in RWSSs and from 2018, these systems transitioned to on-grid as electricity from the grid became available. Off-grid solar power systems directly provide power to submersible pumps for groundwater extraction or water supply to users. At the time of survey, most independent off-grid solar power sources had either stopped operation or were expanded to connect to the national grid managed by Viet Nam Electricity (EVN). The primary reason is these off-grid solar power systems lacked energy storage devices, resulting in RWSSs operating only during sunny conditions. Additionally, the effective operation and maintenance of solar power systems and water pumps was not adequately executed.

On-grid solar power systems, also known as grid-connected solar power, is a system that takes energy from the sun's radiation stream, converts it into electricity and connects directly to the existing grid system. On-grid solar power systems in RWSSs operate efficiently, contributing 15-30 percent of total electricity demand of the system, thus reducing electricity costs and increasing revenue through selling power to the grid. However, implementation of new on-grid solar power systems has been suspended since 31 December 2020, due to the expiration of Prime Minister's Decision No.13 (6 April 2020), which outlined the mechanism to encourage the development of solar power systems in Viet Nam.

Power load capacity of RWSSs is generally small, ranging from a few kW to a few hundred kW, averaging 40kW-60kW. Therefore, solar power systems for RWSSs are also small capacity and can be directly connected to local low-voltage grids.

In Viet Nam, more than 98 percent of rural communes were currently connected to the national electricity grid. In coming years, this rate will increase and the grid-connected solar power system configuration becoming more feasible.

Most solar power systems in RWSSs were installed about 10 years ago, and relevant data from this period is no longer available. While evaluating their economic efficiency may not yield realistic results, two more recently installed solar power systems are now available. A solar power system installed in an RWSS in Thanh An, Thanh Thang and Thanh Loi communes (Vinh Thanh district, Can Tho city) was constructed in 2015 and reportedly had a payback period of 10 years. Another solar power system installed by the Provincial Centre for Rural Water Supply and Environmental Sanitation (PCERWASS) in Binh Thuan province was constructed in 2019 with a payback period of eight years. It is apparent that the payback periods for these types of projects are becoming shorter due to decreasing prices of solar power systems, while prices of fossil-based fuels used to produce grid electricity are rising. Using current investment costs and based on representative capacity size of 50Wp, the economic assessment of a typical solar power pumping system in Viet Nam has a payback period of eight years, in contrast to four-six years in other countries. The main reason is higher investment costs, but low electricity tariffs in Viet Nam. Nevertheless, a solar pumping system in Viet Nam is still financially viable since its estimated net present value is positive and its internal rate of return is 12 percent, per annum. This rate of return is higher than the prevailing average cost of money in Viet Nam, which was of approximately 8 percent, per annum at the time of research. Therefore, the solar pumping system is deemed economically viable.

Applications of EE in RWSSs

In the context of government policies to promote EE use and increasing electricity costs for water production and supply, implementation of energy-saving measures – especially in electricity usage – are a feature of RWSSs. All 25 surveyed RWSSs have implemented EE-saving measures, although the level of interest and investment varied significantly. Larger-scale systems tended to better implement EE measures than smaller and micro-scale ones. Most implemented technologies and technical solutions contribute to energy savings ranging from 10-25 percent in all 25 surveyed RWSSs, with an average payback period of less than five years.

The EE solutions applied by the 25 RWSSs with their respective adoption rates are as follows: 1) use of high-performance lighting devices (LED and compact bulbs): 100 percent, 2) use of variable frequency drives for pumps: 76 percent, 3) Installation of power factor correction capacitors for transformer substations: 36 percent, 4) use of high-efficiency motors IE2/IE3: 28 percent and 5) installation of pressure sensors: 20 percent. A few water supply projects have also implemented energy management solutions, such as adjusting pump operating hours mainly to avoid high electricity costs during peak hours, installing soft-start systems, Supervisory Control and Data Acquisition SCADA systems and fixed monthly electricity consumption quotas.

POTENTIAL AND OPPORTUNITIES FOR RE-EE IN RWSSs

Renewable Energy: The survey results indicated that among RE sources, solar power systems have potential, feasibility and favourable opportunities for widespread implementation in RWSSs. This is based on factors such as: 1) Viet Nam's favourable natural conditions for solar power development, 2) the government's emphasis on solar power system development[1], 3) solar power systems offering numerous advantages adaptable to all RWSSs, 4) the majority of RWSS owners expressing interest in adopting solar power systems, 5) competitive pricing of solar power systems compared to fossil fuels, with decreasing investment costs and shorter payback periods and 6) the government's commitment to achieve net-zero CO_2 emissions by 2050 as part of international agreements.

The potential size of solar power applications for RWSSs is estimated to be at least 3,457 systems, with a total capacity of 172,850kWp and total initial investment capital requirement of about VND2,765.6 billion. The amount of grid power that the solar power systems will replace is estimated to be at least 232.17 million kWh/year, thus saving RWSSs at least 424.4 billion VND/year of electricity cost. The reduction in greenhouse gas (GHG) emissions is 167,164 tonnes/year.

Energy Efficiency**:** Compared to other sectors, RWSSs are not considered large-scale energy consumers. The electricity cost is a substantial portion of RWSSs' total operating costs. For more than 75 percent of surveyed RWSSs , electricity comprises 15-35 percent of costs, for 15 percent of RWSSs it amounts to more than 50 percent and for less than 15 percent of RWSSs it totals 10 percent. The potential for reducing electricity costs in RWSSs is still substantial, with an estimated 20 -35 percent reduction in current electricity costs viewed possible depending on each facility. This potential arises from the prevalent use of outdated pump technology, inadequate equipment maintenance, inefficient operational procedures, and significant energy wastage due to leaky pipes in the majority of RWSSs.

BARRIERS TO THE PROMOTION OF RE-EE APPLICATIONS IN RWSSs

Although the applications of RE-EE in RWSSs has great potential, its implementation still faces challenges in terms of policy, awareness, investment and capacity for project management and operation.

Policy: While the government has issued a series of documents and implemented programmes and projects to promote adoption of RE-EE in production, services, and daily life, still limitations and bottlenecks are evident in policies and mechanisms supporting development of solar power and EE. Specifically: 1) there is no policy provision allowing for the grid connection of solar power projects,[2] 2) there are no implementing guidelines for RWSSs that receive investment capital from the state or agencies, such as PCERWASS, in terms of lease arrangements for solar power systems, solar power

1 *According to Decision No. 500/QD-TTg on the approval of the National Power Development Plan for 2021-2030, with a vision to 2050 (referred to as Power Plan VIII), the government sets the target for power capacity to reach 20,750MW by 2030 and 178,944MW by 2050.*

2 *Policy support for solar power development expired at the end of 2022. Until now there are no new mechanisms or policies in place. As a result, the implementation of solar power systems, including those for rural clean water supply projects, has been put on hold. Recently, the Government of Viet Nam issued a decision No.500/QD/TTg (dated 15 May 2023) approve the national electricity development plan for 2021-2030, with a vision to 2050. While this decision recognizes solar power as a crucial energy source, it does not provide clear guidance on whether solar photovoltaic systems for RWSSs will be allowed to connect to the grid.*

purchase agreements, or implementation of solar projects with energy services companies (ESCOs) and 3) there are no regulations regarding energy consumption standards for the rural clean water supply sector. This absence of standards leaves RWSSs without a basis to evaluate the EE of their operations. Moreover, there is no government policy directly and specifically promoting EE and RE solutions in the water supply sector.

Financing: While there is a wide range of funding sources for RE-EE projects, they are difficult for RWSSs to access as they are primarily designed to address funding needs in other sectors. There are no dedicated RE-EE financing programmes for rural clean water supply. Getting a loan is difficult because most owners of RWSSs do not have collateral. In addition, investment loans for solar power in RWSSs, especially for implementation of EE solutions, are often small and not attractive for financial institutions. Furthermore, with an estimated payback period of eight years, solar pumping projects require longer loan terms. The payback period can be accelerated if the solar pumping system is on-grid, as extra power generated can be sold to the grid.

Awareness and implementation capacity: There is limited awareness of the applications and advantages of solar power, while inadequate capacity in managing and operating solar power systems and energy-consuming equipment within most clean water supply systems is evident. Additionally, there is a lack of capacity to assess the feasibility of solar power projects and EE solutions, both from technical and financial standpoints. RWSSs often lack trained personnel in solar power and EE.

RECOMMENDATIONS:

In order to promote solar power-focused RE-EE in RWSSs within Viet Nam, government agencies and RWSSs are recommended to take the following steps:

Policy mechanisms: (1) develop implementation guidelines for Power Plan VIII, particularly concerning rooftop solar systems, allowing grid connections for solar power projects of RWSSs, (2) introduce policies that encourage socialization in investment for solar power and EE projects within RWSSs, (3) provide guidance for state-owned RWSSs to collaborate with external entities to execute solar power and EE projects through PPPs or ESCOs, (4) develop and issue government policy directly promoting the use RE and adoption of EE in the water supply sector with clear goals and targets, (5) establish energy consumption standards for the rural clean water supply as a reference for RWSSs to improve EE and (6) develop a market for GHG emission reductions or carbon credit trading.

Finance: The MARD considers the government's proposal to allocate funding sources to prioritize RE applications , such as solar power systems, for RWSSs. Although there are on-going financial mechanisms for RE-EE – such as the World Bank guarantee facility, environmental funds and other green funds – they are designed for other industry and commercial sectors. Dedicated financial mechanisms for EE and RE projects in the water supply sector should be developed by the government. These would include low interest-bearing loans, long-term loans, guarantee funds or risk-sharing mechanisms.

Awareness and capacity enhancement**:** (1) conduct campaigns to raise awareness of the applications of RE and EE in RWSSs, (2) establish pilot models showcasing the successful integration of solar power and EE solutions in RWSSs to replicate these models widely, (3) organize capacity-building activities focused on management and operation of solar power systems, the comprehensive evaluation (technically and financially) of solar power projects to determine viability, development and implementation of EE solutions, and adoption of energy management systems within RWSSs. This would include trainings to improve profitability and sustainability of RWSSs. Trainings would focus on water audits based on international best practice to address water leakages and community participation in setting tariff rates to help achieve sustainable operations of RWSSs.

Entities owning and managing RWSSs[3]: (1) develop comprehensive plans and roadmaps for implementation of RE-EE solutions in entities. This should aim to promote the adoption of clean energy sources, contribute to reducing greenhouse gas emissions, and enhance the overall efficiency of clean water production and distribution, (2) develop and implement policies on energy management within RWSSs, (3) implement regular monitoring, energy reporting, and periodic assessments to identify energy losses and root causes and (4) strengthen capacity-building initiatives to enhance the skills and knowledge of personnel managing and operating solar power systems, EE solutions and energy management systems.

3 *Encompassing: Provincial/City Centres for Rural Clean Water Supply and Environmental Sanitation, joint stock companies, private companies, Commune People's Committees and cooperatives.*

Filtering tank of water plant Hoa Thuong, Thai Nguyen province

1. INTRODUCTION

1.1. BACKGROUND

Economic reforms since the launch of *Doi moi* in 1986, coupled with global trends, have helped propel Viet Nam from being one of the world's poorest nations to a middle-income economy in one generation. Between 2002-2022, gross domestic product (GDP) per capita increased 3.6 times, reaching almost USD3,700. Poverty rates (USD3.65/day, 2017 PPP) declined from 14 percent in 2010 to 3.8 percent in 2020.[4] The country had an average annual GDP growth rate of 6.27 percent from 2000-2022. Despite the COVID-19 pandemic, it posted a growth rate of 2.9 percent in 2020 and 2.6 percent in 2021, before bouncing back with a forecasted average annual growth rate of 6.7 percent in 2023.[5]

Viet Nam's dynamic economic story since 2000 has been driven by rapid expansion of industrial and service sectors. Consequently, there has been an increase in the use of fossil fuels and growth of environmentally harmful industries. Moreover, the demand for energy, particularly electricity, has surged. According to the MOIT, Viet Nam's electricity production has more than doubled in 10 years, from 93 billion kWh in 2011 to 215 billion kWh in 2020. Projections indicate that electricity demand will continue to grow at 8.5 percent annually over the next 5 years.[6] Another issue is the increasing energy demand, while the energy supply is becoming more challenging due to scarcity and rising costs of primary fuel imports. Viet Nam is facing electricity shortages, as illustrated by the 2023 summer blackouts, and this situation could potentially worsen.

The energy sector is the largest GHG emitter in the country, accounting for about 58 percent of total CO_2 emissions.[7]

4 *Overview: Development news, research, data | World Bank*

5 *Strong Economic Fundamentals—Key to Fast Recovery in Viet Nam, Says ADB – adb.org*

6 *The 2023 National Energy Saving Conference, the Ministry of Industry and Trade , 20 July 2023.*

7 *Ministry of Natural Resources and Environment - National Greenhouse Gas Audit Report, 2014*

Water plant Giao Thuy, Giao Thuy district, Nam Dinh province

According to the "Global Climate Risk Index 2021" summary report by Germanwatch, Viet Nam is assessed as being heavily affected by climate change and ranked 13th globally in terms of impacts during 2000-2019.[8] According to estimates, climate change could reduce Viet Nam's national income by up to 3.5 percent by 2050.[9]

Amidst environmental pollution and the adverse impacts of climate change, Viet Nam has introduced and executed numerous significant policies pertaining to climate change mitigation. By 2030, Viet Nam aims to achieve a 9 percent reduction in total GHG emissions compared to the business as usual (BAU) scenario[10], utilizing its internal resources. This reduction could reach 27 percent with international support through bilateral and multilateral collaborations, coupled with implementation of new mechanisms under the Paris Agreement. During COP26, Viet Nam announced its commitment to reach net-zero

8 *Global Climate Risk Index 2021, www.germanwatch.org/en/cri*

9 *Climate Risk Country Profile - Viet Nam - Viet Nam | Relief Web*

10 *Document No.1982/VPCP-QHQT of the Office of the Government. July 24, 2020 on approving Vietnam's Nationally Determined Contribution (NDC) report to make a strong commitment to climate change adaptation and mitigation*

carbon emissions by 2050 and emphasized the importance of equity in meeting the climate change challenge. Additionally, it committed to ending deforestation by 2030 and phasing out coal-fired power generation by 2040.

In recent years, to meet low-carbon emission commitments and ensure energy security, Viet Nam has implemented various policies to promote energy development, with a primary focus on increasing the share of RE, particularly solar and wind energy. Additionally, it has actively promoted the applications of EE. Currently, the government is executing the Viet Nam National EE Programme 2019-2030 (VNEEP3) with the goal of achieving EE of 5-7 percent of total national energy consumption by 2025 and reaching 8-10 percent savings during 2019-2030. This is equivalent to around 60 million tonnes of oil equivalent (TOE)[11] of GHG emission reductions.

With policies enacted and implemented, adoption of RE-EE in Viet Nam has been widely integrated across economic and social sectors, particularly in industries and commerce. By the end of 2020, the cumulative installed capacity of solar power in Viet Nam had reached 16.640 MW, generating an electricity output of 12,084MW in 2020 alone. The actual installed capacity is even higher, exceeding 20,000MW. As outlined in the Power Development Plan VIII (PDP VIII), solar power is projected to contribute 6.3 percent to total commercial electricity production by 2030 and increase to 19.6 percent by 2050.

Alongside other sectors, adoption of RE (particularly solar power) and EE solutions in RWSSs is evident. In 2021, the *Viet Nam National Strategy for Rural Water Supply and Sanitation by 2030, with a vision to 2045*, was promulgated by the prime minister. It actively promotes utilization of RE-EE solutions, including solar and wind energy, in RWSSs (pictured). Numerous provinces and cities have developed plan for implementing *Strategies for Rural Water Supply and Sanitation by 2030, with a vision to 2045*, placing emphasis on the integration of RE-EE solutions into RWSSs. With domestic and international support, several water supply systems in rural Viet Nam have successfully realized RE-EE solutions.

In practice, solar power systems have been installed in RWSSs with international assistance or as part of State-run demonstration projects. Some water supply facilities have implemented EE solutions such as installing variable frequency drives and upgrading lighting systems in control rooms. However, the full effects of implementing solar power systems as well as improvements in EE within these projects have not been thoroughly assessed. Additionally, barriers to scaling-up these models nationwide have not been evaluated or studied. Therefore, evaluating the applications of RE-EE solutions in selected RWSS projects and identifying the encountered barriers is necessary to provide evidence and a clear understanding of factors and specific steps involved in applying RE-EE solutions.

To meet this need, UNICEF and NCERWASS commissioned GreenDC to conduct this study as part of a five-year partnership between Viet Nam's MARD and UNICEF that is exploring the applications of RE and EE for rural water supplies in the country. The primary objective of this study, conducted from March to July 2023, was to assess the current status and potential of EE and RE solutions for rural clean water systems, with the aim of promoting the use of clean energy and reducing the cost of clean water production and operations in rural areas. The research findings will also serve as a foundation for the development of EE and RE guidelines in RWSSs in Viet Nam.

11 *Decision 280/QĐ-TTg on the Approval of the National Energy Efficiency Programme (VNEEP) for the period of 2019 -2030*

1.2. OBJECTIVES

The objectives of this report are to assess the potential for scaling-up RE-EE for RWSSs.

The insights will be used to:

- Provide an overview and analysis of the potential landscape of EE-RE for RWSS in Viet Nam.
- Explore the potential for RE in the rural water supply sector to contribute to development of the RE market and GHG emission reductions in Viet Nam.
- Enhance evidence and data on clean energy and contribute to the Government of Viet Nam and UNICEF's efforts to promote sustainable energy for children.
- Explore opportunities for EE-RE models for RWSS.

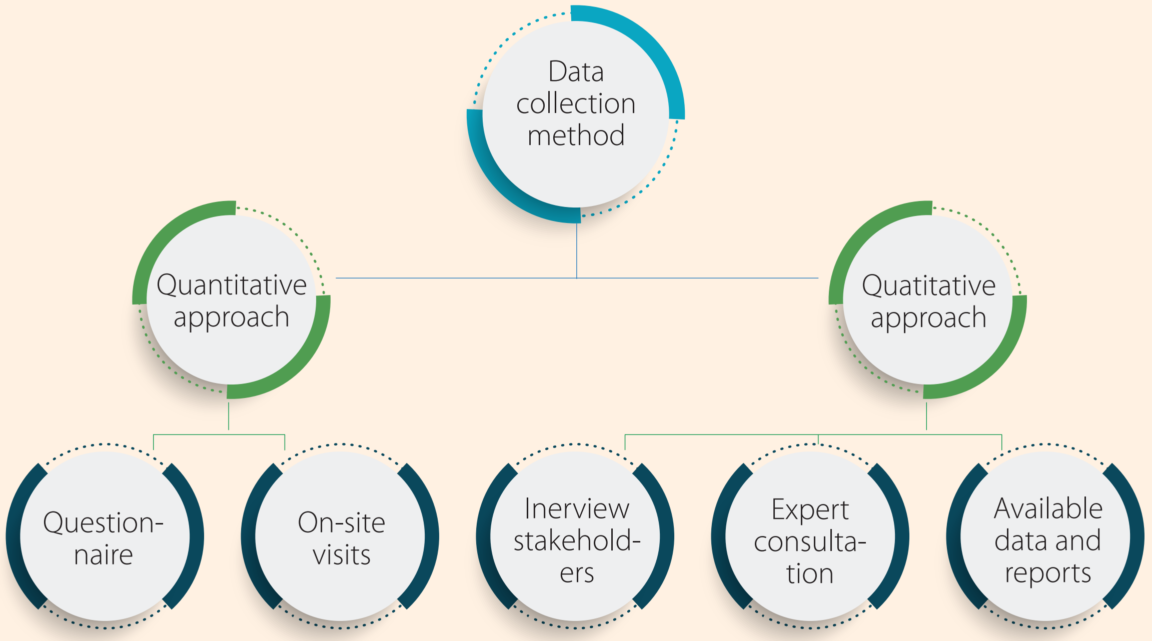
The report will focus on:

- **A situation analysis** of awareness, practices, policies and plans, actions/measures, technologies, and investment in EE and RE.
- **Assessment of challenges** in scaling-up RE-EE, as well as opportunities to overcome those challenges, including the feasibility of accessing carbon credits.
- **An assessment of clean water supply systems** that have applied RE-EE modalities to calculate resource-saving and GHG emission reductions, thereby providing lessons learned for applications in RWSS units.

1.3. METHODOLOGY

This study applied a combination of qualitative and quantitative research methods. The main sources of information were collected from: (1) existing literature research, (2) survey questionnaires for clean water supply projects, (3) interviews with representatives of relevant agencies, (4) on-site surveys at clean water supply projects and (5) consultations with organizations and experts.

FIGURE 1. ILLUSTRATIVE DIAGRAM OF THE RESEARCH METHODOLOGY



Review of existing document

Data collected from the document review was a crucial source of information for this study, particularly on policies, international experiences, and past RWSS projects with RE elements. The literature review covered the following aspects:

- International experiences on RE-EE in rural clean water supply sector and good practices from other countries.
- National context review:
  - Current government policy (including financing), documents and reports relating to RE-EE development in Viet Nam, relevant regulations for deployment of RE solar power and carbon credits focusing on implications for water supply, especially piped water systems for hard-to-reach areas and marginalized communities, as well as the needs and potential of the energy market. Accessing carbon credits and the enabling environment supporting water supply units were also analyzed.
  - Existing practices in terms of scale, financing, models, technology, market supply and demand for RE-EE in rural water supply in Viet Nam.
  - Assessments, good practices and experiences in RE-EE in Viet Nam.
  - Evaluation of projects and programmes that have promoted RE-EE modalities in water supply systems, thereby providing lessons learned for applications of RE-EE solutions in RWSSs.

Surveying through questionnaires and on-site visits to water supply systems

Due to time and resource constraints that prevented a nationwide survey, the study selected six highly representative provinces and cities to conduct surveys using questionnaires and on-site visits to water supply systems. The selected provinces/cities met the following criteria: (1) Geographical location (North, Central, South), (2) Presence of RWSSs that have implemented RE or EE solutions, varying management models, different scales of water supply systems, and have solar power applications potential. Accordingly, provinces that met the criteria were: Northern region (Nam Dinh, Thai Nguyen), Central region (Binh Thuan), Southern region (An Giang, Can Tho, Soc Trang).

From the selected provinces, 25 RWSSs were chosen for surveying through questionnaires and on-site visits. The selection of these water supply systems adhered to the following criteria: (1) Implementation of solar power systems or adoption of EE solutions, (2) Diverse scales (large, medium, small), (3) Varied management models (State-owned enterprise, private enterprise, Commune People's Committee, cooperative and community management).

The survey through questionnaires aimed to gather information and data from each water supply system regarding its current energy usage status, investments in RE-EE solutions, implemented EE measures and scale of water supply systems. This helped assess the current situation, cost-effectiveness, trends and potential for applying RE-EE solutions, as well as GHG emission reduction potential for each surveyed water supply system and collectively for all surveyed systems.

Actual on-site visits at RWSSs were conducted to verify information and data provided in questionnaires by survey respondents. This involved inspecting the equipment and machinery of water supply systems, measuring, and calculating potential for applying RE-EE solutions, and engaging in discussions with representatives of water supply systems regarding solutions, advantages and challenges in implementing RE-EE measures. During these on-site visits various actions were taken – including collecting documents such as operation records, energy bills, investment records/reports of RWSSs – to assess current energy usage status, evaluate potential for EE solutions of systems, and assess the awareness and relevant capacity of personnel regarding RE-EE.

Interviews with relevant parties

Interviews were conducted with relevant parties to gain a deeper understanding of current regulations and policies, as well as the direction and plans of the government and related agencies. This process also aimed to identify available resources (financial, technological, human) that could be allocated for applications of RE-EE solutions in RWSSs. Additionally, interviews aimed to clarify the advantages and challenges of implementing RE-EE solutions in RWSSs, and to identify necessary measures for promoting the applications of these solutions, encompassing policy, finance, technology, and implementation capacity.

Interviewed parties included State government agencies (MOST, MARD, MOIT, DARD, DOIT,in some provinces and cities), PCERWASS, rural clean water supply units (joint-stock companies, cooperatives), organizations providing RE-EE services, financial institutions, and commercial banks.

Consultation

A consultation workshop was held on 6 April 2023 in Ha Noi to present the survey findings and gather feedback from relevant stakeholders, including MOIT, MOST, MARD, PCERWASS, experts, and sponsors. Feedback received from the consultation workshop was carefully studied and incorporated to enhance the completeness and quality of this report.

1.4. Limitations of the research

Viet Nam possesses the ingredients for developing various sources of RE, such as solar, wind, hydropower and biomass. However, to date, only solar power has been applied within RWSSs. In response, the research was based on best international practices that indicated that solar power, particularly for pump operations, is the most widely adopted RE technology in the water supply sector of other countries. Therefore, there is no existing model to assess the feasibility and effectiveness of other forms of RE apart from solar.

The majority of solar power systems installed in water supply systems in Viet Nam were implemented around a decade ago. As a result, pertinent data related to project preparation, construction, and installation phases (such as technical design documents, project description files, socio-economic assessment reports) have not been retained by rural clean water supply organizations. Additionally, the installed capacity of solar power systems in these entities has primarily been small, and initial investment costs for solar power systems at that time were high. As a result, evaluating economic efficiency within the framework of this historical context may not align with the current situation. In order to overcome this constraint, the authors used a model with appropriate assumptions relevant to the present context for assessment purposes.

2. GENERAL OVERVIEW

2.1. OVERVIEW OF RURAL WATER SUPPLY SECTOR IN VIET NAM

Rural clean water supply technology

Viet Nam's water supply system consists of components shown in Figure 3. The sources or methods used in water supply differ mainly due to geography and water availability. Water supply infrastructure include sources such as rivers, reservoirs, sea water and ground water (well, tube wells),transmission pipes and canals, treatment and storage facilities, distribution network elements.

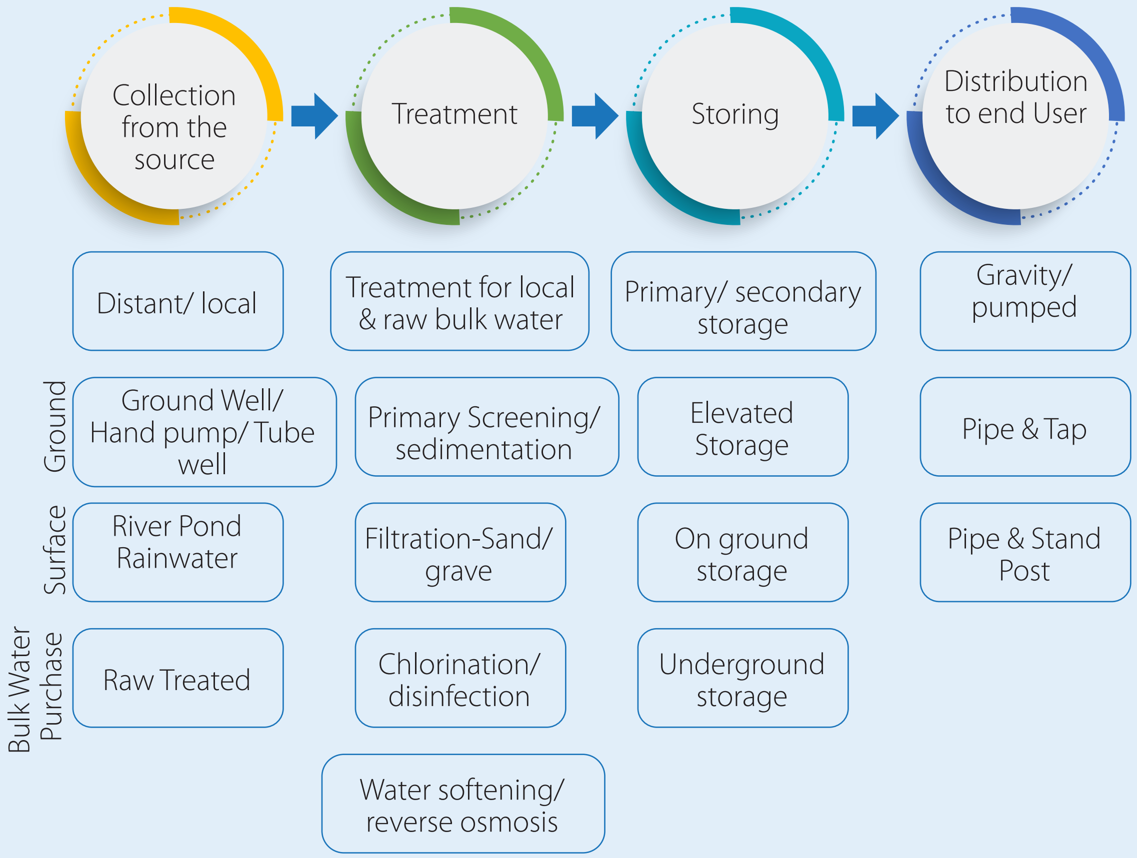
According to a NCERWASS report, in 2022 there were 18,109 RWSSs across Viet Nam's 63 provinces and cities. Among these, two typical water supply technologies were identified: use of mechanized pumps (powered by electricity, gasoline, or diesel) and self-flowing systems. Self-flowing water supplyaccounted for 61 percent of systems, while 39 percent (7,000 systems) utilize mechanized pumps.

Percentage of rural population with access to clean water

Viet Nam has a relatively high rural population, accounting for 62.7 percent of the national total in 2022 (62.37 million people). With efforts to improve the Government's water supply infrastructure, 69.7 percent of the rural population (12,430,994 households) used clean water meeting QCVN 02:2009/BYT[12] standards in 2022. However, there are still regions significantly below the national average,include the Northern Mountains, North Central Coast and Central Highlands, with high poverty rates and ethnic minority communities.

12 QCVN02:2009/BYT National Technical Regulation on Domestic Water quality.

FIGURE 2. COMPONENTS OF WATER SUPPLY SYSTEM



Operational status of rural clean water supply system

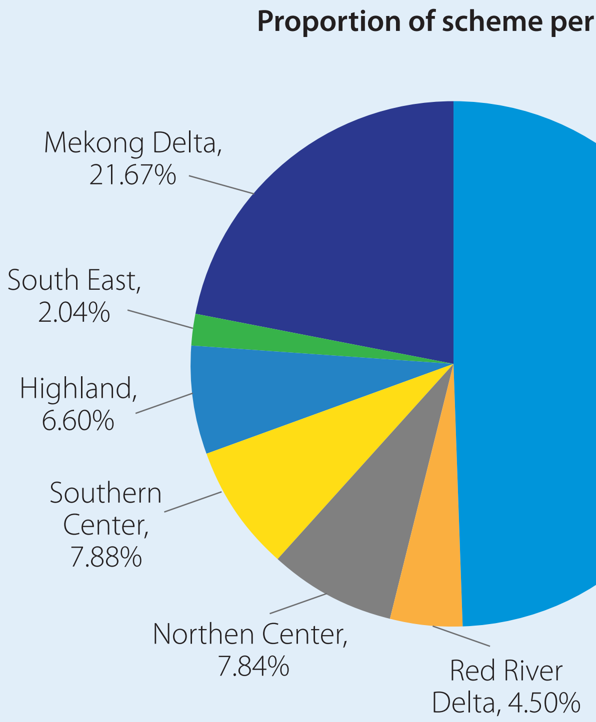
Rural centralized water supply systems are distributed across all geographical regions of Viet Nam, with the highest proportion in the Northern Mountains region, accounting for 49 percent or 8,957 systems.

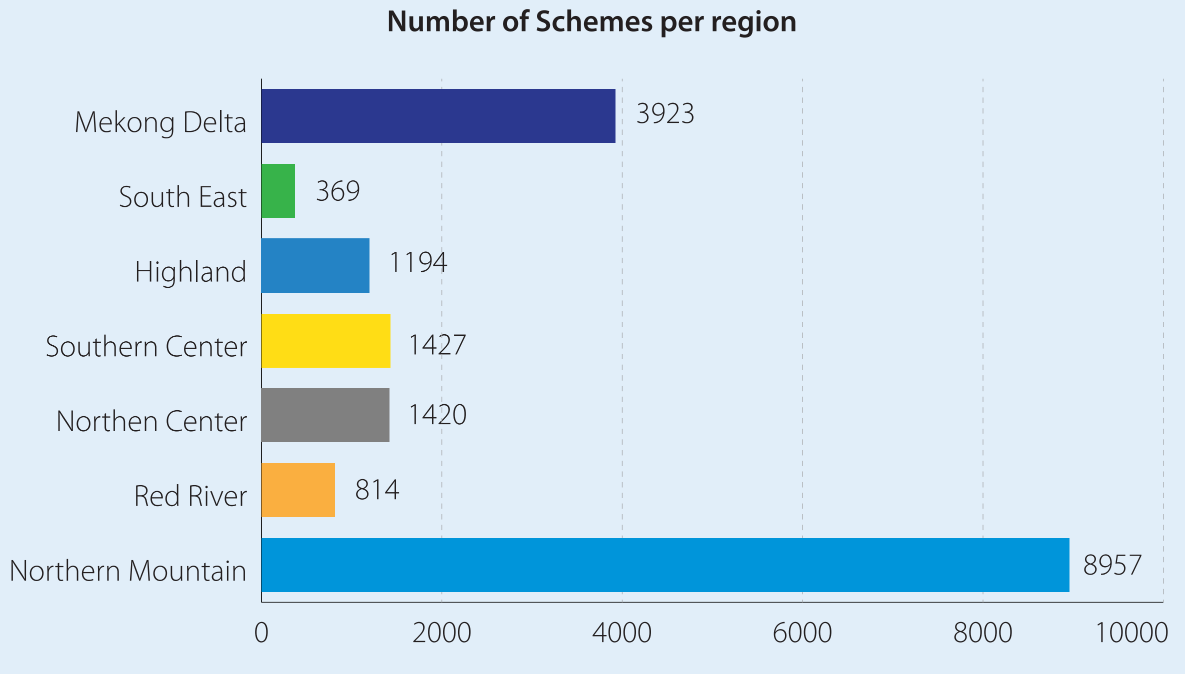
According to a NCERWASS report, the current operational status of RWSSs is as follows:

- Sustainable operational rate: 32.0 percent
- Relatively sustainable operational rate: 26.0 percent
- Unsustainable operational rate: 27.0 percent
- Non-operational rate: 15.0 percent

The relatively high rates of unsustainability and non-operation (42 percent) are attributed to: aging infrastructure resulting in deterioration, weak management and operation of water supply systems. This leads to system damage and sub-optimal clean water production efficiency, insufficient funds for maintenance, upgrades or expansion, and limited management capacity and operational skills of staff members.

FIGURE 3. PERCENTAGE OF RWSSs BY GEOGRAPHICAL REGION



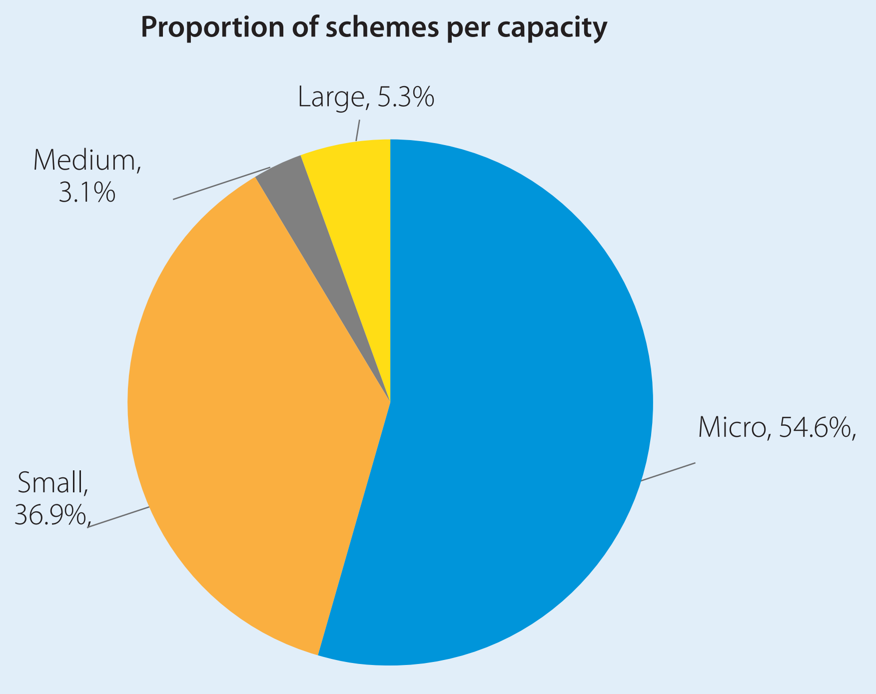


Scale of RWSSs

RWSSs are categorized per capacity as follows:

- Very small-scale: capacity less than 50 m^3/day and serves a maximum of 100 households.
- Small-scale: capacity less than 300 m^3/day and serves a maximum of 500 households.
- Medium-scale: capacity less than 500 m^3/day and serves a maximum of 1,000 households.
- Large-scale: capacity equal and more than 500 m^3/day and more and serves more than 1,000 households.

FIGURE 4. PROPORTION OF SYSTEMS CATEGORIZED PER CAPACITY OF SYSTEMS

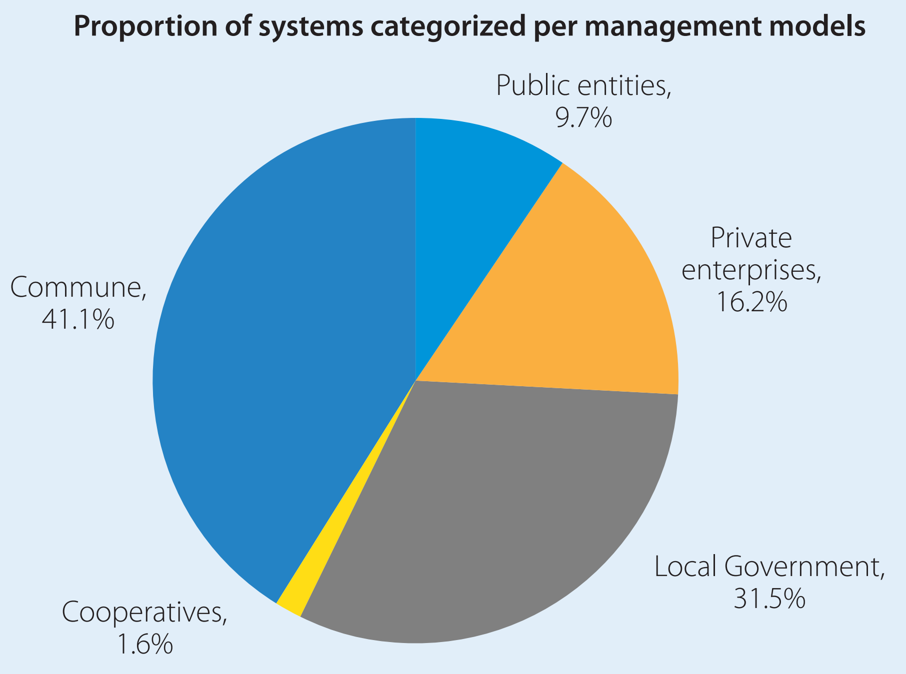


Management models of RWSSs

In the rural water supply sector, several management models being applied:

- Public entities (PCERWASS, management board) directly manage, operate and exploit: 1,757 out of 18,109 systems (9.7 percent).
- Private enterprises manage, operate, and exploit: 2,931 out of 18,109 systems (16.2 percent).
- Commune People's Committees (local government) manage, operate and exploit: 5,701 out of 18,109 systems (31.5 percent).
- Cooperatives manage, operate, and exploit: 283 out of 18,109 systems (1.6 percent).
- Commune People's Committees delegate community management, operation, and exploitation: 7,437 out of 18,109 systems (41.1 percent).

FIGURE 5. PROPORTION OF SYSTEMS CATEGORIZED PER MANAGEMENT MODELS

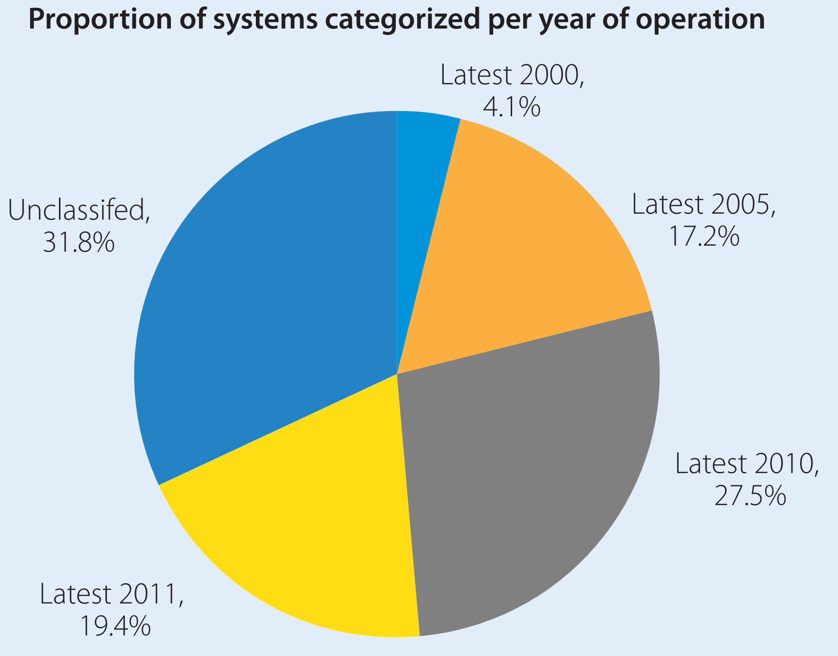


Years of construction of RWSSs

According to aggregate data of 63 provinces, operations of RWSSs commenced as follows:

- Pre-2000 (more than 22 years): 740 systems (4.1 percent).
- 2001-2005: (17-21 years) 3,115 systems (17.2 percent).
- 2006-2010 (12-16 years): 4,976 systems (27.5 percent).
- Since 2011-present (11 or less years): 3,516 systems (19.4 percent).
- Uncategorized: 5,762 systems (31.8 percent).

FIGURE 6. PROPORTION OF SYSTEMS CATEGORIZED PER YEAR OF OPERATION



Energy sources for RWSSs

Electricity is a main energy source to operate the systems.

- Currently, nearly 100 percent of water supply systems use grid electricity, 3-phase 380V-50 Hz grid or single-phase electricity, 220 V-50 Hz. Few systems are equipped with backup generators.
- Only 40 water supply systems have solar power systems installed and these have small capacities. Solar power systems only serve as an additional and supporting power source for systems.
- RWSSs require a constant and stable power supply as they produce water all day-night.

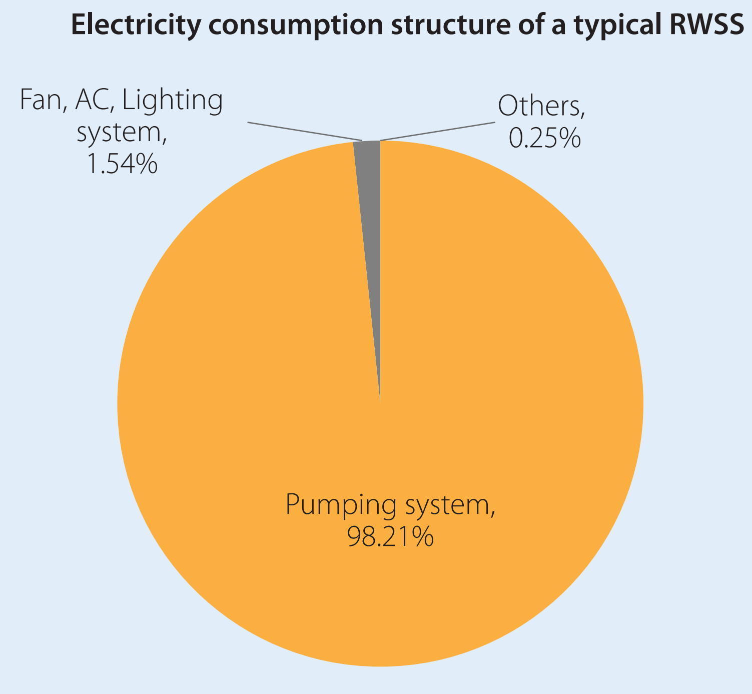
Electricity consumption structure of RWSSs

RWSSs operate 24 hours a day. The water pumping activity is the most energy consuming step in the operation of the water supply system.

A typical electricity consumption profile of a RWSS is as follows:

- The raw water pumping system (level 1) and clean water pumping system supplying water to consumers (level 2), auxiliary pumps (chemical pumps, washing pumps) account for 95 percent-98percent of the station's electricity consumption.
- Lighting, fans and air conditioning systems account for 1.5percent -2percent of the station's total electricity consumption.
- Other electrical devices (computers, electric water heaters, rice cookers, televisions) account for 0.25percent -0.5percent of the station's total electricity consumption.

FIGURE 7. POWER CONSUMPTION STRUCTURE OF A TYPICAL RWSS

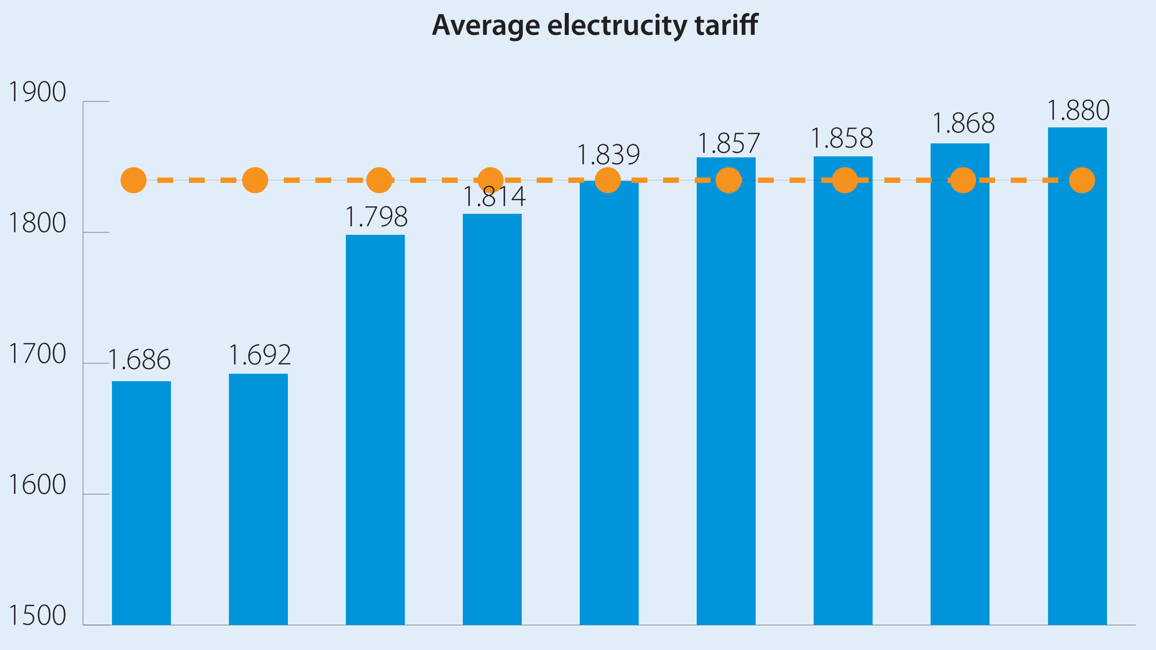


Pumping clean water for distribution to consumers is the major energy use of surface water-based supply systems, usually accounting for 95 percent of electricity consumption. The remaining electricity usage is split between raw water pumping and the treatment process. Groundwater-based supply systems are generally more energy intensive than surface water-based systems because of higher pumping needs for water extraction. However, groundwater usually requires much less treatment than surface water, often only for the chlorination of raw water, which requires little electricity.

Electricity tariff

In 2022, the average electricity tariff ranged from 1,686 VND/kWh to 1,936 VND/kWh. The variation is due to differences in the systems' mode of operation. The sector average is 1,840 VND/kWh (Figure 8).

FIGURE 8. ANNUAL AVERAGE OF ELECTRICITY TARIFF IN SURVEYED SITES (VND/KWH)



Clean water tariff

Currently, the applied rural clean water tariff ranges from 500-12,000 VND/m^3 depending on the province, water source (surface or underground water) and type of technology used, specifically:

- Northern mountains: 500-3,500 VND/m^3
- Red River Delta: 3,000-12,000 VND/m^3
- North Central Coast: 5,000-8,000 VND/m^3
- South Central Coast: 5,500-9,500 VND/m^3
- Central Highlands: 3,000-5,000 VND/m^3
- Southeast: 6,000-10,000 VND/m^3
- Cuu Long River Delta: 4,000-12,000 VND/m^3

Red River Delta, Mekong Delta, and Central Coast region provinces generally charge based on tariff rates enough to cover water supply system management and operation costs, while northern mountainous and Central Highlands provinces hardly collect enough water revenue. Most gravity flowing water supply systems in mountainous areas usually do not charge based on water consumption. They simply charge minimal flat rate (2,000-15,000 VND/household/month). Some localities, such as Tay Ninh and Kien Giang, have policies to subsidize about 50 percent of poor households' water bills.

Specific Energy Consumption

The average specific energy consumption of surveyed RWSSs is 0.465 kWh/m^3 of production water. However, there is a large difference in the size of water supply capacity. Specifically, the specific energy consumption of RWSS has:

- Small scale (50 - 300 m^3/day night): 0.385 kWh/m^3;
- Medium scale (300 - 1000 m^3/day night): 0.569 kWh/m^3;
- Large scale (1000 - 5000 m^3/day night): 0.460 kWh/m^3;
- Very large scale (>5000 m^3/day/night): 0.310 kWh/m^3

Ratio of electricity tariff to total operating cost of water supply systems

The ratio of electricity tariff to total operating cost for RWSSs differs between provinces and systems.

The survey results indicate that current electricity consumption costs account for a relatively significant portion of most RWSSs' overall operating expenses, averaging 15-35 percent of total costs. However, for 10 percent of surveyed systems this proportion exceeds 50 percent of total expenses. Conversely, less than 15 percent of RWSSs have a payment rate for electricity bills below 10 percent.

2.2. RELEVANT POLICY AND REGULATORY FRAMEWORKS

2.2.1. POLICY FOR RE SOLUTION

The government has set ambitious quality goals for the water sector and rural clean water supply, in particular. Specifically, in the *National Strategy for RWSSs and Environmental Sanitation until 2030, with a vision to 2045*[13], the government aims to have 65 percent of the rural population using clean water that meets quality standards by 2030, with a minimum quantity of 60 liters per person per day. By 2045, the goal is 100 percent of rural residents access safe, sustainable and clean water and sanitation. It is estimated that to achieve the 2030 target, Viet Nam needs around USD 384 million to upgrade RWSSs to access to clean water for 23.5 million people.[14]

To ensure the sustainable development of the rural clean water supply – in addition to financial, technological and capacity-building solutions – the strategy also includes applications of RE solutions such as solar, waves and wind energy for clean water production.

2.2.2. POLICY FOR APPLICATIONS OF RE

Viet Nam is implementing policies to promote nationwide development of RE, especially solar and wind energy. By the end of 2020, the total capacity of solar power put into operation in Viet Nam reached 16,640GW with electricity output in 2020 of 12,084GWh. The actual installed capacity is more than 20,000MW. According to the *Electricity Development Master Plan in Viet Nam for 2021-2030, vision to 2050* referred to as Power Development Plan VIII (PDP VIII) approved on 15 May 2023 (Decision No.500/QD-TTg), solar power will contribute 6.3 percent by 2030 and 19.3 percent by 2050 to the total commercial electricity produced in Viet Nam.

Resolution 55-NQ/TW, issued by the Politburo on 11 February 2020 on the *Orientation of the Viet Nam's National Energy Development Strategy to 2030, vision to 2045* (Resolution 55-NQ/TW) expressed new views on the Party's policies on national energy development: "a priority for exploitation, thorough and effective applications of RE, new energy, clean energy". Moreover, it sets specific targets as follows: the proportion of renewable energy sources in the total primary energy supply will reach 15 percent -20 percent by 2030, 25 percent -30 percent by 2045.

The goal of the recently approved PDP is that by 2030, 50 percent each of public buildings and residential houses willuse self-production and self-consumption solar power. The development plan for solar power is a breakthrough policy to promote development of solar power on roofs of homes and office building, especially in areas at risk of power shortages By 2030, the capacity of these power systems is estimated to increase by 2,600MW. This type of power system is prioritized for unlimited capacity development, provided it is reasonably priced and makes use of the existing power grid, without having to upgrade. It should be emphasized that solar power systems for RWSSs belong to this type of rooftop solar power.

13 *Decision No. 1978/QD-TTg by the Prime Minister: Approval of the National Strategy for Rural Clean Water Supply and Environmental Sanitation until 2030, with a vision to 2045.*

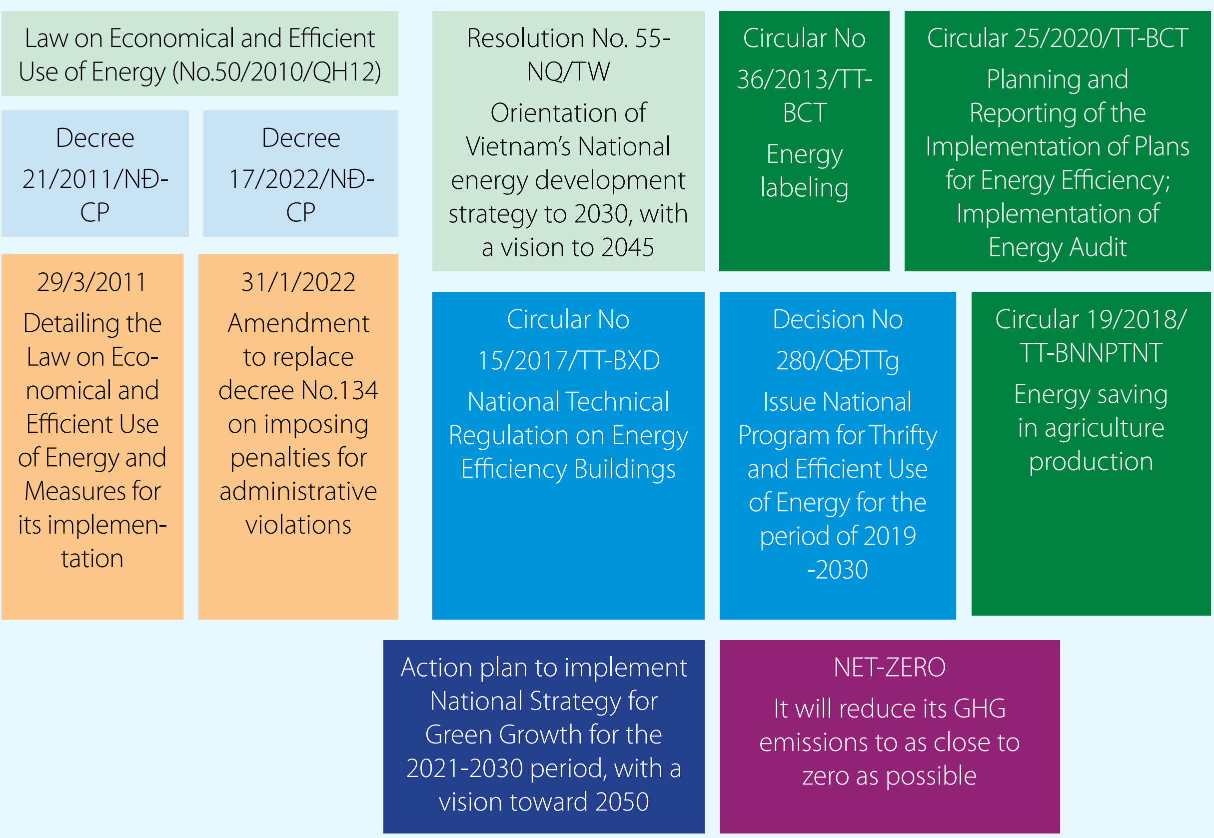
14 *UNICEF: Summary report on mobilizing funds for the water sector: investment capital needs and potential financing tools.*

The *National Strategy on Water Supply and Rural Sanitation by 2030, vision to 2045* identified the need to research and deploy, apply, exploit and use RE such as solar, wave, wind energy in clean water production. Besides, many provinces have developed and approved this national strategy for exploitation and use of RE such as solar energy, wave, wind in rural clean water production and treatment of domestic wastewater and livestock waste.

2.2.3. POLICY FOR PROMOTING EE USE

Over the past decade, Viet Nam has developed and enacted mechanisms and policies to promote EE. Figure 9 presents several legal documents related to EE promulgated by the National Assembly, Government, Ministries and Sectors.

FIGURE 9. POLICY FRAMEWORK ON EE



In 2010, the *Law on Economical and Efficient Use of* Energy (Law No. 50/2010/QH12) was approved by the 12th National Assembly and took effect on 1 January 2011.

This law is considered a breakthrough in creating a favourable environment for EE in Viet Nam. Since then, a system of macro-level legal documents including government decrees, prime ministerial decisions and ministry circulars (nearly 30 legal documents) has been developed, instituted and issued. This has formed a relatively complete legal framework unifying activities in the field of EE.

Resolution No.55-NQ/TW (11 February 2020) of the Politburo on strategic orientations for *Viet Nam's National Energy Development to 2030, with a vision to 2045* sets out the guiding principle that economical and efficient use of energy and environmental protection must be considered as an important national policy and be the responsibility of society.

Viet Nam is implementing the *Viet Nam National EE Programme* (known as VNEEP3) as regulated by Decision 280/QD-TTg issued on 13 March 2019. According to VNEEP3, the country has set a target to save 5-7 percent of total energy consumption during 2019-2025 with a series of activities such as applying high-efficiency energy-consuming technology, eliminating outdated technology, implementing EE management, a financial mechanism for investment in EE, and mobilizing private participation. During 2026-2030, the programme is expected to save 8 percent -10 percent of total energy consumption.

In addition, VNEEP3 defines groups of target sectors, identifies specific actions and expenses for EE activities. The programme consists of a set of activities to encourage, promote and propagate EE, a programme for science and technology research, and development and implementation of necessary management measures. Some EE targets have been set for major energy users. The rural water supply sector is not on the list of major energy users. Nevertheless, it is important to note that the EE potential for this sector is high since electricity consumption is a major cost component in RWSS operating costs.

There are several national programmes that focus on energy benchmarking. The baseline for such energy consumption benchmarks is usually related to national energy statistics collected and consolidated by the MOIT. Since 2017, the energy balance at a national level was conducted by the General Statistics Office (GSO), which shares its data with MOIT. There are also studies and roadmaps set for EE, conducted through benchmarking methodologies by MOIT and international donors. Some industrial sectors have sector-specific regulatory frameworks to streamline efforts for facilities to use efficient equipment and technologies. But, the rural water supply sector has not been identified yet.

Table 1 summarizes Viet Nam's EE targets according to policy documents in recent years.

TABLE 1. POLICY GOALS ON EE AND GREENHOUSE GAS EMISSION REDUCTIONS

Document	Main content	Target
Resolution No. 55-NQ/TW (11 February 2020) issued by Politburo	Orientation of Viet Nam's National Energy Development Strategy to 2030, with a vision to 2045	The ratio of EE to total final energy consumption compared with the BAU will reach 7% in 2030 and 14% in 2045.
Decision No. 896/ QĐ-TTg dated 26/7/2022	National Strategy for Climate Change until 2050	Reducing GHG emissions according to net-zero emission target by 2050. In which, the energy sector will reduce 32.6% by 2030 and 91.6% by 2050.
Decision No. 1658/QĐ-TTg dated 1/10/2021	National Strategy for Green Growth for 2021-2030, with a vision toward 2050	Primary energy consumption per average GDP in 2021-2030 will decrease 1.0% -1.5%/year. By 2050, on average, each 10-year period will decrease by 1.0%/year. The intensity of GHG emissions as a percentage of GDP decreased at least 15% compared to 2014, and by 2050 will reduce by at least 30% compared to 2014.
Decision No. 280/ QĐ-TTg dated 13/3/2019	Viet Nam National EE Programme from 2019-2030 (VNEEP3)	Achieve EE of 5% -7% of total national energy consumption in 2019 to 2025 and from 8-10% of total national energy consumption during 2019-2030.

2.2.4. GREENHOUSE GAS EMISSION REDUCTION POLICIES OF VIET NAM

Viet Nam's Green Growth Strategy sets strategic tasks to reduce GHG intensity of industry, promote clean energy and realize clean industrialization. Its targets include objectives of energy intensity and energy consumption, and have mirrored VNEEP targets to some extent as follow:

- During 2011-2020:
  - Reduce intensity of GHG by 8 percent -10 percent in 2020, compared to 2010 baseline
  - Reduce energy intensity by 1 percent -1.5 percent per year
  - Reduce energy consumption by 10 percent -20 percent compared to BAU case and 2010 baseline.
- Vision to 2030:
  - Reduce intensity of GHG by at least 1.5 percent -2 percent
  - In energy activities, reduce GHG by 20 percent -30 percent compared to BAU case and 2010 baseline.

At the COP26 climate conference, Viet Nam made a commitment to bring net emissions to zero by 2050 and joined the pledge to reduce global methane emissions by 2030. It also joined Glasgow leaders' declaration on forests and land use, and the Global Coal to Clean Power Transition Statement.

Decree 06/2022/ND-CP forms the legal corridor for Viet Nam's carbon emission reductions commitment. Passed on 7 January 2022, it outlines key reduction targets for each ministry and the fields in which these ministries are responsible for reducing GHG emissions. Table below presents ministries 's GHG reduction targets by 2030.

TABLE 2. VIET NAM'S GREENHOUSE GAS REDUCTION TARGETS BY MINISTRY BY 2030

Ministry	Field	CO_2 million tonnes
Ministry of Industry and Trade	Energy production Energy consumption in industry	268.5
Ministry of Transport	Energy consumption in transportation	37.5
Ministry of Agriculture and Rural Development	Energy consumption in agriculture Agricultural production Forestry	129.8
Ministry of Construction	Industrial processes Energy consumption in cement production Building	74.3
Ministry of Natural Resources and Environment	Waste treatment	53.7
Total by 2030		**563.8**

Source: Decree 06/2022/ND-CP on Mitigation of Green House Gas (GHG) Emissions and Protection of Ozone

BOX 1. HOW CAN NET-ZERO BE ACHIEVED

Transitioning to a net-zero world is one of the greatest challenges humankind has faced. It calls for nothing less than a complete transformation of how we produce, consume, and move about.

The energy sector is the source of around three-quarters of greenhouse gas emissions today (*) and holds the key to averting the worst effects of climate change. Replacing polluting coal, gas, and oil-fired power with energy from renewable sources, such as wind or solar, would dramatically reduce CO2 emissions.

Decree 06/2022/ND-CP also reflects Viet Nam's ambitious plan for establishing a carbon trading market. It outlines the key foundations of the platform and sets a timeline for trial operation by 2025, and full operation by 2028.

2.3. AVAILABLE FINANCING PROGRAMMES FOR EE AND RE

To promote the economical and efficient use of energy, and gradually increase the contribution of RE to the country's energy mix, the Government of Viet Nam has issued numerous mechanisms and policies to mobilize financial sources into development of RE and implementation of EE projects.

Law on Economical and Efficient Use of Energy 2010 which sets the obligations and rights of individuals and companies with respect to efficient energy use. It established several incentives for EE projects including tax exemptions and reduction, land use incentives, soft loans from Viet Nam Development Bank, National Foundation for Science and Technology Development, and the National Technology Innovation Fund.

In 2018, the State Bank issued Decision No.1604/QD-NHNN (7 August 2018) approving a system for green banking growth in Viet Nam, which encourages banks to increase the proportion of loan capital allocated for prioritized green sectors and areas specified in the green project list promulgated by the State Bank.

Aside from the public budget, Viet Nam has mobilized many international organizations and foreign donors such as UNDP, WB, ADB, UNIDO, IFC, JICA, DANIDA, USAID, KOICA, GIZ... to provide grants or technical assistance in implementation of several EE and RE projects. These projects have also supported the formation of various financial mechanisms.

The World Bank together with the Green Climate Fund co-financed and started the programme *Viet Nam Scaling up EE for Industrial Enterprises* (VSUEE) for implementation from 2021-2025. It established *a Risk sharing* fund (RSF) to more effectively support access to commercial capital for EE projects. RSF will provide partial credit guarantees to participating financial institutions to cover the risk of potential losses in case a borrower defaults. This is a guarantee facility for industrial enterprises and ESCOs. The project is expected to mobilize approximately USD250 million in financing from five commercial banks for EE projects by 2025.

Loans from financial institutions and banks are another key source. Numerous local banks have arranged credit to finance projects related to RE-EE investments or green credit. This is often done in cooperation with international funding organizations such as International Finance Corporation and the World Bank. Loans to EE-RE projects are often under a financing programme with preferential or lower loan interest rates compared to commercial lending programmes.

In addition, RE-EE projects can also borrow with preferential interest rates from the Viet Nam Environmental Protection Fund.[15]

15 Viet Nam Environment Protection Fund (VEPF) is a State financial body under the Ministry of Natural Resources and Environment

3. RENEWABLE ENERGY APPLICATIONS FOR RURAL WATER SUPPLY SYSTEMS IN VIET NAM

3.1. CURRENT STATUS OF RE APPLICATIONS IN RURAL WATER SUPPLY SYSTEMS

3.1.1. RENEWABLE ENERGY SOURCES TO RWSSs

Viet Nam has significant potential for the utilization and development of various RE sources, including wind energy, solar power, hydro power, biomass energy, geothermal energy, and offshore energy (waves, tides, ocean heat). To leverage these strengths, Viet Nam has actively promoted development and applications of RE – especially solar power, wind power and hydroelectricity – for several years. By the end of December 2022, electricity generation from RE sources was estimated to have reached 130 billion kWh, accounting for nearly 48 percent of electricity generation in Viet Nam's power system. This includes 35 percent from hydroelectricity and 13 percent from wind power, solar power, and biomass energy combined.[16]

In rural clean water supply, according to PCERWASS reports and survey results in six provinces, it is evident that **among RE sources, only solar power has provided electricity for RWSSs**. The total number of systems equipped with solar power exceeds 40, distributed across 20 provinces and cities nationwide.

The reason for exclusive applications of solar power in these systems can be attributed to the following main factors:

- RWSSs are scattered in rural residential areas, so only solar power systems are appropriate as they can be installed anywhere.
- In general, electricity demand for each rural clean water project is unique and typically not significant. Solar power systems are modular, with capacity easily changed depending on the load requirement.

16 *Renewable Energy in Viet Nam in 2022: Events, Achievements, and Challenges. Viet Nam Energy Journal, 2023.*

- Solar power systems are available everywhere, especially in the central, Central Highlands and southern regions with high levels of sunlight.
- The design, investment and installation of solar power system is fast and convenient, with relatively simple operation and maintenance.
- The government has established mechanisms and policies to support development of solar power projects.[17] Accordingly, solar power systems are recognized by the government as one of two pivotal sources of RE alongside wind power in the national power structure by 2050.

3.1.2. AREAS WITH RWSS SOLAR POWER SYSTEMS

By 2022, about 40 solar power systems had been installed in RWSSs in 20 provinces and cities nationwide.

During 2013-2015, within the framework of the "Supplying Water to Mekong Delta with RE project" funded by the Danish government (DANIDA). Among 32 solar power systems with a total aggregate capacity of 320kWp were installed in RWWSs in 13 provinces of the Mekong Delta.[18] During that time, most rural and remote areas in 13 southern provinces did not have grid power. Out of the 32 solar power systems installed, 30 are off-grid solar power systems, and 2 are on-grid solar power systems.

Furthermore, within the framework of the Danish Government-funded project and in cooperation with the Centre for Rural Water Supply and Sanitation, two other solar power projects were implemented. One is to supply electricity to a water supply pump system at Binh Yen ethnic minority boarding high school in Dinh Hoa district, Thai Nguyen province and the other is in Quang Binh province.

In recent years, mainly during 2018-2020, a number of government and local agency-funded solar power systems were installed to assess their ability to supply electricity to RWSSs in the provinces of Nghe An (one system, installed in 2019), Dak Lak (one, 2008), Tay Ninh (one, 2018), and Binh Thuan (one, 2019).

3.1.3. SOLAR POWER TECHNOLOGIES APPLIED IN RWSSs

There are two types of solar power systems, off-grid and grid-connected, which have been installed in RWSSs in Viet Nam as follows:

Independent solar power system configuration (off-grid solar power system)

Based on surveys of RWSSs, it was noted that most independent solar power systems installedin RWSSs were no longer operational or had been expanded to connect to the grid due to:

- Independent solar power systems installed for RWSSs during 2014-2015 have small capacites (£ 12kWp), use independent solar power system configurations and do not have battery storage or power storage units.
- Water pumps used in these systems are small capacity submersible pumps. These pumps are suitable for small capacity solar power systems and have good water pumping efficiency. However, most submersible pumps had broken down after five-seven years of operation. When

17 Decision No. 11/2017/QD-TTg on mechanism for encouragement of development of solar power in Vietnam, and Decision No. 13/2020/QD-TTg on Mechanisms to Promote the Development of Solar Power Projects in Viet Nam

18 An Giang, Bac Lieu, Ben Tre, Can Tho, Ca Mau, Dong Thap, Kien Giang, Hau Giang, Long An, Soc Trang, Tien Giang, Tra Vinh and Vinh Long.

submersible pumps are damaged, they are not replaced with the same types of pumps due to costs and wait times when buying from foreign suppliers. At the same time, installed solar power systems were not used as they were no longer needed because they are already powered by electricity from the national grid. A small number of RWSSs collect unused solar panels from other RWSSs to assemble them into larger capacity solar power systems and convert the configuration into a grid-connected power system.

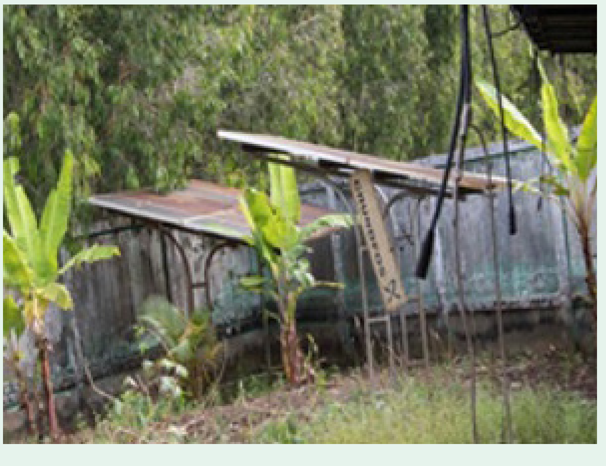
- The national electricity grid is now available in almost all rural communes, including remote and isolated areas. As the capacity of RWSSs is growing and the investment cost of solar power is still high, RWSSs have switched to using grid electricity. Currently, all RWSSs use low-voltage grid electricity to operate clean water production equipment.
- Another important reason is technical staff and workers operating RWSSs are not professionally trained in solar power systems, hence they lack operation and maintenance knowledge. Meanwhile, solar power systems are new and high-tech power technology in Viet Nam. Some solar power systems were found to be damaged as the solar panel was not cleaned and repaired (Figure 11).

ON-GRID SOLAR POWER SYSTEM[19]

At present, almost all rural communes (98 percent) have grid access and all solar power systems installed after 2018 are grid-connected. The electricity grid has the role of stabilizing the power supply for RWSSs so they can operate continuously and effectively. If solar power systems are not grid connected, the electricity produced will change continuously and there is no assurance of supply at night.

FIGURE 10. COMMON DAMAGE OF SOLAR CELLS

THE PANEL ARE RUSTED, PEELED



SOME ARE SHADED BY TREES

19 *"On-grid" is the type of solar power system connected to the grid, to distinguish it from the off-grid type, not connected to the grid. "Grid connected" is solar power technology connected to the grid. The concept of "net metering" only appeared recently in 2017, after Decision No.11/2017/QD-TTg on the purchase and sale of grid-connected solar power. In the year of installing Hoa Binh solar power, in 2015, there was no electricity purchase and sale mechanism. At that time, the solar power source connected to the grid was simply to provide stable power for RWSSs.*

The number of grid-connected solar power systems installed after RWSSs is not much, mainly concentrated in the south and south central regions. It should also be added that funding to set up these solar power systems was either from PCERCWSS or donor organizations. There are no solar power systems self-financed by RWSSs, including privately-owned ones.

On-grid solar power systems installed in RWSSs have small capacity, up to 50kWp, but most operate effectively with significant contributions to total electricity used by RWSSs.

3.1.4. SAMPLE CASES OF RWSSS WITH SOLAR POWER SYSTEM APPLICATIONS

The following section outlines the operational status of some surveyed *RWSSs*.

Case 1: RWSSs in Hoa Binh commune – An Giang

Year installed	2015
Source of funds	International (sponsored by DANIDA)
Capacity of RWSS	600m^3/day
Capacity of solar power system	10kWp grid-connected, consisting of 40 solar modules, 250Wp/module from Topraysolar, two grid connection inverters and one electrical cabinet to connect direct current (DC) and alternating current (AC)
Technology	On grid
Annual electricity production	13.768 kWh/year
GHG emission reduction/year	11,01 tCO_2/year

Operating Status:

The solar power system is currently functioning stably. The tasks of operation, maintenance and servicing of the solar power system are carried out by the technical personnel of the RWSS. However, it was noted that these technical staff are only trained on operating procedures and clean water treatment technology, not on the operation and maintenance of the solar power system. In the eveant of a technical issue, staff members typically search for information on the internet to find temporary solutions. Furthermore, the RWSS lacks manuals for the operation and maintenance of the solar power system.

Case 2: RWSSs in My Thanh – An Giang province

Year installed	2014
Source of funds	DANIDA
Capacity of RWSS	200m^3/day
Capacity of solar power system	Total capacity is 6kWp, consisting of four solar panels with capacity of 1.5kWp per panel
Technology	Provide power directly for DC pump and supported by grid power
Annual electricity production	8,261 kWh/year
GHG emission reduction/ year	6.6 tCO_2/year

Operational Status:

The system has total solar power capacity of 6kWp, generated by four solar panels, each with a capacity of 1.5kWp. The system is designed to supply power to four DC water pumps, with two pumps serving as level I pumps (primary pumps), and two pumps serving as level II pumps (secondary pumps).

Normally, the pumps are directly powered by the solar power system. However, when the solar power system does not generate enough electricity (at night), the plant turns off and switches to mains power. The mains power supplies AC current which passes through the converter to be converted to DC current to power DC pumps.

In 2019-2020, two level I (primary) pumps were damaged and replaced by AC pumps, which get electricity directly from the grid. Two DC pumps level II (secondary) still operate stably.

Two solar panels, each with a capacity of 1.5kWp, previously supplied power to two level 1 pumps. After the DC pumps failed, RWSSs reconnected the control cabinet system to integrate the solar panel together into solar panel 3kWp. DC current generated by the solar panel is converted to AC current, 220V, 50Hz, by an inverter. The current after this inverter is combined with the grid current, supplying power to two pumps of level 1, which have been replaced by AC pumps. Thus, the RWSS has been creative and made full use of the solar panel capacity. However, this is only a short-term solution and not part of the original design. According to technical staff, in the near future, all DC pumps will need be replaced with AC pumps due to ease of replacement and maintenance. The pumps do not need to be submerged in the water tank.

Regarding operations, warranty and maintenance, RWSS technical staff have only been trained in operating procedures and clean water treatment technology, not in the use of solar power sources and efficient use of energy.

Case 3: RWSSs in Thanh An, Thanh Thang, Thanh Loi - Can Tho province

Year installed	2015
Source of funds	Can Tho PCERWASS
Capacity of RWSS	6.600m^3/day
Capacity of solar power system	55kWp
Technology	Rooftop, on-grid connection
Annual electricity production	75,723 kWh/year
GHG emission reduction/year	60.58 tCO_2/year

Operational Status:

In 2015, PCERWASS implemented a pilot investment in a 55KWp grid-connected solar power system with a total cost of more than VND2 billion for RWSSs concentrated for Thanh An, Thanh Thang and Thanh Loi communes, Vinh Thanh district. According to PCERWASS, the expected payback period is 10 years. Currently, the system is operating well and efficiently, largely due to the successful integration of selling electricity back to the grid.

Case 4: PCERWASS Binh Thuan province

Year installed	2019
Source of funds	National Programme on Demand Side Management
Capacity of solar power system	20kWp, total installation cost is VND470 million
Technology	Rooftop, on-grid connection
Annual electricity production	27,536 kWh/year
GHG emission reduction/year	22.03 tCO_2/year

Operational Status:

In 2019, Binh Thuan PCERWASS installed the rooftop solar power system at its headquarters, with a capacity of 20kWp and total cost installation of VND470 million. According to the Binh Thuan PCERWASS, the system works efficiently and saves an average of VND5 million per month. The expected payback period is about eight years.

On the basis of the efficiency of the solar power system installed at its headquarters, Binh Thuan PCERWASS proposed and requested a policy framework to install pilot solar power systems for water supply stations in the province. However, as the mechanism for buying and selling solar power under Prime Minister's Decision No.13/2020/QD-TTg had expired, along with difficulties in the process of applying for a construction permit, fire and explosion prevention, construction safety and environmental assurance, replication of the model has been held in abeyance.

Case 5: Thuan Hoa centralized water supply system

In 2014, the Thuan Hoa Centralized Water Supply System in Soc Trang province received funds from a DANIDA project to install a solar power system. Currently, the system is not operational. All solar panels have been relocated and moved to My Huong 2 RWSS. In the operating room of Thuan Hoa RWSS, there is only a control cabinet not connected to the station grid power system.

Solar power pump control cabinet that stopped working in Thuan Hoa RWSS

The reason for the system no longer functioning is due to malfunction of the submersible pump and use of grid electricity to operate the facility.

3.1.5. DEVELOPMENT OF SOLAR ENERGY APPLICATION PROJECT/PROGRAMMES

The increased adoption of solar power in Viet Nam – along with its potential to positively impact the economy, environment and society – is widely acknowledged. This is particularly significant given the escalating complexity of climate change and its heavy impact on people's lives, resources, productivity and health. As a result, numerous PCERWASS plan to apply solar power systems for electricity supply of RWSSs to lower production costs, reduce clean water costs and protect the environment.

Leading this trend is Soc Trang PCERWASS. It surveyed the current roofing status of 80 out of 147 RWSSs with an estimated area of 12,110 m^2. The centre then developed the project "*Applications of solar power systems for RWSSs in Soc Trang province*" with a total expected capacity of 2,018kWp and total investment of VND35,523 million. Its objective is to reduce RWSSs' use of grid electricity by 20 percent and electricity costs by at least 5 percent through use of solar power systems. Soc Trang PCERWASS will hire a package of solar power systems through public bidding.

At the time of writing this report, Soc Trang PCERWASS' draft has been submitted to relevant departments and sectors for comments to consolidate the investment plan, identify ways to cooperate with investors and use public roof space to implement the project.

An Giang PCERWASS also planned to lease whole solar power systems to supply electricity to RWSSs in its province. Binh Thuan PCERWASS, based on the efficiency of the solar power system installed at its headquarters, proposed a policy framework to pilot solar power systems for the RWSSs in its area. However, these initiatives by the three PCERWASS have not gained traction due to changes in the government's policies on solar power. Hence, with no new mechanisms and policies issued yet, the absence of implementing regulations on public asset management and lack of guidance for public-private partnership (PPP) projects.

3.2. ECONOMIC, SOCIAL AND ENVIRONMENTAL BENEFIT OF SOLAR POWER SYSTEM IN RWSS

As previously highlighted, with most solar power systems in RWSSs installed 10 years ago, relevant data is no longer available. Additionally, the capacity of these solar power systems is small due to the time of installation, when the initial investment for solar power technology was relatively high. Therefore, evaluating their economic efficiency may not yield impactful results. However, based on the current operational status of these solar power systems as described above, it is evident they have positive economic, social, and environmental impacts.

From an environmental perspective, solar power systems help reduce GHG emissions as they replace fossil fuel-based electricity sources and contribute to environmental protection. On the social front, these systems ensure stable water supply even when grid electricity is unavailable. Economically, they assist RWSSs to reduce electricity costs and contribute to cost savings in water production.

PRELIMINARY ECONOMIC ASSESSMENT OF SOLAR POWER SYSTEMS APPLICATIONS FOR A RWSS

Centralized water supply system in Thanh An - Thanh Thang - Thanh Loi commune, Can Tho province

Below is an estimate of the economic efficiency of applying solar power to a RWSS. The preliminary economic assessment of solar power systems for RWSSs is based on the following assumptions:

(1) Presumptive entry criteria

Items	Parameters	Note
Capacity of solar power system	50kWp	Average capacity of one RWSS
Solar power intensity	4.6kWh/m^2/day	Average solar power intensity in Viet Nam
Investment cost	16 million VND/kWp	Current estimated investment cost
Efficiency of solar power system	82%	Popular value
Average electricity purchase price from the grid for RWSSs	1,828 VND/kWh	1) Normal load hours: 04.00-9.30; 11.30-17.00 and 20.00-22.00 (total 13 hrs): tariff = 1,685 VND/kWh. 2) Peak load hours: 9.30-11.30; 17.00-20.00 (total 5 hrs): tariff = 3,075 VND/kWh. 3) Low load hours: 22.00-04.00 (6 hrs), tariff = 1,100 VND/kWh. So, the average electricity tariff is 1,828 VND/kWh per kWh
Maintenance cost	2.5% of initial investment cost/year	Average value from international data
Bank interest rate	8.2%/year	Based on average bank lending rates as of July 2023
CO2 emission coefficient of Vietnam's power grid	0,7221kg CO2/kWh[20]	The CO2 emission coefficient of Vietnam's power grid in 2021 is 0.7221 kg CO2/kWh
Price of GHG emissions in global market	90 USD/tCO2[21]	Exchange rate in 2023 is 23,500 VND/USD
Lifespan of solar power source	20 years	

20 *Viet Nam's electricity grid emission coefficient in 2021; "Synthesis of data on the CO_2 emission coefficient of the Vietnamese power grid. ITVC GLOBAL, 2021.*

21 *Source: "A visual primer on global carbon market". The HINRICH-IMD sustainable Trade Index 2022 (in collaboration with visual capitalist), page 15. "Currently, in Viet Nam, there is no established carbon market, so the estimates of revenue from selling carbon credits resulting from GHG emission reduciton in the immediate future are only "potential". But certainly in the near future, when the carbon market operates in Viet Nam, this will be an important source of revenue."*

(2) Estimation methods

- Estimate initial ***investment costs***
- Estimate ***annual electricity production*** generated by solar power system and, therefore, electricity not bought from the grid.
- Estimate ***annual costs*** for operation, maintenance.
- Estimate ***the savings realized*** from solar power system due to not having to buy electricity from the grid.
- Estimate ***annual cash flow*** = savings/year – cost/year.
- Estimate ***payback period***.
- Estimate ***net present value (NPV)*** assuming cost of money based on bank interest rate of 8 percent per year.
- Estimate project financial ***internal rate of return (IRR).***
- Estimated cash inflow from two sources: (i) Financial savings from not having to buy electricity from the grid and (ii) Sales of carbon credits resulting from GHG emission reductions (as the carbon market has not yet been formed in Viet Nam, this is only potential cash inflow).

(3) Estimation results

The estimated results are shown in Table 3:

TABLE 3. ECONOMIC FEASIBILITY ASSESSMENT OF SOLAR POWER APPLICATIONS FOR RWSSs

TT	Items	Method	Results (VND)	Results USD)
1	Initial investment cost	(50 kWp x 16 mil/kWp)	VND800 million	USD33,000
2	Annual electricity production	(50kWp x 4.6 x 0.82 x 365)	68,839 kWh/year	
3	Savings from not having to buy electricity from the grid	(68,839 kWh/year x 1,828 VND/kWh)	125.84 million VND/year	USD5,500
4	Operation and maintenance cost/year	(0.025 x 800)	20 million VND/ year	USD830
5	Annual net cash flow	(125.84-20)	105.84 million VND/year	USD4,400
6	Payback period excluding revenue from the sale of carbon credits resulting from GHG emission reduction	(800/105.84)	7.56 years	

TT	Items	Method	Results (VND)	Results USD)
7	Annual revenue potential from sale of annual carbon credits resulting from GHG emission reduction	(68,839 x .00072 x 90 x 23,500)	VND 104.8 million	USD4,400
8	Total revenue potential from the sale of carbon credits resulting from total GHG emission reduction, over 20 years	(68,839 x .00072 x 90 x 23,500 x 20)	VND2,096,56 million	USD87,000
9	NPV of project excluding revenue from sale of carbon credits	The sum of the present value of all project net cash flows at the appropriate discount rate	VND239.15 million Based on 8%/ year discount rate	USD10,000
10	NPV of project including sale of carbon credits at end of project life	The sum of present value of all net cash flows of project at appropriate discount rate	VND688.96 million Based on 8%/ year discount rate	USD28,000
11	Financial IRR of project excluding revenue from sale of carbon credits	The rate at which the sum of present values of all future net cash flows is equal to present value of investment cost IRR compared to required rate of return of investors	12% per year	
12	Financial IRR of project, including cash inflow from sale of carbon credits assumed to be at end of project	The rate at which the sum of present values of all future net cash flow is equal to present value of investment cost IRR compared to required rate of return of investors	15% per year	

Note: (*) Potential revenue from the sale of carbon credits resulting from GHG emission reduction depends on the prevailing market price of carbon credits at the time of sale.

The details of the computation of the net present value and financial internal rate of return are shown in Annext 1 of this report.

(4) Comments

- **Payback period** is estimated to be 7.56 years, which means it will take about eight years to recover capital or recoup the initial cash investment on the solar energy project, while the project has a life cycle of 20 years. In other countries, payback periods of solar water pumping sytems are four-six years. This longer payback period for solar pumping systems in the Viet Nam context does not necessarily mean solar water pumping systems are not financially viable as will be shown in the succeeding analysis using NPV and IRR methods. It only means that in Viet Nam based on current prices, it takes longer to recoup the initial investment for solar water pumping systems. This payback period can be shortened if the solar water systems are connected to the grid to allow excess solar power generated to be sold to the grid, a scheme called net-metering.

  Moreover, solar power systems become cheaper as the years pass. The solar pumping system in Case 3 (RWSS in Thanh An, Thanh Thang, Thanh Loi), constructed in 2015 had a payback period of 10 years. And the solar pumping system in Case 4 (PCERWASS Binh Thuan province), constructed in 2019 had a payback period of eight years. The payback periods of these types of projects are becoming shorter. One of the reasons is prices of solar power systems are decreasing, while prices of fossil-based fuels used to produce grid electricity are increasing.

- **Present value** is the concept that shows an current amount of money today is worth more than that same amount in the future. In other words, money received in the future is not worth as much as an equal amount received today. It is an estimation of how much a future cash flow (or stream of cash flows) is worth now.

- **The estimated net present value (NPV**) **of the project, excluding sale of carbon credits** is VND239.15 million. This is the current worth of all netcash flows a project will generate throughout its life, net of initial project investment cost but excluding sale of carbon credits. The project is, therefore, financially viable since NPV is more than zero even if the sale of the carbon credits is not included in the computation. A NPV that is not negative or more than zero is considered financially viable.

- **The estimated NPV of the project including future sale of carbon credits** is VND688.96 million. The additional monetary present value as a result of the total carbon credits is estimated to be at least VND449.8 million. For purposes of computation it is assumed that the sale of carbon credits will occur in year 20. Revenue from the sale of the carbon credits depends on the price of the carbon credit per metric tonne at the time of sale. However, even though carbon credit price fluctuates from high to low, it is still a very sizeable source of revenue, so it is important to keep track of the carbon trading market. Profits from selling GHG emissions reduction credits are significant, so this market should be taken into account.

- Financial **internal rate of return (IRR) of the project excluding revenue from the sale of carbon credits** is estimated to be 12 percent, per year. The IRR is a metric used to estimate the discounted cash flow return on investment. The higher the IRR, the better the return of an investment. A project is financially viable if the IRR is higher than the cost at the time of investment. Assuming we use the prevailing interest rate of 8 percent, per year as the cost of money, then the project with an IRR of 12 percent is certainly financially viable.

- **Financial IRR** of the project including revenue from the sale of carbon credits at the end of the project life is estimated to be 15 percent, per year. To be on the conservative side, it is assumed that the sale of the carbon credits will be at the end of the project. Any sale of carbon credits at an earlier time will simply mean a higher NPV and IRR of the project.

Based on these financial parameters and assumptions used, the solar power project for RWSSs was found to be financially viable, since the estimated NPV is positive and the estimated IRR is higher that the prevailing interest rate in Viet Nam. Although the payback period is longer than typical ones in other countries, it can be made shorter if the solar energy systems are connected to the grid to allow for net-metering scheme. Furthermore, based on historical trends, prices of solar power systems are expected to decrease as years pass, while prices of fossil fuels used to produce grid electricity are expected to continually increase.

3.3. POTENTIAL AND OPPORTUNITIES FOR RENEWABLE ENERGY IN RURAL WATER SUPPLY SYSTEMS

3.3.1. APPLICATIONS OF RE IN RWSSs

i. RE has potential applications in RWSSs

Among sources of RE, the applications of solar power for RWSSs in Viet Nam has much potential due to the following factors:

Viet Nam has favourable natural conditions for development of solar power

Viet Nam is considered to have great potential for solar power, especially in the south central, Central Highlands and southern regions. Located in the sub-equatorial region and the total average number of sunshine hours exceeding 2,500 per year, the annual average total solar radiation is about 3.2-5.5 kWh/m^2. This is an advantage for Viet Nam to exploit this RE source (Table 4).

TABLE 4. POTENTIAL OF SOLAR POWER IN VIET NAM

TT	Region	Average daily solar radiation density (kWh/m^2 day)	Average annual hours of sunshine
1	Northeast	3.2-3.9	1,500-1,700
2	Northwest	3.9-4.8	1,750-1,900
3	North Central	4.4-5.1	1,700-2,000
4	South Central and Central Highlands	4.8-5.5	2,000-2,600
5	Southern	4.1-4.8	2,200-2,500

ii. Estimating the potential of installing and applying solar power systems for RWSSs in Viet Nam

According to NCERWASS statistics, by the end of 2022, Viet Nam had 18,109 RWSSs, of which 11,000 are gravity water supply systems or self-flowing water, with the remainder using electric pumps.

To assess the size of the potential applications of solar power systems in RWSSs, the following parameters are used:

- RWSSs considered are only those using conduction pumps. Those using gravity water systems are excluded, as their operation is not largely dependent on pumps for water extraction and transportation. RWSSs in areas with high solar power density and sufficient space to install solar panels (such as roofs, reservoirs and open ground) will ensure economic efficiency of solar power systems.
- Regions with high solar power intensity and the corresponding number of RWSSs are: southern region (3,923 RWSSs), southeast (369 RWSSs), Central Highlands (1,194 RWSSs) and south-central region (1,427 RWSSs). This gives a total of 6,913 RWSSs located in regions with high power intensity. Average daily solar power intensity in these regions is 4.6 kWh/m^2/day.
- It is assumed that around 50 percent of these 6,913 RWSSs (3,457) will apply solar power systems. The other assumptions are: (1) capacity of each solar power system is 50 kWp, (2) average investment cost is 16 million VND/kWp, (3) solar power system efficiency of 80 percent, (4) electricity price that RWSSs purchase from the grid is 1,828 VND/kWh (actual price in April 2023), (5) GHG emission factor 0.72 kg/kWh, (6) trading price of carbon credits is 90 USD/tonne and (7) exchange rate is 23,500 VND to 1 USD.

Based on these parameters and assumptions, the estimated potential is shown in Table 5*:*

TABLE 5. ESTIMATING THE POTENTIAL APPLICATIONS OF SOLAR POWER SYSTEMS IN RWSSs

No.	Items	Result
1	Total number of RWSSs with solar power sytems	3,457
2	Capacity of each solar power system/RWSS	50 kWp
3	Total installed capacity of solar power systems	172,850 kWp
4	Total initial investment cost	2,765.6 billion VND
5	Annual solar power output	232.17 million kWh/year
6	Total savings from electricity costs	424.4 billion VND/year
7	Annual GHG emissions reduction	167,164 tonne/year
8	Revenue potential from sales of annual GHG emissions	353.552 billion VND/year

From Table 5, the assessment is:

- The potential of solar power applications for RWSSs is estimated to be at least 3.457 systems, with a total capacity of 172,850kWp and total initial investment capital requirement of about VND2,765.6 billion.

- The amount of grid power that the solar power systems will replace is estimated at 232.17 million kWh/year, thus saving RWSSs VND424.4 billion per year in electricity costs. The reduction in GHG emissions is 167,164 tonnes/year. The value of carbon credits, based on the European Union (EU) price in 2022, is estimated to be VND353.552 billion per year.

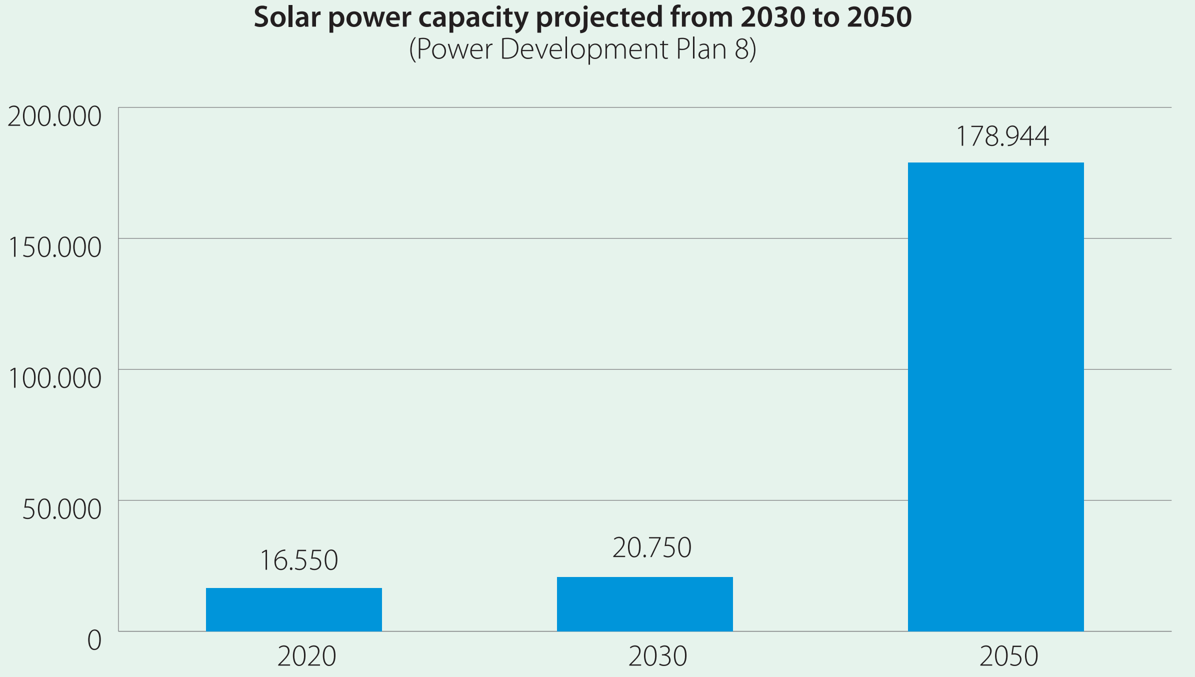
3.3.3. OPPORTUNITIES FOR RE APPLICATIONS IN RWSSs

i. Conversion from fossil energy to RE sources

RE is considered an inevitable solution to meet the world's looming climate-driven energy crisis. As fossil fuel sources such as coal, oil and natural gas become increasingly depleted and cause serious environmental pollution, countries around the world are forced to accelerate the restructuring of the energy industry towards clean and sustainable energy sources. The development of RE sources is gradually taking an important position in the sustainable development of countries, due to the great benefits of using the most of inexhaustible natural resources (such as wind, sun), as well as contribute to reducing the impact of GHG effects and climate change. Viet Nam is no exception to this trend.

According to a MOIT report, by 2020 the total capacity of on-grid solar power systems put into operation in Viet Nam was 16,650MW. On 15 May 2023, the government approved the PDP VIII. Accordingly, the capacity of solar power systems by 2030 will be 20,750MW, and increase to 178,944MW by 2050. The share of electricity from solar power systems will rise from 6.3 percent in 2030 to more than 20 percent in 2050. Thus, from 2030 solar power in Viet Nam will develop at a fast rate, increasing at an average of 7,750 MW/year or 32 percent/year (Figure 11).

FIGURE 11. SOLAR POWER CAPACITY (MW) PROJECTED DURING 2020-2050



Source: Decision No.500/QD-TTg (15 May 2023)

ii. The Government of Viet Nam strongly encourages and supports development of RE, including solar power

The government is interested in development of solar power systems and RE in general to contribute to meeting international commitments that by 2050, Viet Nam will reduce GHG emissions to "net-zero".

Besides, PCERWASS in many provinces have developed plans and programmes to apply solar power for their RWSSs.

iii. Solar power systems have many advantages

Key advantages of solar power systems are: a clean and free fuel source of electricity, the design, installation and operation are simple and safe, maintenance is easy and cost-effective, solar power prices are now competitive with those of fossil-based electricity, the capacity design can easily be changed since solar power systems are modular in nature and can be installed and applied in any RWSS.

iv. Investment costs are decreasing

The current average investment cost in Viet Nam for a ground solar power system is typically 23 million VND/kWp and a rooftop solar power system is 15 million VND/kWp. The current investment rate has decreased compared to 10 years ago and is forecasted to drop further, while electricity prices in Viet Nam are forecast to rise. These are factors to promote applications of solar power systems.

v. High demand is increasing

As analyzed above, all localities have incorporated the applications of solar power systems into provincial implementation plans for Strategy. Some provinces have planned and initiated projects to implement solar power systems in RWSS projects within their respective areas. This presents an opportunity for development of solar power systems in RWSSs.

3.4. LESSONS LEARNED FROM APPLICATIONS OF SOLAR POWER WITHIN RWSSs IN VIET NAM

- Power load capacity of RWSSs is generally small, averaging 40kW-60kW. Therefore, solar power systems for RWSSs have a small capacity, and can be directly connected to the local low-voltage grid.
- In Viet Nam, at present, more than 98 percent of rural communes are connected to the national electricity grid. In the future, this rate will climb. So, the grid connected solar power system configuration will be the most common and feasible configuration.
- The applications of off-grid solar power systems to power RWSSs is only suitable if RWSSs are located in areas where there is no electricity grid and the demand for clean water is low.

3.5. CHALLENGES AND BARRIERS TO RE APPLICATIONS FOR RURAL WATER SUPPLY SYSTEMS

Through the process of researching and evaluating the current status of solar power systems for RWSSs, a number of challenges have been identified as follows:

i. The lack of mechanisms and policies to develop solar power systems installed after 2020 leads to problems with the applications of solar power systems for RWSSs. Mechanisms and policies to support development of solar power expired at the end of 2020 (Decision No.13/2020/QD-TTg). So far, no new mechanisms or policies for 2021-2030 and beyond have emerged. Hence, the applications of solar power systems, including solar power systems for RWSSs, has stalled. Although PDP VIII was recently approved (Decision No.500/QD0TTg), there is no circular guiding implementation yet. Therefore, it is unclear whether essential grid connections will be permitted in the applications of solar power systems in RWSSs.

ii. The estimated payback period of solar power systems for RWSSs is eight years in Viet Nam compared to four-six years in other countries. This could discourage investors biased towards quick recovery of investments. Note that some projects may have longer periods to recover investments, yet still offer good rates of returns. This is the case for solar pumping systems in Viet Nam. Note, however, that this common for long-term projects.

iii. There are barriers to PPPs. With current regulations, cooperation between RWSS and private energy service companies (ESCOs) faces difficulties, despite such cooperation bringing many benefits to both sides. As RWSSs are State-owned, assets such as land, office buildings are also state-owned. If a RWSS leases solar power system from an ESCO privately, ESCO's solar power must be installed on RWSS land or roofs which must be leased. However, private sector entities face hurdles to lease public property.

iv. Lack of Initial investment capital to implement a sector-wide solar power system in RWSSs.

v. A key cause of inefficient applications of solar power systems in RWSSs is the lack of capacity of technical staff to manage, operate and maintain solar power systems. Currently, staff operating water production and supply are also responsible for the management and operation of solar power systems, despite not being professionally trained. This lack of knowledge is problematic as solar power technology is new and still a high-technology field in Viet Nam.

vi. Lack of capacity to assess and appreciate the financial benefits of adapting solar power systems in RWSS operations.

vii. The market for GHG emission reductions in Viet Nam is in its infancy, with no implementation guidelines yet. As a result, leaders of State and private businesses are not equipped with knowledge related to GHG emissions and carbon credits. Moreover, enterprises have not paid sufficient attention to GHG audits, valuation and purchase prices of carbon credits, lack an understanding of GHG emission quotas and purchases, sales and exchanges, while the domestic GHG emission market does not have an effective relationship with the international market.

3.6. SOLAR POWER SCALING-UP OF SOLUTIONS IN RWSSs

Clean water is also an essential need like electricity, especially for rural populations. Therefore, it is critical the clean water production and supply sector receives government support to ensure adequate supply of clean water and sanitation for rural communities at reasonable prices.

As highlighted in previous sections of the report, it is evident that the applications of RE and solar electricity, in particular, to provide clean energy for RWSSs is necessary as:

i. It contributes to implementation of the Party and government's key energy transformation policy to ensure energy security and protect the environment, including the goal of reducing net GHG emissions to "zero" by 2050 that Viet Nam committed to the world community at COP26.

ii. The applications of solar power systems for RWSSs benefits the economy, society and environment.

iii. Viet Nam has excellent solar power potential. The applications of solar power systems is highly efficient in terms of exploitation, use and conservation of natural energy resources.

However, due to difficulties such as high investment rates, fragmented mechanisms and policies and lack of long-term synchronization, the applications of RE and solar power in particular in RWSSs faces limitations.

As mentioned in previous sections, PDP VIII was recently approved in May 2023 by the government with the general objective of promoting development of RE and solar power to ensure energy security, fully supply energy demand for economic and social development and make a significant contribution in the fight against climate change. Key content includes:

- Specific objectives: "To strongly develop renewable energy for electricity production, reaching the rate of 30.9-39.2 percent by 2030, towards the target rate of RE reaching 47 percent with the condition that there is a support cooperation of the international community. Orientation to 2050, the rate of RE up to 67.5-71.5 percent.
- Power development plan: "Accelerate the development of power from RE, continue to increase the proportion of RE in the structure of power sources and electricity production".
- "From now to 2030, the total capacity of solar power is expected to increase by 4,100MW. Oriented to 2050, the total capacity will reach 168,594-189,294MW, producing 252.1-291.5 billion kWh", in which: "Priority and breakthrough policies to promote the development of rooftop solar power, especially areas at risk of electricity shortage such as the north and self-consumption of solar power. From now to 2030, capacity of these types of solar power is estimated to increase by 2,600MW. This type of power is prioritized for unlimited capacity development, provided it is reasonably priced and makes use of the existing power grid, without having to upgrade".

As seen, solar power applications in RWSSs is classified as rooftop solar power systems for two main reasons: small capacity (< 1MW) and most solar power arrays are installed on RWSS roofs. This means solar power systems applications in RWSSs are included in prioritized sectors under PDP VIII.

The following recommendations could help address the above-highlighted shortcomings, promote applications of clean electricity for production and provide clean water for rural communities.

3.6.1. POLICY ASPECTS

i. Urgently develop circulars guiding implementation of PDP VIII for rooftop solar power systems for RWSSs

There is currently no PDP VIII-related circular to implement rooftop solar power systems and solar power for RWSS. Therefore, the MARD, MOIT should address this issue to ensure solar power sources for RWSSs are connected to the grid.

ii. Promote socialization in the investment of solar power resources for RWSSs

As highlighted in the previous section, the initial investment in solar power systems to power RWSSs are still high. While RWSSs want to develop solar power system applications but lack investment capital, private service enterprises such as ESCOs have capital but face difficulties conducting business with stated-owned RWSSs. In order to quickly and sustainably realize solar power systems in RWSSs, there is a need for stronger government involvement. It is recommended that MARD, with the focal point being NCERWASS, work with the Ministry of Finance (MOF), Ministry of Planning and Investment (MOPI) and other relevant ministries, departments and sectors to remove barriers to PPPs between RWSSs and private ESCOs on solar power development as follows:

- Allow RWSSs to enter into lease or other agreements such as Build Operate Transfer for solar power equipment of private ESCOs to serve RWSS power supplies through contractual terms agreed by both parties, such as electricity prices, terms, costs of operation, maintenance and tax.
- Allow private ESCOs to enter into lease agreements with RWSSs so they can lease spaces or premises to install solar power equipment components in areas the State has assigned for RWSS to manage. Examples are roof tops of headquarters, water surfaces of reservoirs, and vacant areas.

3.6.2. FINANCIAL SOLUTIONS

As the investment cost of solar power is still relatively high, the government and MARD need to engage the State Bank of Viet Nam to prioritize capital for RE and solar power systems in RWSSs with preferential interest rates.

This is feasible as clean water, rural environmental hygiene and clean energy technology, such as solar power, are prioritized for government support. In addition, the government is supporting sustainable business development by requesting banks to provide credit at reasonable interest rates to priority sectors.

To realize further support, the MARD needs to negotiate with the State Bank, Viet Nam Development Bank and related ministries to reduce loan interest rates for solar power and RE for RWSSs. Lowering bank interest rate (below the prevailing 8 percent/year), will further encourage RWSSs to invest in solar power systems.

3.6.3. PROFESSIONAL HUMAN RESOURCE TRAINING

In the RWSS sector, untrained technical staff and workers to operate and maintain RE and solar power systems is evident. Therefore, it is recommended that:

The MARD, with its direct focal point being NCERWASS, actively builds a team of technical staff with professional skills in the operation and maintenance of RWSS renewable and solar power systems to ensure clean energy systems operate with high efficiency.

There is also a need to provide capacity building for RWSSs to evaluate the financial benefits of adapting solar power systems in their operations. The lack of knowledge to assess the financial benefits of using solar power instead of national grid electricity is a key reason for RWSSs' reliance on grid power, despite solar power's potential to reduce operating costs.

Although the unavailability of submersible pumps in the local market was a reason for the switch to AC pumps, the use of inverters to convert DC power from solar sources to AC current will now allow RWSSs to continue use of solar power systems. The ability to conduct proper financial evaluation of different options to source electricity will optimize the most economical options.

3.6.4. DEVELOPMENT OF GREENHOUSE GAS TRADING MARKETS

As evidenced in the above-mentioned estimates, GHG emission reductions from the applications of RE and solar power technologies in RWSSs is significant. However, the GHG emissions market in Viet Nam is still in its infancy because: (i) key agency leaders are not equipped with knowledge related to GHG emissions and carbon credits, (ii) enterprises have not paid sufficient attention to GHG audits, valuations and purchase prices, (iii) a lack of understanding of GHG emission quotas and purchases, sales and exchanges is evident and (iv) the domestic GHG emission market does not have a effective relationship with international peers.

This is understandable, as despite being an active participant in the early stages of the Kyoto Protocol, the applications and development of clean technologies including solar power technology, only happened recently in Viet Nam. Hence, GHG emission reductions are insignificant. In addition, Viet Nam still lacks experienced and large enterprises operating in the GHG market and has yet to gain international cooperation experience in this field.

As a result, "revenues from carbon sales" discussed in previous sections of this report are only estimates of this "revenue potential". However, once the carbon market is established and operating in Viet Nam it will become a significant source of real income.

For the above reasons, it is recommended that:

- It is recommended relevant agencies organizes training courses to increase knowledge on clean energy and GHG emission markets within the sector.

- Establish a system and teams from relevant agenciesS to transparently conduct audits, assessments and synthesis of GHG emission reductions in the sector from the applications of RE, solar power and other clean technologies according to international standards. There is a need to determine a GHG emission reduction roadmap for each provincial centre and find domestic and foreign markets to exchange, buy and sell Carbon credits and generate funding for RWSSs.

4. ENERGY EFFICIENCY FOR RURAL WATER SUPPLY SYSTEMS IN VIET NAM

4.1. CURRENT STATUS OF EE IN RURAL WATER SUPPLY SYSTEMS

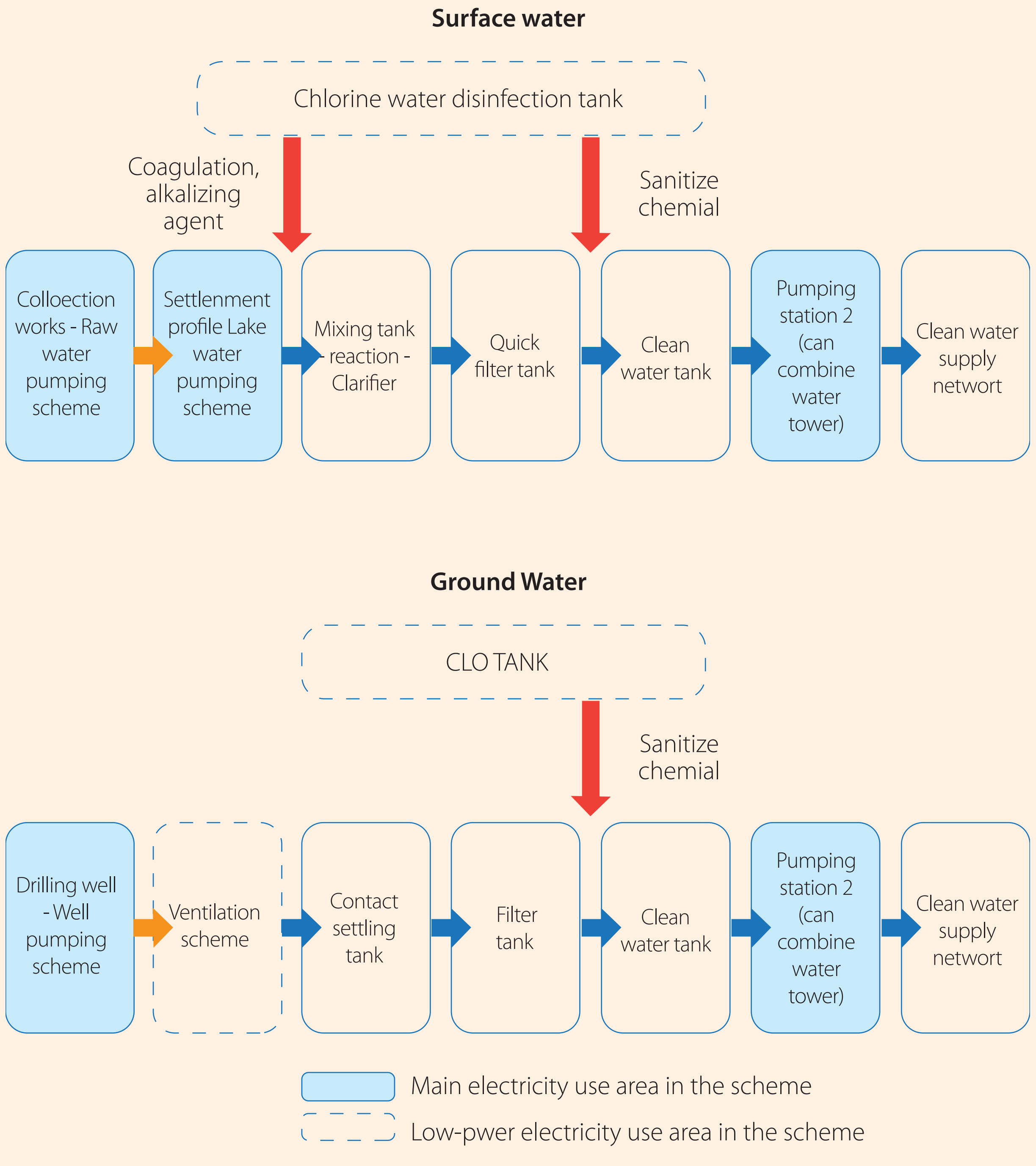
4.1.1. ENERGY-USING AREAS AND EQUIPMENT IN RURAL WATER SUPPLY SYSTEMS

There are two typical water supply technologies applied in rural water supply systems across the country: power pumps or self-flowing.

Self-flowing RWSSs operate based on the force of gravity utilized to transport water from higher sources to lower areas, without the need for electricity-driven pumping, to provide water for people.

RWSSs utilize power pumps on the principle of using force from pumping stations or water towers to deliver water to consumers. Specifically, a more detailed description is provided for cases where water supply systems use surface water and groundwater (subterranean water) (Figure 12).

FIGURE 12. TYPICAL TECHNOLOGICAL LINES FOR SURFACE AND GROUNDWATER TREATMENT



Self-flowing water supply systems usually use very little energy for water treatment and supply, so although there is potential for energy reduction, it is not significant. Therefore, this chapter focuses mainly on water supply systems using conduction pumping technology.

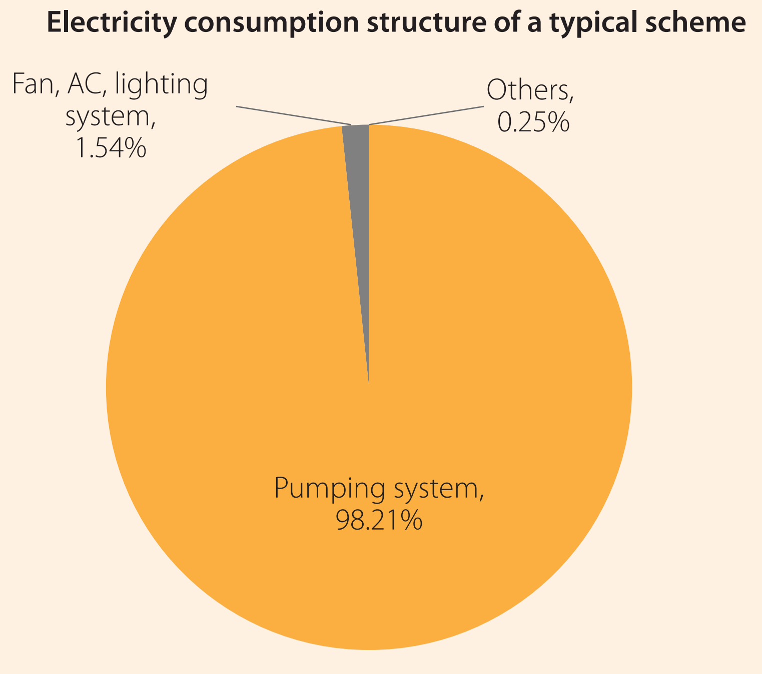
A water supply system usually has the following main energy consuming devices:

- Pumping system
- Lighting, fan and air conditioning systems
- Other auxiliary systems: equipment for working and daily use at work (TV, computer, printer).

Equipment used in the water supply system mainly consumes electrical energy. Some water supply systems use backup generators only when grid power is out. Consumption of oil for running and maintenance of the generator is almost negligible compared to electricity consumption.

In general, larger rural water systems tend to be less energy intensive than smaller ones. Electricity use in administrative and production buildings, such as lighting and space conditioning, is a small percentage of overall energy use.

FIGURE 13. ELECTRICITY CONSUMPTION PROFILE OF A TYPICAL SYSTEM



4.1.2. CAUSES OF WASTED ENERGY IN RWSSs

Wasted energy in RWSSs is often caused by technical and management reasons.

i. Technical factors

- Many RWSSs were built more than 10 years ago and now use low efficiency pumps, old technology, some section in the pipelines have broken or leaking that cause water loss.
- Pumping systems of some RWSSs are always in full load running state, even overloaded, running continuously without stopping or running alternately between pumps. This damages the pump and reduces its lifespan.
- Pump oversizing during selection due to calculation errors, such as double entry of losses and redundancy factors which are often cumulative, as system designers already factor in losses and redundancy. This leads to pumps having a much higher capacity than demand resulting in the pump running under load or not at full capacity resulting in energy waste.
- Managers and operating staff of RWSSs still have limited knowledge of EE. For example, the status of operation and lines in each energy-using device are not fully understood, and energy waste is not identified.
- Control systems are not completely optimized as most are manually controlled and based on gut feel.
- There are no production management and monitoring systems.
- High water loss rates.

ii. Management reasons

- RWSSs are not designated energy users so there is no professional monitoring system applied. The recording of raw materials usage, input and output energy to monitor losses is inconsistent and not regularly done, so losses are not detected on time.
- RWSSs lack policies and mechanisms to manage energy use in systems.

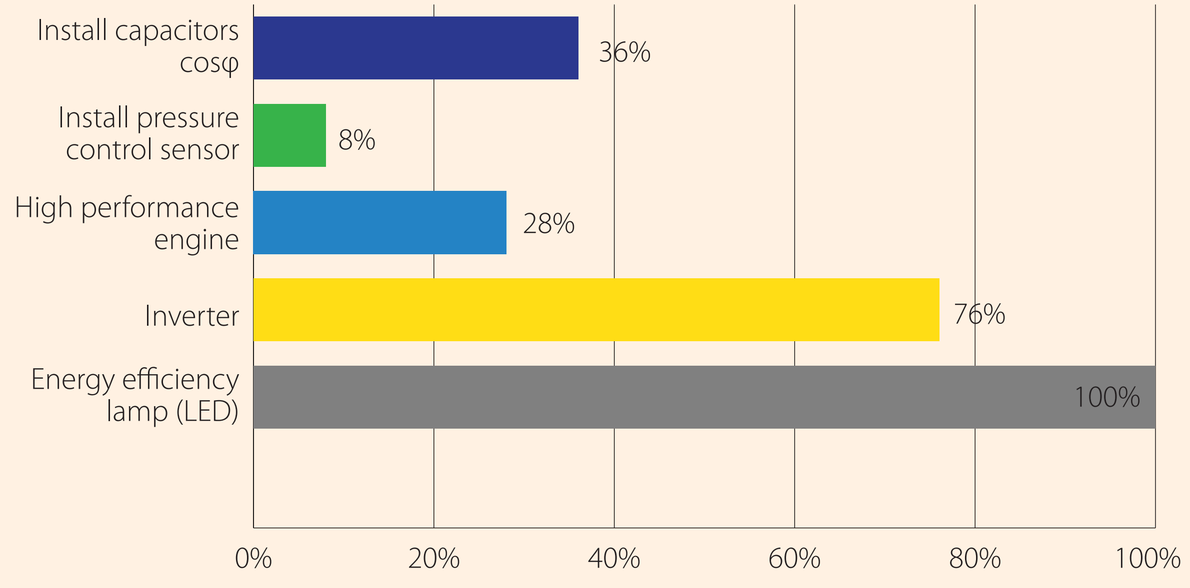
4.1.3. APPLIED EE TECHNOLOGIES, SOLUTIONS AND EFFECTIVENESS

The applications of advanced technologies and sustainable solutions is implemented by RWSSs in Viet Nam. However, larger-scale projects tend to implement these solutions more effectively than smaller and micro-scale ones. Most technological solutions contribute to EE ranging from 10-25 percent, with an average payback period of less than five years.

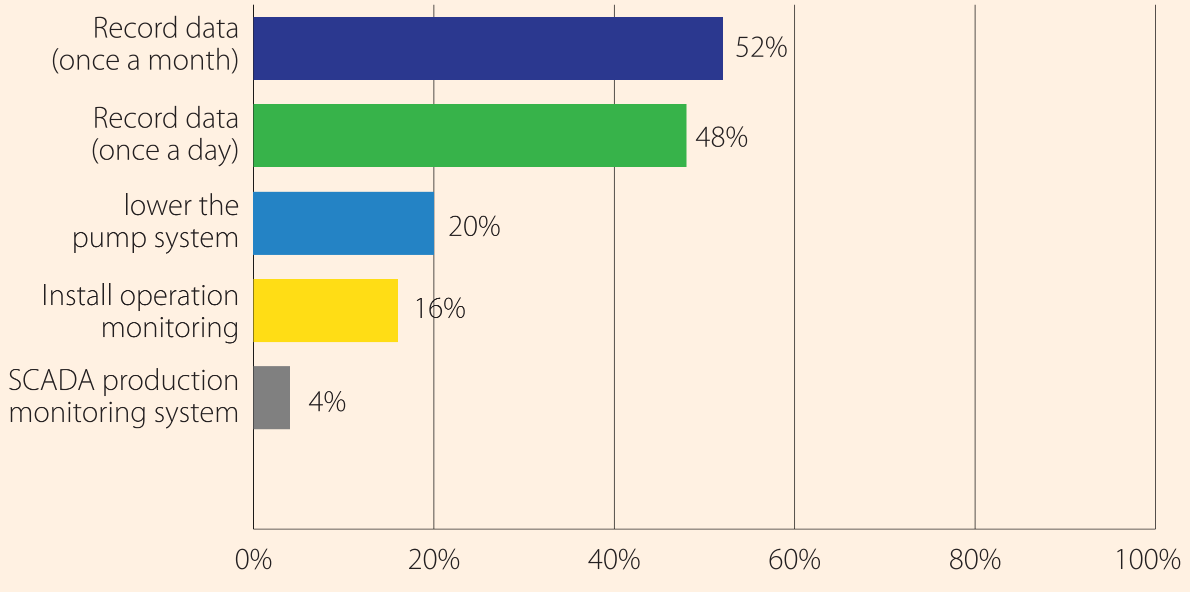
The following chart highlights some prominent solutions applied at surveyed RWSSs:

FIGURE 14. CURRENT STATUS OF APPLYING EE SOLUTIONS IN RWSSs

Technical solution of energy efficiency at 25 surveyed water supply schemes



Technical solution of management at 25 surveyed water supply schemes



i. Inverter

Nineteen of the 25 surveyed RWSSs have applied inverters in water supply systems. Inverters are fitted to raw water and treated water pumps with a relatively wide power range from 1.5kW to 30kW.

According to assessment, the use of inverters contributes to RWSSs saving about 10 percent of electricity consumption.

ii. LED

All 25 surveyed RWSSs have adopted LED lighting, including two RWSSs in the northern region that still use both LED and fluorescent lights, and one central region RWSS that utilizes compact lights alongside LED. These advanced lighting solutions replace various types of indoor, outdoor, and landscape lighting fixtures. Based on assessment outcomes, these lighting fixtures contribute to 50 percent electricity consumption savings.

iii. High efficiency motor (IE2) and Premium efficiency motor (IE3)

Five RWSSs use high-efficiency IE2 motors, comprising 11 motors, and four installations had IE3 pumps equipped with 15 motors. The power range of these motors is extensive and commonly ranges from 5.5kW to 22kW, applied to raw water and treated water pumps.

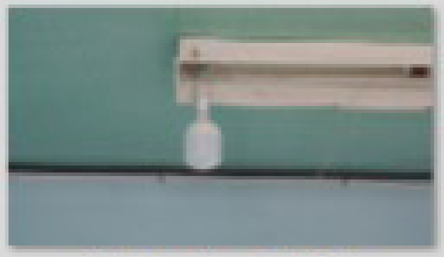
IE2 motors have resulted in a 10.9 percent reduction in electricity consumption compared to conventional motors under similar operating conditions. Similarly, IE3 motors have contributed to an even greater reductions (12.7 percent) in electricity consumption compared to conventional motors under the same operating conditions.

iv. Other solutions

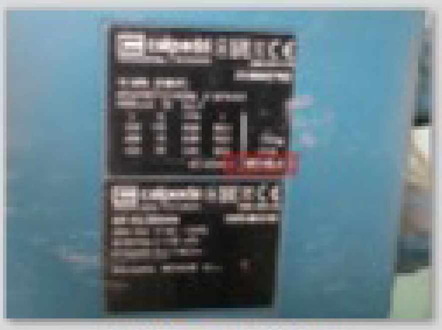
Several other EE solutions also have significantly yielded of efficiency energy that also widely applied, such as lowering pressure at consumer locations and retrofitting electrical distribution cabinets.

FIGURE 15. COLLECTION OF TYPICAL EE SOLUTIONS APPLIED IN RWSSs

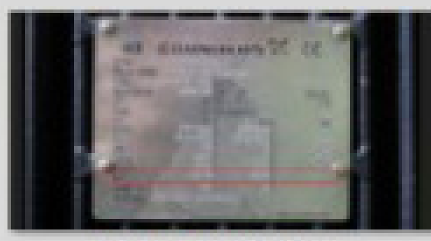
Inverter VSD Thach An system



LED bulb An Quoi system



IE2 Hoa Binh system



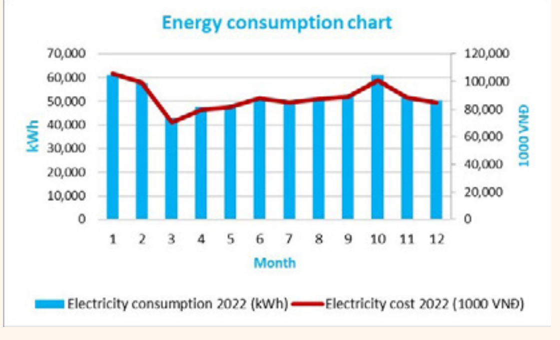
IE3 Ham Thuan Bac 2

IE3 Hàm Thuận Bắc

4.1.4. CASE STUDY

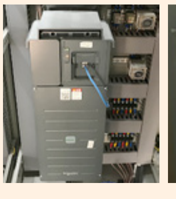
Case No.1: Xuan Truong water supply plant

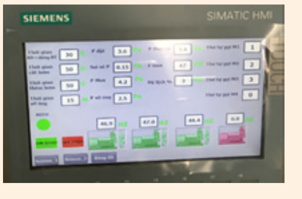
General Information:	
Name of system:	Xuan Truong Water Supply Plant
Address:	Xuan Ngoc, Xuan Truong, Nam Dinh
Design capacity:	13.000 m^3/day/night
Water treatment technology:	conduction pump
Hours of use:	18 hours/day
Output (2022):	3,048,295 m^3 of industrial water.

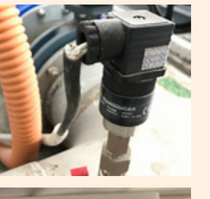


Energy Information:	
Energy consumption:	625,986 kWh per year
Energy cost:	VND1,059,098,133 per year
Energy consumption level:	0.249 kWh/m^3 of water produced
Energy consuming equipment:	pumping system, led light system, equipment for life needs, air conditioner, ceiling fan.

EE Solutions:
Install reactive power compensation capacitors
Renovate centralized electrical cabinets to support effective management
Install air conditioner (EE type) to cool the electrical cabinet
Use energy efficient lighting system (LEDs)
Install soft starter for pump motor
Install an inverter to control the pump
Install pressure control sensor to support inverter
Install camera to monitor pressure (at location of households)
Pump water at off-peak and normal hours, limit pumping during peak hours (for households installed water storage tanks, with automatic float valves).





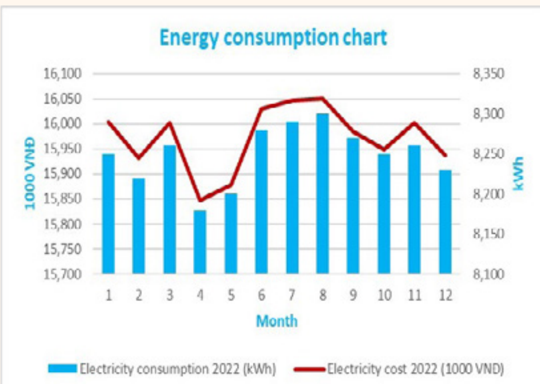


Rate of water loss:	18%

Proposed Solutions:
• Install Supervisory Control and Data Acquisition (SCADA) system to monitor production
• Replace the pump motor with higher capacity
• Record data (daily or weekly)
• Perform annual calculation of energy conservation and CO_2 reduction
• Apply energy management solutions (according to ISO 50001) (case of factory scale expansion) .

Case No. 2: Huong Thuong water supply plant

General Information:	
Name of system:	Huong Thuong Water Supply Plant
Address:	Huong Thuong commune, Thai Nguyen city, Thai Nguyen province
Design capacity:	400 m^3/day
Water treatment technology:	conduction pump
Hours of use:	18 hours/day
Output (2022):	108.650 m^3 of water.



Energy Information:	
Energy consumption (2022):	98.990 kWh per year
Energy cost:	VND191.660,325
Energy consumption level:	1.369 kWh/m3 of industrial water
Energy consumption profile:	pumping system (98.4%), lighting system and equipment for daily life (1.6%).

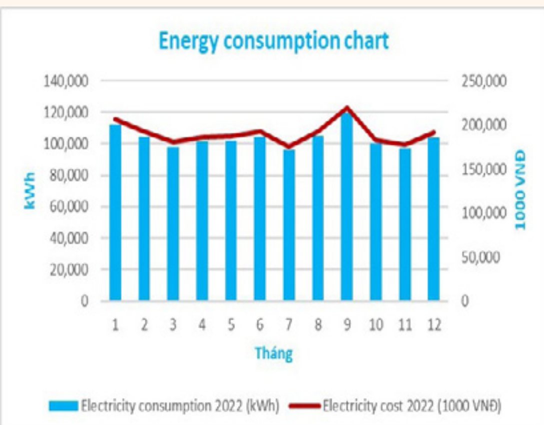
EE Solutions:
Using EE lighting system (LEDs)
Installing an inverter to control the pump
Using reactive power compensating capacitor.

Rate of water loss:	33%

Proposed Solutions:
• Replace with EE lamps (LED)
• Replace the motor for pumps with higher efficiency
• Record data (daily or weekly)
• Optimize water pumping schedule: limit pumping during peak hours
• Carry out annual calculation of energy conservation and CO2 reduction
• Apply energy management measures.

Case No. 3: Ham Thuan Bac water supply plant

General Information:	
Name of system:	Ham Thuan Bac Water Supply Plant
Address:	Thuan Minh commune, Ham Thuan Bac District, Binh Thuan province
Design capacity:	8160 m^3/day
Water treatment technology:	conduction pump
Hours of use:	24 hours/day
Output (2022):	2.851.425 m^3 of water.



Energy Information:	
Energy consumption (2022):	1.244.890 kWh per year
Energy cost:	VND2.284.238.016 per year
Energy consumption level:	0.542 kWh/m^3 of industrial water
Energy consumption profile:	pumping system (97.4%), lighting system and equipment for daily life, office equipment + compressor + industrial fan (2.6%).

EE Solutions applied:
Use EE lighting system (LEDs)
Installing inverter to control the pump
Using reactive power compensating capacitor
Installing soft starter for pump motor
Using high efficiency motor (IE3)
Installing Closed-circuit television (CCTV) at the RWSS.

Rate of water loss:	13%

Proposed Solutions:
• Record data (daily or weekly)
• Optimize water pumping schedule: limit pumping during peak hours
• Carry out annual calculation of energy conservation and CO2 reduction
• Apply energy management measures.

4.2. POTENTIAL AND BENEFIT OF EE FOR RURAL WATER SUPPLY SYSTEMS

For RWSSs, there are some areas with most potential for EE—pumps of most types and functions, and other areas. The following are applicable EE measures with corresponding potential:

- Enhanced energy management including process optimization, maintenance improvement and closer matching of pumps to their functions, such as using inverters (up to 10 percent savings).
- Improving existing lighting system (up to 50 percent savings)
- Upgrading to new pumping technology (up to 15 percent savings).

4.2.1. ENERGY MANAGEMENT

EE is often the focus of energy management activities. But, energy management includes activities that reduce energy costs but not necessarily energy consumption. Maintaining a long-term commitment to improving energy performance requires an organized and sustained effort to identify gaps, develop cost-effective solutions, and secure financing for needed investments.

The main goal of energy management is to reduce energy costs without compromising environmental regulatory compliance, and service obligations. The premise is that energy management must pay for itself and provide net financial benefits. Energy management activities, not all of which necessarily lead to net EE, can be divided into three categories by objective:

- ***Reducing power demand and energy consumption*** by improving EE of equipment, processes, and overall service delivery. This includes all activities/measures that result in actual reduction of power demand and energy consumption while maintaining the same level of service and regulatory compliance. Examples of specific EE measures include regular maintenance, installation of variable speed drives (VSDs) to manage pump duties, lighting and space-conditioning efficiency in offices and control rooms, energy optimization of processes, rehabilitation of leaky networks and active leakage control through pressure management.
- ***Managing peak demand and other power system charges*** by adjusting operation schedules and preventing billing penalties. These activities generate energy cost savings, but not EE. EVN charges for consumption (kWh) during power system peak load period(s) at a much higher rate than off-peak period(s). Systems can reduce energy costs by reducing peak power demand by shifting some pumping operations to off-peak period(s), possibly using automated control systems. This may involve the use of elevated reservoirs and water tanks for off-peak pumped storage. Additionally, EVN may penalize systems for drawing more power than needed due to low power factors, which can be corrected by installing power capacitors.

To be able to carry out the above activities effectively and efficiently, systems need to adopt a structured approach in energy management. The international standard for enterprise Energy Management Systems (ISO50001) offers useful guidance for good energy management. The practices in general follow an iterative process of "Plan-Do-Check-Act." Also, well documented guidebooks provide detailed guidance to systems on setting up and implementing an in-house energy management system.

4.2.2. SWITCHING TO LEDS IN LIGHTING SYSTEM

The solution assumes that the systems will switch from conventional lighting devices to LED. It is expected that the solution can help to save up to 50 percent of electricity consumption by the lighting system.

4.2.3. USING INVERTERS IN PUMPING SYSTEM

The solution assumes that the systems will use inverters for raw water pumps and treated water pumps. It is expected that the solution can help to save up to 10 percent of electricity consumption. It also assumes that the applications ratio of total unapplied systems is 75 percent of total systems in Viet Nam.

4.2.4. APPLICATIONS OF IE2 MOTORS IN PUMPING SYSTEM

The solution assumes that the systems will use IE2 motors for raw water pumps and treated water pumps. It is expected that the solution can help to save up to 10 percent of electricity consumption. It also assumes that the applications ratio of total unapplied systems is 75 percent of total systems in Viet Nam.

4.2.5. APPLICATIONS IE3 MOTORS IN PUMPING SYSTEM

The solution is assumed that the systems will use IE3 motors for raw water pumps and treated water pumps. It is expected that the solution can help to save up to 12.7 percent of electricity consumption. It also assumes that the application ratio of total unapplied systems is 10 percent of total systems in Viet Nam.

Solar power system installed at the centralized water supply system in Thanh An, Thanh Thang, Thanh Loi commune, Can Tho province

4.3. LESSONS LEARNED FROM EE APPLICATIONS IN RWSSs

Many factors lead to inefficient use of energy in RWSSs, such as inappropriate operation and maintenance, out-dated technology and design of RWSS facilities.

Implementation of energy-saving solutions requires unified policies and regulations of governing units of RWSSs, including regulations on energy benchmarking for each cubic metre of water sold, the ratio of electricity costs and benefits of energy and cost savings.

As most RWSSs are small- and medium-sized, they are not major energy users as regulated by the Government of Viet Nam. Therefore, it is not necessary to carry out a periodical energy audit every three years as well as develop an annual EE implementation plan. However, RWSSs should perform preliminary energy audits to assess the current state of energy use, identify energy waste items, and thereby determine energy conservation potential. From there, propose solutions for energy conservation.

4.4. CHALLENGES AND BARRIERS IN PROMOTING EE IN THE SECTOR

The survey has highlighted numerous challenges and barriers affecting the adoption of EE solutions in RWSSs. Overcoming these barriers requires solutions specific to systems and their institutional and regulatory environment. From a management perspective, strengthening the incentives for taking up EE interventions by political, regulatory and financial means and increasing the flow of quality information on EE solutions, and associated costs and benefits are essential for decision-makers to become champions of EE.

The main obstacles and commonly observed consequences are policy barriers, limited financial resources, inadequate technical understanding, weak operational management capacity and limited awareness of EE. Table 6 summarizes the challenges and barriers.

TABLE 6. BARRIERS IN EE APPLICATION FOR RWSSs

Cause	Effect
Low cost of electricity	Reducing or removing incentives to improve EE of RWS-Ss.
EE is not a required element for assessing systems' performance	The paramount importance of protecting the community tends to make regulators overly conservative when balancing EE and process performance.
Operational staff are often given distinctive roles	Limiting responsibilities and level of interest in the field of EE
Inadequate information about EE opportunities, solutions, and their costs and benefits, credibility of savings	RWSSs and financial institutions lack interest and support for EE solutions
Limited internal capacity of systems to identify and undertake energy optimization and EE feasible measures	Preventing systems to take systematic and well sequenced EE interventions, and undermining ability to put together feasible EE investment projects.
Small size of EE investments	Making EE investments in systems unattractive to commercial lenders or banks due to high transaction costs.
Underdeveloped EE financing market	Many financially attractive EE investments cannot be implemented.
Regulations on public-private cooperation are unclear	Unable to mobilize investment sources for EE from the private sector.
Most RWSSs have out-dated technology, and high rates of non-revenue water	Require comprehensive upgrades and high costs.

4.5. RECOMENDED SOLUTIONS FOR EE PROMOTION

A systems approach is essential for maximizing EE in a most cost-effective manner. This often requires optimization of system architecture and operations, instead of just focusing on specific equipment.

4.5.1. POLICY AND INSTITUTIONAL ENVIRONMENT

The main challenges for scaling-up EE in systems ranges from sector governance issues, knowledge gaps, and financing hurdles. Utility governance affects the overall performance of individual systems and influences decision-making, incentives and actions for energy management. This is likely the most significant barrier to EE. Addressing knowledge gaps requires efforts to systematize data collection, training, and capacity building at utilities, supported by local and national government. Access to EE financing is a hurdle because of systemic credit risk issues associated with the municipal sector, as well as a lack of a broad-based enabling environment for EE investments.

National and/or local governments' commitment to market reforms and EE are most critical in removing barriers to enhancing EE performance. Specific actions include developing policies to shore-up financing for EE, including creating special financing vehicles for investments in EE improvements, such as dedicated EE funds, developing markets for ESCOs, and promoting PPPs. The government may also facilitate commercial financing for large-scale rehabilitation projects through loan guarantees. The national government could play a key role in setting up programmes to tap into climate investment resources, such as Global Environment Facility. It could also develop and issue regulations for establishing energy consumption benchmarks for RWSSs to enhance energy usage efficiency.

4.5.2. UNLOCKING INVESTMENT CAPITAL

Besides internal financing, accessing external financing is often necessary for implementing capital-intensive energy optimization projects or ones with relatively long payback periods. RWSSs may be able to take advantage of the following financing approaches to partially or fully fund EE investments.

i. Internal cash flow

RWSSs may use funds from internal cash flow to finance EE improvements. But they usually operate under tight operation and maintenance budgets. Therefore, the system should consider gradually implementing solutions and give priority to solutions with quick capital recovery

ii. Deferred payment financing

Deferred payment financing is also considered an internal financing source. It is a short-term borrowing process where the utility makes payments to the vendor soon after receiving supplies and services. Such arrangements may allow RWSSs to purchase high efficiency equipment to upgrade facilities if the incremental cost can be recouped quickly through operational savings.

iii. Project financing through ESCOs

ESCOs provide energy consumers or "host facilities" with a range of services related to applications of EE products, technologies, and equipment. By purchasing external EE services, a system will gain much-needed technical expertise. The more innovative part of ESCOs is they can serve as financial tools, in addition to being energy management tools.

It requires the ESCO to cover the project cost using its own funds (credit provided by equipment suppliers) or arranging for third-party financing (commercial banks). Repayments for this type of project financing are derived from energy cost savings resulted from the project but will depend on the specific nature of ESCO service agreement.

iv. Public-private partnership

PPP can be seen as an EE delivery mechanism for RWSSs. PPP cooperation to invest in EE in the field of Rural water supply will help solve the problem of lack of investment funds from state owned RWSSs.

v. Other climate financing mechanisms.

Financing mechanisms currently available in Viet Nam that could help scale-up EE solutions are the following:

The Viet Nam Environmental Protection Fund is a state-owned financial organization established by the government. It provides financial support for environmental protection, biodiversity, projects, and activities at national, inter-sectorial and inter-regional levels on environmental pollution prevention and recovery or severe local environmental issues. The financial support provided comes in the following forms: preferential loans, preferential interest rates or grants. Industrial wastewater treatment is one of the priority areas of the fund, not the clean water supply sector. Nevertheless, the priority areas are changed annually by the Fund Management Board. If proper consultations and lobbying are undertaken by the RWSSs sector, it could be possible for EE projects by RWSS to be included in the priority areas of the fund.

The World Bank with funding support from the Green Climate Fund has also established the risk sharing facility to increase the accessibility to commercial bank lending for EE undertakings. This is a guarantee facility that the commercial banks can avail to lower the risk of lending to enterprises wanting to borrow for EE projects. This includes ESCOs enterprises that need loans to implement EE projects for their clients. Approximately USD250 million of financing from five commercial banks for EE projects is expected to be mobilized by 2025.

4.5.3. TECHNOLOGY DISSEMINATION AND ENERGY MANAGEMENT SYSTEMS ESTABLISHMENT

i. Establish organizational commitment and an energy management team

For large- and medium-sized systems, there are countless opportunities and options to reduce energy costs. However, system-wide energy optimization is a complex undertaking, involving balancing multiple goals and significant efforts to collect and analyze operational data, which may require external expertise and external financial sources. A long-term and incremental process will enable RWSS to better meet organizational and financial requirements to achieve cost-effective results. Energy management can start with one facility and expand to additional facilities over time as internal capacity increases.

ii. Conduct Energy Consumption Assessment

In order to implement EE , it is necessary to have basic of energy use and the cost (where, how much, and when) to help identify energy cost reduction opportunities, measures and prioritize measures for implementation. The initial baseline analysis may only involve a walkthrough audit of the facilities or even just one facility, staff interviews, desk analysis of metering and billing data to reveal areas for immediate improvement and those for further assessment.

For large-scale RWSSs, a detailed energy audit or investment-grade energy audit may be required. This includes an in-depth evaluation of individual equipment and processes to determine individual end-use and facility-wide energy performances with actual tests and measurements, as well as detailed analysis of historical energy use and billing data. This provides robustly quantified energy and cost savings, capital requirements, and return on investments for all identified improvements. It should be noted that detailed energy audits often have to be performed by professional energy service providers and must pay service fees.

iii. Develop an energy management plan

As data gathering and analyses progress, and key opportunities and options are identified and prioritized, a plan should be developed to guide the energy management efforts with:

- Specific targets
- Underlying measures and activities
- Expenditure
- Implementation arrangements (own-executed vs. contracted services)
- Financing options

To make sure that the proposed plan is within the implementation capacity and do not overleverage the technical, financial, and management resources. The plan should be made for five years and annually. Simple, easy-to-implement, low-cost measures need to be identified and prioritized for implementation. For large-cost EE investments, investment-grade energy audits or investment reports should be performed. For large-cost EE investments, investment-grade energy audits or investment reports should be performed depending on financing options and implementation arrangements.

4.5.4. CAPACITY BUILDING AND AWARENESS RAISING

It is necessary to support sector-wide capacity strengthening, focused on:

- Establishing key EE metrics (e.g., kWh/m^3 water produced, kWh/m^3 billed) as part of RWSS performance evaluations.
- Technical and informational support programmes, template contracting options for ESCOs
- Evaluation of EE potential and feasible measures for RWSSs to help identify performance gaps and solutions in systems.
- Determine financial viability of RWSS.
- Enhancing awareness and understanding of the benefits of energy savings and the importance of implementing energy saving policies and behaviours.

4.5.5. CROSS-CUTTING ASPECTS

For RWSSs that have not yet implemented a plan to manage energy use, initial steps can be taken to organize and gradually ramp up energy management programmes, such as:

- Establishing a small energy team to begin improving internal energy (consumption and billing) data collection, reporting, and analysis.
- Implementing small/low-cost, high-return measures to demonstrate energy management benefits and build capacity and interest, while creating a revenue stream to finance future initiatives.
- Learning to establish energy management practice and sharing performance benchmark data.

With initial results and support from RWSS management and staff, the energy team could begin to address broader issues and scale-up efforts, possibly with external specialist assistance.

Water treatment area at Xuan Truong Water Plant, Nam Dinh province

5. INTERNATIONAL RE & EE BEST PRACTICES IN RURAL WATER SUPPLY

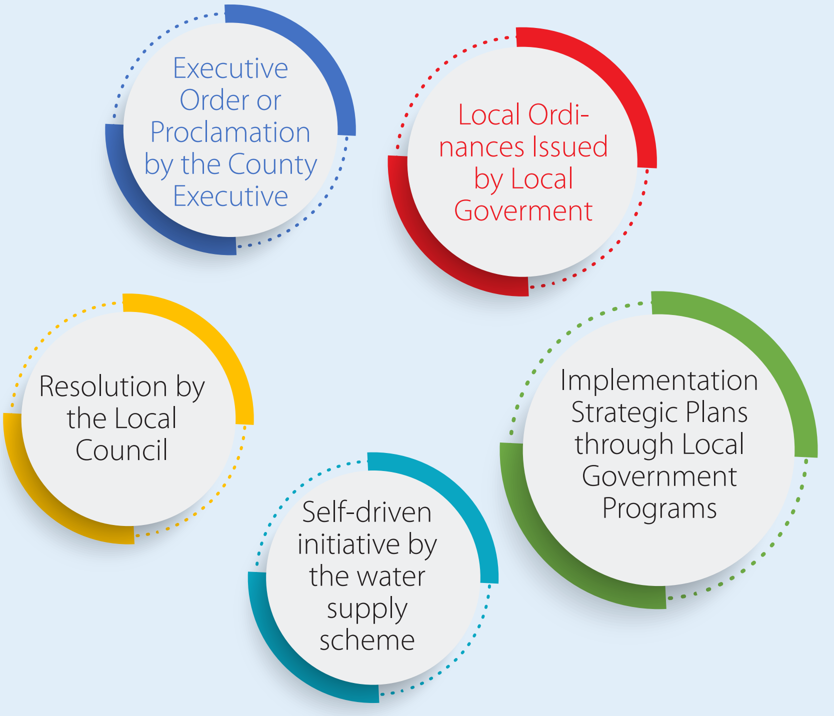
5.1. BEST PRACTICES IN POLICIES AND STRATEGIES

Water supply systems are diverse in terms of their size, water sources, processes, distribution systems, needs and complexity. Numerous policy interventions in other countries to promote EE-RE in the water supply sector are those targeted at large typically urban water systems that serve larger populations. While there is some pertinent information from policy interventions in other countries, they are for rural water supplies for irrigation not drinking.

5.1.1. POLICIES

Around the world different strategies have been employed at a local level to launch EE programmes in the water supply sector (Figure 16).

FIGURE 16. STRATEGIES EMPLOYED TO LAUNCH EE-RE PROGRAMMES AT LOCAL LEVEL



Strategies used by local governments to launch EE programmes in the water supply sector include:[22]

- Mayor or county executives issuing an executive order or other proclamations encouraging local water supply facilities to improve EE.
- Local council issuing a resolution to implement EE-RE programmes in the water supply sector e.g., adoption of certain energy and water efficiency standards.
- Local government programmes implementing strategic plans that improve EE within their territorial jurisdiction, thus providing a conducive environment for the local water supply sector to implement EE in their operations.
- Local government issuing local ordinances on water conservation to save/protect local resources. This effectively reduces the use of water, thereby reducing energy consumption of the water supply facility.
- Self-driven Initiative of the water supply facility to adopt EE measures in its operation.

There is a dearth of information on EE-RE interventions and programmes targeted specifically at rural water supply systems, more so on rural water for drinking. But, one example of a government policy on EE-RE applications targeted specifically at rural water systems is the 2016 EE and RE water sector policy issued by the Government of Jordan through the Ministry of Water and Irrigation. The policy has clearly

22 *Energy Efficiency in Water and Wastewater Facilities: A Guide to Developing and Implementing Greenhouse Gas Reduction Programmes, US Environmental Protection Agency, 2013.*

defined targets specifically per cubic metre of water produced, as follows:

- 15 percent reduction in specific energy consumption of billed water corresponding to a 0.47kg reduction of CO_2 emissions for production per each billed cubic metre of water.
- Raise the share of renewable energy resources in power consumption to 10 percent corresponding to a total saving of 0.31kg of CO_2 emissions per each billed cubic metre of water.

A brief discussion on the parameters to be used in measuring the achievement of goals and activities to be undertaken is presented in Annex2 of this report.

5.1.2. PARTNERSHIP AND COLLABORATION

In India, several programmes have facilitated the applications of RE in the rural water supply sector. One is the National Rural Drinking Water Programme (NRDWP) implemented by the Government of India through the Ministry of Drinking Water and Sanitation. The programme is focused on ensuring the sustainability of water availability in terms of adequacy, affordability, portability, convenience and equity. It was launched in 2009. In 2013, its implementing guidelines were revised. Among the added guidelines is a focus on states with districts included in Integrated Action Plans for selected Tribal and Backward Districts.[23] This is a government programme launched in 2010 by the Planning Commission.[24] Qualified districts can access grant funds for developmental projects. One of the qualified projects installs solar pumps in places that are remote, thinly populated, and experiencing irregular power supply. To supplement the grant funds, the National Clean Energy Fund (NCEF) was accessed to co-finance the investments. The NCEF in India was created in 2010 to provide financial support for clean energy initiatives in the country, including deployment of RE technologies in rural areas.[25]

Through the NRDWP, the Integrated Action Plans for Selected Tribal and Backward Districts and the National Clean Energy Fund, several solar pumps were installed in rural areas to supply drinking water. This shows that to promote the applications of RE in the rural water supply sector, at the onset relevant government programmes should be identified, and their objectives incorporated as part and parcel of the project.

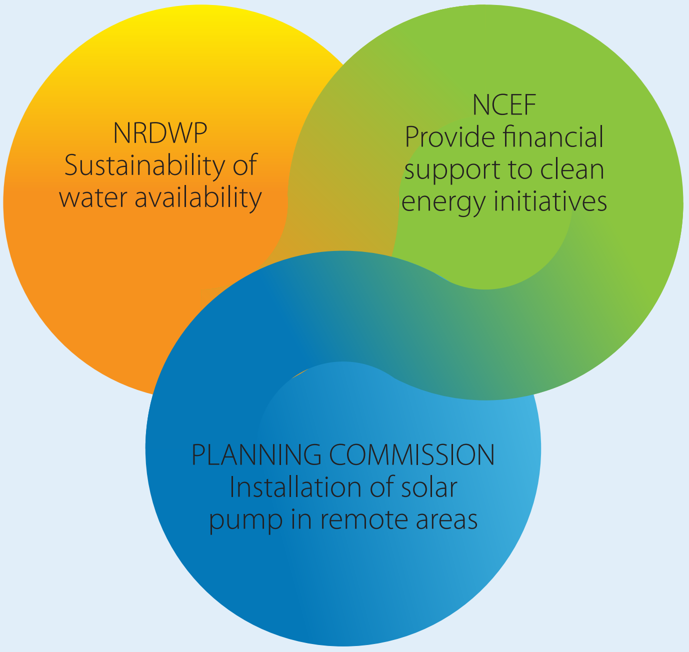
Figure 17 illustrates how the collaborative effort of three different government programmes was able to promote and implement the applications of RE-EE in India's rural water supply sector despite limited programmes and funding targeting the sector.

23 National Rural Drinking Water Programme, Movement towards ensuring people's drinking. Water Security in Rural India Guidelines – 2013

24 Integrated Action Plan for Select Tribal and Backward Districts - Press Information Bureau Government of India, Planning Commission

25 National Clean Energy & Environment Fund (NCEEF)

FIGURE 17. PARTNERSHIP AND COLLABORATION PROGRAMME IN INDIA



5.1.3. COMMUNITY PARTICIPATION

One key element repeatedly mentioned in the reports reviewed was community involvement in the management and maintenance of rural solar powered water systems. Several UNICEF country offices have also used this strategy of involving the targeted community in solar-powered water supply projects. Community participation has been noted as a key factor in achieving a sustainable installation and operation of solar-powered RWSSs. This includes community participation in equity ownership of 40-60 percent of initial system installation costs. Upon completion of construction/ installation, the community is responsible for management of the system including repairs, maintenance and collection of user/s fees. A water user's committee is typically formed to oversee daily management of water systems, to collect monthly fees based on water consumption. The fee rate is agreed upon by the community during the inception phase to ensure affordability. The collected fees are used to maintain the system and fund other community projects, such as road construction and garbage collection.[26]

Engaging the local community in the design and implementation of RE systems can help build support and ensure long-term sustainability of the rural water systems installed.

26 *Myanmar Water Supply, Sanitation and Hygiene Sectoral and ORR (Thematic) Report January to December 2018*

5.2. BEST PRACTICES OF EE APPLICATIONS IN WATER SUPPLY SECTOR

EE in water and wastewater facilities are measured in terms of electricity consumption per volume of water (kWh/m^3 water) delivered to end users and the amount of electricity used per unit of wastewater treated (kWh/m^3 wastewater). On the water supply side, energy consumed per unit of water delivered or billed is used as an energy intensity indicator instead of unit of water produced in order to consider the important efficiency factor of water losses in the distribution process.

Comparative analysis of this energy intensity indicator with other water and wastewater facilities is challenging. Due to many variables, but not limited to operating conditions and technology used, differences in the energy intensity do not necessarily indicate actual EE gaps between facilities. It is potentially misleading to generalize system-level energy consumption performance. Thus, instead of benchmarking the overall energy intensity of the facility, it is more practical to benchmark the energy consumption for specific processing technologies and equipment. It is more useful to define disaggregated indicators for individual facilities to monitor and manage energy consumption and EE improvements.[27]

5.2.1. ENERGY AUDIT

Conducting an energy audit is a key aspect in improving the EE of a water supply system. This is undertaken to identify areas where energy is being wasted and where improvements can be made.

Generally, there are two levels of energy audit. The simple walk through audit and the investment grade audit. The choice of which level of energy audit to perform depends on the audit's purpose and the resources available.

- The simple walkthrough audit is done in one or two days and at low cost. It will generate basic information on: major energy consuming equipment and processes, obvious energy waste and inefficiencies, gaps in the metering and reporting of energy use, priority areas for further investigations and preliminary estimates of investments/savings for measures identified.
- The detailed energy audit or investment grade audit involves a more in-depth assessment of equipment and process with actual tests and measurements conducted. Historical energy use and billing data are analyzed. Detailed estimates of the energy and cost savings, capital investment requirements and returns are computed and assessed.

5.2.2. WATER AUDIT

A water audit is conducted to identify sources of leaks and ways to save water. It quantifies all water flows in the system from water extraction, treatment, distribution, to end use.

The current international best practice to conduct a water audit uses the Standard Water Balance approach developed by the International Water Association (IWA), as shown in Table 7.

27 *A Primer on EE for Municipal Water and Wastewater Facilities, Energy Sector Management Assistance Programme (ESMAP), 2012, IBRD World Bank.*

TABLE 7. INTERNATIONAL WATER ASSOCIATION'S WATER BALANCE APPROACH[28]

System Input Volume (A)	Authorizeb consumption (B1)	Billed authorizeb consumption (C1)	Billed Meter consumption (D1)	Revenue water (E1)
			Billed umetered consumption (D2)	
		Tiêu thụ ủy quyền không có hóa đơn (C2)	Unbilled metered consumption (D3)	Non - Revenue Water (E2)
			Unbilled umetered consumption (D4)	
	Water Losses (B2)	Apparent Losses (C3)	Unauthorized consumption (D5)	
			Customer Metering inaccuracies (D6)	
		Real Losses (C4)	Leakages on transmission & / or distribution mains (D7)	
			Leakages & overflows at utility's storage tanks (D8)	
			Leakages on service con-nections up to point of customer metering (D9)	

The definition of terms presented in Table 7 is as follows:

- System Input Volume: the annual input to a defined part of the water supply system.
- Authorized Consumption: the annual volume of metered and/or non-metered water taken by registered customers, the water supplier and others implicitly or explicitly authorized to do so. It includes water exported, and leaks and overflows after the point of customer metering.
- Non-revenue water (NRW): the difference between system input volume and billed authorized c+onsumption. NRW consists of unbilled authorized consumption and water losses.
- Water Losses: the difference between System Input Volume and Authorized Consumption, consisting of apparent losses and real losses.
- Apparent Losses: consists of unauthorized consumption and metering inaccuracies.
- Real Losses: the annual volumes lost through all types of leaks, bursts and overflows on mains, service reservoirs and service connections, up to the point of customer metering.

Non-revenue water accounts for 25-25 percent of total water supply and in some developing countries this even reaches 75 percent.[29] Reducing the volume of non-revenue water will decrease operating costs of the water supply system and substantially lower its energy cost. Identifying and quantifying each component is a key step in determining ways to reduce the NRW.

28 *The IWA Water Loss Task Force, Water 21 - Article No 2, Assessing Non-Revenue Water and its Components: A Practical Approach.*

29 *Reduction of Non-Revenue Water Around the World - iwa-network.org*

Some countries have already started to conduct trainings regarding this water audit approach developed by the International Water Association.

5.2.3. COMMON EE MEASURES APPLIED

On average, the commonly applied EE measures in water and wastewater facilities have generated 10-30 percent EE with payback of one to five years.

The operation of the water and wastewater system can be divided into raw water extraction, water treatment, and clean water distribution. The pumping process, common in each of these operations, is most energy consuming. Excluding gravity-fed systems, the pumping process in transmission and distribution account for about 70-80 percent of total electricity consumption. Thus, opportunities for EE are highest in this processing step and common EE measures applied to significantly reduce energy consumption while maintaining the same flow rates as less efficient pumps includes the following:

- Use of variable frequency drives (VFD) to control the speed of pump equipment
- Upgrade to high efficiency pumps
- Schedule pumping plan properly to water use demand
- Implementing water conservation measures, such as water leakage and encouraging water-saving behaviours.

5.3. BEST PRACTICES OF RE TECHNOLOGIES IN RURAL WATER SUPPLY

5.3.1. SOLAR POWER PUMPING

Water pumping is the most energy consuming processing step in the water supply system. Using an RE source to replace a fossil fuel-based energy source to operate pumps will bring about substantial savings in the operating costs of a water supply system. The use of solar power to operate pumps is the most widely applied RE technology in the water supply sector.

The world market for solar pumps has grown fast over the past decade. Its market size was valued at USD1.5 billion in 2022 and is projected to grow from USD1.64 billion in 2023 to USD2.83 billion by 2030. This estimate is based on compounded annual growth rate of 9.5 percent during the forecast period 2022-2030.[30] The solar pump is now considered a mature technology. However, most solar pumps installed worldwide are for irrigation and not for drinking water supply.

The following case studies focus on the use of solar pumps to supply drinking water in rural areas.

30 *Solar water pumps market research report information – Anshular Mandaokar*

5.3.2. SOLAR-POWERED WATER KIOSK/ WATER ATM

This type of solar powered water supply has existed not only in Zimbabwe, but also in Bangladesh, Ethiopia, Ghana, Kenya, India, Nepal, Pakistan, Tanzania and Uganda, among others. These solar powered kiosks are usually located in far flung rural off-grid areas. This is not an exhaustive list, but shows that solar powered pumps are now a proven and tried tested technology for drinking water supply. The selling price of water is usually determined through community consultations and its operation and management is based on the social enterprise model.

5.3.3. RETROFITTING EXISTING ELECTROMECHANICAL PUMP TO SOLAR PUMP

In a community in Puerto Rico, the water distribution system used to be powered by the AC grid power system that often experienced disruptions. When hurricane Maria ravaged the country, the power grid system was extensively damaged. The water system which used to supply 75m^3 water/day for the community could not be operated for months. To operate the water system again, solar power was installed to provide a more reliable power source. It was funded from a donation.

The existing pump, piping, water treatment, and water storage were reused. A 15kW Variable Frequency Drive inverter was installed, with 72 solar panels arranged in nine strings of eight panels in series were installed to provide total rated capacity of 345W. Disconnect and changeover switches were added so that AC grid power could be used if needed.

Retrofitting to solar was a viable option since the solar system can provide the needed power to meet the water demand in six hours. There was enough space near the existing water system to install the solar panels, community leaders supported the proposal to retrofit, and funding was available.[31]

5.3.4. SUPPLEMENTARY EQUIPMENT

In some solar pumping installations, auxiliary equipment is used to allow a seamless and automatic blending of another power source, such as diesel or a grid connected power source, when solar power is insufficient to meet the required demand for water.

5.3.5. SOFTWARE APPLICATIONS

Several parameters need to be considered when designing a solar pumping system. This includes among others: water demand (volume), water storage, water depth (head), location of solar panels, and solar irradiance at the site. Software is available for free and user friendly for engineers to use in designing and sizing-a solar pumping system.

There are now also software applications that allow remote monitoring and control of solar pumping systems located hundreds of kilometres away with the use of smartphones and tablets.

31 *Retrofitting Existing Electromechanical Pump Installations to Solar Power – Water Mission*

5.4. LESSONS LEARNED FOR VIET NAM

- To promote the wide applications of EE-RE in the rural water supply system sector, the relevant government ministry mandated to improve the performance of the water supply systems sector has issued EE-RE policy settings with specific energy targets. The government has developed clear indicators to measure how far the targets have been achieved.
- Community participation is a key factor to achieve sustainable installation and operation of an RE applications in the RWSS.
- Instead of benchmarking the overall energy intensity of the facility, it is more practical to benchmark the energy consumption for specific processing technologies and equipment. It is more useful to define disaggregated indicators for individual facilities to monitor and manage energy consumption and EE improvements.
- The option of which type/level of energy audit should be conducted will depend on the purpose of the energy audit and resources available.
- The pumping process is the most energy consuming processing step in the operation of a water supply system.
- Common EE interventions for the water supply system are:
    - Use of variable frequency drives (VFD) to control the speed of pumping equipment.
    - Upgrade to high efficiency pumps.
    - Pump scheduling to match the water demand.
    - Implementing water conservation measures, such as fixing leaks and encouraging water-saving behaviours.
- The use of solar power to operate pumps is the most widely applied RE technology in the water supply sector. In some solar pumping installations, auxiliary equipment is installed to allow a seamless and automatic blending of another power source such as diesel or a grid-connected power source when solar power is insufficient to meet the required demand of water. Aside from solar pumping, there are now new solar technologies being developed for possible applications in the water treatment operation to supply drinking water.
- There is software available for free and user friendly for engineers to use in designing and sizing a solar pumping system. Remote monitoring and control of solar pumping systems located hundreds of kilometres away are now possible with the use of software applications that can be downloaded on smartphones and tablets.

6. CONCLUSION AND RECOMMENDATION

6.1. CONCLUSIONS

6.1.1. ENERGY EFFICIENCY

This study highlighted the potential impacts of EE on Viet Nam's RWSS sector. Key findings include:

- Although RWSSs are relatively small energy users compared to other industrial sectors, there is ***still significant potential for EE due to the high proportion of electricity costs out of total operating expenses*** of RWSSs. Typically, electricity expenses make up a significant portion, ranging from 15 to 40 percent, of total operating costs for most systems. These energy expenditures frequently lead to elevated costs and unsustainable operations, which directly impact the financial sustainability of RWSSs.
- Improving EE is a key strategy for reducing operational costs of water systems. Energy typically represents the largest controllable operational expenditure for most systems and investing in EE measures can yield significant energy savings. Many EE measures have payback periods of less than five years, which means that ***investing in EE can support faster and greater expansion of clean water access for the poor by making systems cheaper to operate.***
- According to the survey, most commonly applied technical measures to improve EE generate ***savings of 10-25 percent per measure, with paybacks of less than five years***. However, the ***financial*** viability of EE ***depends on various factors*** such as the age and conditions of facilities, technologies used, effective energy prices, and other factors that affect the technical and financial performances of individual systems.
- Adopting efficiency measures, could realize EE potential of the sector at its current level of operation in the range of ***252 million kWh per year.*** This could also help ***save 68.9MW at peak-load*** and reduce GHG emissions of ***201.3 thousand tCO2 per year.***
- The main challenges to scaling-up EE in the rural clean water sector ***are governance issues,***

knowledge and awareness gaps, and financing bariers. RWSS governance affects the overall performance of individual systems and influences decision-making, incentives and actions for energy management. Addressing knowledge gaps will require intensive efforts in ***systematic data collection, training, and capacity building for rural water supply officers.*** Supported by local and national governments. Financing hurdles can be reduced by ***introducing dedicated EE funds*** to address large, but disaggregated investment needs and by promoting third-party financing through EE performance contracts.

- Currently, ***there is no EE policy specifically for RWSSs***. In other countries, the government ministry responsible for water supply systems commonly issues clear policies with goals for EE implementation in the sector.

6.1.2. RENEWABLE ENERGY

The survey revealed the current status of RE and solar power applications in the RWSS sector as follows:

- In Viet Nam, ***solar power is the only RE source applied in RWSSs*** up to the point of this survey. The majority (more than 80 percent) of these systems have small capacities (£ 12kWp), primarily concentrated in provinces within the Mekong Delta region.
- There are two types of solar power system configurations implemented in RWSSs: off-grid and grid-connected. At the time of survey, grid-connected solar power systems were operating steadily and effectively, ***supplying a portion of electricity needs (15-35 percent) for RWSSs***. On the other hand, most off-grid solar power systems were no longer operational or had been integrated into grid-connected systems.
- ***Solar power systems have been installed in RWSSs in Viet Nam for quite some time, but the pace of development has been slow.*** Among the 40 RWSSs that have installed solar power systems, 34 project systems were installed during 2014-2015. All solar power systems installed recently were funded by foreign aid or State budget allocations. No RWSSs invested their own funds, existing or borrowed, for these installations. The primary reasons were the relatively high upfront investment cost of solar power systems in the past, lack of financial resources for investment by RWSSs and limited awareness of solar power technology among staff and personnel of these systems.
- ***Promoting applications of solar power systems in rural water supplies has high potential.*** Against the backdrop of declining solar power costs, intensifying efforts to combat climate change and national grid electricity tariffs trending up, the strong potential of solar power has been recognized by PCERWASS in various provinces. Many provinces have developed plans, projects and programmes to enhance the use of solar power for rural clean water supply facilities to reduce production costs of clean water and contribute to environmental pollution reduction. However, these steps have not been approved and implemented due to ***challenges related to mechanisms, policies, funding sources and organizational capacity for implementation.***
- Current relevant mechanisms and policies still face bottlenecks that need to be resolved. There are two significant issues that need to be addressed: the issue on connecting solar power sources to ***the grid and the issue of public-private partnerships.*** Connecting solar power sources to the grid has been suspended since 2021. Since then, there has been no regulations for resuming

the connection process. Meanwhile, regulations concerning PPPs have not been clearly defined, making it difficult for investors, private ESCOs, and RWSSs to collaborate effectively. Furthermore, ***accessing financing for small-scale solar power projects is challenging, and there are no specific funding sources dedicated to RWSS.*** As a result, RWSSs struggle to secure funds for investment.

- Currently, ***there is no RE policy that specifically promotes RE in RWSS***. In other countries, the government ministry responsible for water supply systems has commonly issued clear policies and goals for the wide applications of RE in the water supply sector.

6.2. RECOMMENDATIONS

6.2.1. FOR GOVERNMENT AGENCIES - NATIONAL LEVEL

- **Developing and refining policies and regulations to address challenges related to connecting solar power systems to the grid and PPPs to promote applications of solar power and EE solutions in RWSSs.**

  - MARD should urgently propose the government ***allow solar power sources for clean water production to be connected to the grid.*** This is entirely possible because firstly, solar power sources at water supply systems are mainly ***rooftop solar power sources with small capacity,*** so they are only connected to the local low-voltage grid without risking system overloads, unlike transmission of large solar power stations (tens, hundreds of MW). Secondly, the rural clean water sector ***should be prioritized for development***. Connecting solar power sources for clean water production will eliminate the need for expensive storage appliances as a requirement for system efficiently and sustainably. It will also shorten the payback period of investment since any excess power generated can be sold to the grid. ***Thirdly, this will help the energy industry increase the percentage of clean energy,*** contributing to sustainable development and energy security. This is in accordance with Viet Nam's commitment to the international community to reduce net emissions to zero by 2050 and, as one of the hardest hit countries, mitigate the intensifying impacts of climate change.

  - The MARD should advocate for the government to ***remove barriers and streamline the PPP mechanism to facilitate implementation of contractual arrangements with ESCOs***. In fact, many RWSSs have the desire to develop solar power applications, but lack necessary investment funds. On the other hand, entities such as ESCOs and equipment manufacturers possess the technology and funds, but face challenges in cooperation due to unclear regulations regarding PPPs and asset management. Therefore, to rapidly and sustainably develop solar power sources in RWSSs, specific guidelines are needed for: (1) allowing entities that own and manage State-invested RWSSs ***to lease premises (office roofs, water reservoir surfaces, empty land areas) for installing solar power systems***, (2) ***enabling the purchase of solar power systems from entities that have installed them on facilities*** and (3) ***facilitating collaboration with other entities*** investing in solar power systems for RWSSs through mutually agreed-upon contract terms.

- **Develop and issue policy that directly promotes and encourages EE implementation and RE applications in RWSSs**

    - Currently, there is no government ministry or agency policy that directly and specifically encourages the RWSS sector to realize EE-RE in its operations. The review of international experiences indicates that a policy directly addressing ***reductions in specific energy consumption of water billed and reducing CO2 emissions per cubic*** metre of water billed is one approach to scale-up RE-EE in the water supply sector. The policy should indicate clear goals, performance targets and indicators to measure to what extent targets have been achieved.

- **Develop and issue regulations for establishing energy and finance consumption benchmarks for RWSSs**

    The MARD should conduct research to develop and issue regulations for establishing energy consumption benchmarks for RWSSs. These benchmarks will serve as a reference basis for RWSSs to enhance energy usage efficiency.

- **Develop sustainable financial mechanisms to promote RE-EE in RWSSs**

    - The current investment cost for solar power systems remains relatively high and some EE solutions also require substantial capital investment beyond the financial capacity of RWSSs. ***Borrowing funds for investment*** has become a practical necessity for these systems.
    - For the short-term scenario, explore the possibility of RWSS projects accessing ***existing financial mechanisms*** such as the World Bank guarantee facility for EE loans, environmental funds and other green funds developed for EE-RE projects and ESCOs.
    - In the long-term, MARD should recommend the government ***prioritize funds for RE applications in RWSSs*** to develop and establish sustainable financial mechanisms dedicated for water supply sector EE-RE projects to promote adoption of RE and EE. This will include offering low interest-bearing loans, long-term loans and guarantees or risk-sharing mechanisms.

- **Enhance communication activities to raise awareness and provide training to strengthen capacity in the development, management, and operation of solar power systems and EE equipment in RWSSs**

    - ***Increasing awareness*** of the benefits and responsibilities of adopting RE technologies in general, and solar power in particular, as well as implementing EE solutions is essential for staff and employees of RWSSs and relevant agencies involved in project development. Therefore, it is important to conduct activities that enhance awareness of solar power utilization and implementation of EE solutions in RWSSs for all stakeholders. Additionally, RWSS lack trained personnel for operating and maintaining RE and solar power systems. It is crucial to organize training activities to build capacity of personnel in managing and operating solar power systems, assessing the feasibility of solar power projects, and developing and implementing EE solutions and energy management systems for RWSSs.

- ° ***The MARD is recommended to mandate relevant agencies to:*** (1) implement awareness-raising communication campaigns, (2) provide training for PCERWASS technical staff in provinces on the operation, maintenance, and servicing of solar power sources, EE solutions and technologies applied in RWSSs, to establish a team of trainers for provinces, (3) develop and issue technical guidance documents to assist management units of RWSSs in developing plans, initiating projects and assessing the financial benefits and viability for implementation of solar power and EE projects in the operation, maintenance, and servicing of solar power systems and in managing the use of energy in RWSSs.

- **Developing the GHG trading market**

  - ° As estimated in the previous section, the significant reduction in GHG emissions achieved through applications of solar power and EE technologies in RWSSs is noteworthy. The government has established policies for developing this market from 2025. However, awareness and understanding of this field within RWSSs is still limited, as evidence by: (1) leadership of RWSSs lacking relevant knowledge of GHG emissions and the market for this commodity, (2) clean water production and business units not fully prioritizing emissions audits, (3) lack of understanding regarding emissions quota and the buying, selling and trading of emissions, (4) the domestic emissions trading market not having a robust and efficient connection with the international market.

  - ° In response, it is recommended that MARD takes the following actions: (1) ***Orgnizing capacity building programmes to enhance knowledge*** on clean energy and the GHG emissions trading market for entities within the sector and (2) ***providing guidences to provinces on conducting audits, assessing and aggregating reductions in GHG emissions*** resulting from applications of solar power system as well as EE solutions and technologies in a transparent and accurate manner according to international standards. This should involve setting a clear pathway for reducing emissions for each entity. Subsequently, efforts should be made to identify domestic and international markets for trading and exchanging emissions.

6.2.2. FOR PROVINCIAL LEVEL

- ***Develop plans for applications of solar power systems and EE solutions for RWSSs*** within the province. Clearly define objectives, timelines and implementation strategies for applying RE and EE solutions for RWSSs.

- Organize training activities to ***enhance the capacity and awareness*** of utilizing RE/ solar power systems and EE for personnel, especially those directly involved in managing and operating RWSSs within provincial RWSS units.

- Conduct training activities for RWSSs to enhance their capacity and awareness of ***international water audit practices*** to identify sources of leaks and ways to save water. This will help improve RWSSs' financial sustainability. Any operational savings could be a source of additional internal cash flows which could co-finance EE or RE projects.

- Conduct training activities to enhance capacity of RWSSs. This includes capacity building and awareness on how to get community participation, ***especially on fee or tariff rates setting.*** Communities should be given information on the importance of financially sustainable water supplies and subsequent negative of maintaining a politicized water tariffs.

6.2.3. FOR RWSSs OWNERSHIP AND MANAGEMENT UNITS

- Enhance training activities to improve the capacity and awareness of RE/ solar power system and EE solutions for personnel, especially those directly involved in managing and operating RWSSs. Enhance the ability to adopt new technologies and evaluate effectiveness and financial sustainability of energy-saving solutions for RWSS management and operation teams.
- Develop and implement plans for the operation, maintenance and servicing of solar power equipment, ensuring efficient and proper utilization of energy in accordance with established procedures.
- Develop and enforce regulations for energy management. Establish monitoring and reporting mechanisms for energy usage, conduct regular assessments to promptly identify energy losses and implement timely corrective measures.
- Implement recognized EE solutions such as: controlling water leakages in the distribution system, utilizing high-efficiency equipment (IE2, IE3 pumps; LED lights), installing variable frequency drives for pump systems, devising appropriate pump system operation plans, investing in pressure sensor systems to optimize the efficiency of variable frequency drives, improving power factor to reduce costs related to reactive power purchase and minimize energy losses.
- The applications of solar power sources in RWSSs must ensure technical compatibility (for example, amplitude, frequency, phase must be appropriate with the current on the power grid, should not generate interference such as harmonic distortion) to avoid affecting the power grid.
- In situations where solar power sources are not connected to the grid, the installed capacity of solar power sources for RWSSs should only be sufficient or partially meet the power demand of RWSSs (for instance, meeting 50-70 percent of demand) to prevent wastage. In cases where full demand is met, energy storage systems are necessary.

Filtering tank at water plant Giao Thuy, Nam Dinh province

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ANNEX

ANNEX 1. NPV AND IRR COMPUTATIONS OF A TYPICAL SOLAR POWER PROJECT FOR AN RWSS

- **Excluding sale of the carrbon credits:**

Period	Year	Cash Out Flow	Cash Inflow		Net Cassh Out-flow/ Inflow		Discount Fac-tor 1/(1+r)^n		Present Value
A	B	C	D		C - D = E		F		E x F = G
		VND	VND		VND		@ 8% p.a.		VND
0	2023	- 800,000,000			- 800,000,000		1.0000		- 800,000,000
1	2024	- 20,000,000	125,840,000		105,840,000		0.9259		98,000,000
2	2025	- 20,000,000	125,840,000		105,840,000		0.8573		90,740,741
3	2026	- 20,000,000	125,840,000		105,840,000		0.7938		84,019,204
4	2027	- 20,000,000	125,840,000		105,840,000		0.7350		77,795,560
5	2028	- 20,000,000	125,840,000		105,840,000		0.6806		72,032,926
6	2029	- 20,000,000	125,840,000		105,840,000		0.6302		66,697,153
7	2030	- 20,000,000	125,840,000		105,840,000		0.5835		61,756,623
8	2031	- 20,000,000	125,840,000		105,840,000		0.5403		57,182,059
9	2032	- 20,000,000	125,840,000		105,840,000		0.5002		52,946,351
10	2033	- 20,000,000	125,840,000		105,840,000		0.4632		49,024,399
11	2034	- 20,000,000	125,840,000		105,840,000		0.4289		45,392,962
12	2035	- 20,000,000	125,840,000		105,840,000		0.3971		42,030,520
13	2036	- 20,000,000	125,840,000		105,840,000		0.3677		38,917,148
14	2037	- 20,000,000	125,840,000		105,840,000		0.3405		36,034,397
15	2038	- 20,000,000	125,840,000		105,840,000		0.3152		33,365,182
16	2039	- 20,000,000	125,840,000		105,840,000		0.2919		30,893,687
17	2040	- 20,000,000	125,840,000		105,840,000		0.2703		28,605,266
18	2041	- 20,000,000	125,840,000		105,840,000		0.2502		26,486,357
19	2042	- 20,000,000	125,840,000		105,840,000		0.2317		24,524,405
20	2043	- 20,000,000	125,840,000		105,840,000		0.2145		22,707,782
				IRR	12%			NPV	239,152,722

- **Including sale of carbon credits in year 20:**

Period	Year	Cash Out Flow	Cash Inflow		Net Cassh Out-flow/ Inflow		Discount Fac-tor $1/(1+r)^n$		Present Value
A	B	C	D		C - D = E		F		E x F = G
		VND	VND		VND		@ 8% p.a.		VND
0	2023	- 800,000,000			- 800,000,000		1.0000		- 800,000,000
1	2024	- 20,000,000	125,840,000		105,840,000		0.9259		98,000,000
2	2025	- 20,000,000	125,840,000		105,840,000		0.8573		90,740,741
3	2026	- 20,000,000	125,840,000		105,840,000		0.7938		84,019,204
4	2027	- 20,000,000	125,840,000		105,840,000		0.7350		77,795,560
5	2028	- 20,000,000	125,840,000		105,840,000		0.6806		72,032,926
6	2029	- 20,000,000	125,840,000		105,840,000		0.6302		66,697,153
7	2030	- 20,000,000	125,840,000		105,840,000		0.5835		61,756,623
8	2031	- 20,000,000	125,840,000		105,840,000		0.5403		57,182,059
9	2032	- 20,000,000	125,840,000		105,840,000		0.5002		52,946,351
10	2033	- 20,000,000	125,840,000		105,840,000		0.4632		49,024,399
11	2034	- 20,000,000	125,840,000		105,840,000		0.4289		45,392,962
12	2035	- 20,000,000	125,840,000		105,840,000		0.3971		42,030,520
13	2036	- 20,000,000	125,840,000		105,840,000		0.3677		38,917,148
14	2037	- 20,000,000	125,840,000		105,840,000		0.3405		36,034,397
15	2038	- 20,000,000	125,840,000		105,840,000		0.3152		33,365,182
16	2039	- 20,000,000	125,840,000		105,840,000		0.2919		30,893,687
17	2040	- 20,000,000	125,840,000		105,840,000		0.2703		28,605,266
18	2041	- 20,000,000	125,840,000		105,840,000		0.2502		26,486,357
19	2042	- 20,000,000	125,840,000		105,840,000		0.2317		24,524,405
20	2043	- 20,000,000	2,222,400,000		2,202,400,000		0.2145		472,520,972
				IRR	15%			NPV	688,965,911

ANNEX 2. EXAMPLE OF A TARGETED EE RE POLICY ON RURAL WATER SUPPLY SECTOR

In Jordan, the Ministry of Water & Irrigation, which is mandated to improve the performance of the water sector, has issued the EE and Renewable Energy in the Water Sector Policy in 2016. Specific energy targets have been set for the year 2025:

- 15 percent reduction in the specific energy consumption of billed water corresponding to a 0.47 kg reduction of CO_2 emissions for the production per each billed cubic meter of water.
- Raise the share of RE resources in power consumption to 10 percent corresponding to a total saving of 0.31 kg of CO_2 emissions per each billed cubic meter of water.

To achieve these targets the government developed clear indicators to measure how far the targets have been achieved.

Goal 1: Improve the level of EE in the water supply and wastewater sector by 15 percent by year 2025 to be measured in terms of kWh/m^3 of water billed and kWh/m^3 of water produced.

Goal 2: Increase the use of RE in the water supply sector to account for 10 percent of the energy consumption (2019 baseline) by 2025 and 20 percent by 2030. This will be measured in terms of GWh generated from RE projects.

Goal 3: Implement Energy Management System (EnMS) such that 60 percent of the water sector is implementing it by 2025 and 100 percent by 2030. This will be measured in terms of kWh consumed by water assets that are included within the scopes and boundaries of the EnMS divided by the total amount of electricity consumed by the Jordan water sector.

Goal 4: Enhance the enabling environment by establishing: a) coding system, b) energy & water data management system implemented in 80 percent of the water sector by 2025 c) energy and GHG emissions balance annual report for the water sector starting in 2025.

The main activities to improve EE include:

- System redesigns e.g., adjustments in the ground water wells slot openings to improve wells efficiency, converting from pumping systems to gravity, restructuring of water distribution districts to reduce and control required pressures, introducing Best Available Technologies to recover kinetic and biotic energy from wastewater plants.
- System rehabilitation e.g., replacement of pumps, changing pumps configurations, and rehabilitation of distribution networks to reduce leakage.
- System Operation and Maintenance by integrating EE in the daily operation practices of water sector operation and maintenance.

EE improvements shall cover all aspects of potable water supply cycle from source water abstraction to treatment & distribution, and the full wastewater cycle from collection & transport to treatment & discharge or reuse.

The EnMS being adopted is in accordance to ISO 50001. It is based on Plan-Do-Check-Act continual improvement framework.

The EnMS is being developed in two phases, first a pilot scale phase then a full-scale implementation phase.

The coding system has been developed and is applied in all the data collection and reporting activities for the water sector. This coding system will be used by water supply systems, relevant government agencies and energy billing power companies.

A monitoring and evaluation tool has been developed summarizing the baseline values of each indicator along with the planned targets with empty blank cells to be filled for the annual monitoring and evaluation reports in order to compare actual progress to the baseline and target values for each indicator for that specific period.

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