Research papers

JULY 2025
No 362

Authors
Nguyen Thi Vinh Ha
Nguyen Thi Hai Ninh
Nghiem Phuong Tuyen

Coordination
Cecilia Poggi

Payment for Forest Environmental Services and Household Energy Consumption Trajectory

The case of Lâm Đồng Province, Vietnam

ÉDITIONS AFD
AGENCE FRANÇAISE DE DÉVELOPPEMENT

Agence française de développement

Papiers de recherche

Les *Papiers de Recherche de l'AFD* ont pour but de diffuser rapidement les résultats de travaux en cours. Ils s'adressent principalement aux chercheurs, aux étudiants et au monde académique. Ils couvrent l'ensemble des sujets de travail de l'AFD : analyse économique, théorie économique, analyse des politiques publiques, sciences de l'ingénieur, sociologie, géographie et anthropologie. Une publication dans les *Papiers de Recherche de l'AFD* n'en exclut aucune autre.

Les opinions exprimées dans ce papier sont celles de son (ses) auteur(s) et ne reflètent pas nécessairement celles de l'AFD. Ce document est publié sous l'entière responsabilité de son (ses) auteur(s) ou des institutions partenaires.

Research Papers

AFD Research Papers are intended to rapidly disseminate findings of ongoing work and mainly target researchers, students and the wider academic community. They cover the full range of AFD work, including economic analysis, economic theory, policy analysis, engineering sciences, sociology, geography and anthropology. *AFD Research Papers* and other publications are not mutually exclusive.

The opinions expressed in this paper are those of the author(s) and do not necessarily reflect the position of AFD. It is therefore published under the sole responsibility of its author(s) or its partner institutions.

Payment for Forest Environmental Services and Household Energy Consumption Trajectory: The case of Lâm Đồng Province, Vietnam

Authors

Nguyen Thi Vinh Ha
University of Economics and Business, Vietnam National University, Hanoi

Nguyen Thi Hai Ninh
Vietnam National University of Agriculture

Nghiem Phuong Tuyen
Central Institute for Natural Resources and Environmental Studies, Vietnam National University, Hanoi

Coordination

Cecilia Poggi (AFD)

Abstract

This research examines the impact of the Payment for Forest Environmental Services (PFES) program in Viet Nam on household income and its interaction with energy consumption behavior. A mixed-method approach was employed, including focus group discussions, interviews with households, program managers, local authorities in Lâm Đồng province, and analysis of household income data from the Viet Nam Living Standard Surveys (VHLSS). Findings show that PFES participation does increase household income, but not significantly. There is a clear shift in energy use patterns among households following energy stacking theory; however, this transition is not driven solely by income but also by factors such as education level, primary occupation, and awareness of clean energy benefits. The study recommends improving the PFES scheme by raising payment caps, adjusting electricity pricing policies for PFES participants, and integrating awareness-raising and education on clean energy transition.

Keywords
Payement for ecosystem services; energy transition; energy stacking theory; Lam Dong province; Vietnam

Acknowledgements
This research is part of the GEMMES Viet Nam 2 program (C3-WP3 project) and has benefited from the financial support of the French Development Agency. Dr. Cecilia Poggi provided significant supervision thoughout the analytical and writing process. We thank for his research assistance Mr. Ramaholimihaso, who made valuable contributions to the literature review and analysis of the article. We also thank Eva Tène and two Expert Panel members for valuable comments.

JEL Classification
Q56; Q41; D12

Original version
English

Accepted
July 2025

Résumé

Cette recherche examine l'impact du programme Paiement pour les services environnementaux forestiers (PFES) au Viet Nam sur le revenu des ménages et son interaction avec le comportement de consommation d'énergie. Une approche à méthodes mixtes a été utilisée, incluant des groupes de discussion, des entretiens avec les ménages, les gestionnaires du programme et les autorités locales dans la province de Lâm Đồng, ainsi que l'analyse des données sur le revenu des ménages tirées des enquêtes sur les conditions de vie au Viet Nam (VHLSS). Les résultats montrent que la participation au PFES augmente le revenu des ménages, mais pas de manière significative. Il y a un changement clair dans les modèles d'utilisation de l'énergie parmi les ménages, en ligne avec la théorie de l'accumulation d'options énergétiques; cependant, cette transition n'est pas uniquement motivée par le revenu mais aussi par des facteurs tels que le niveau d'éducation, l'occupation primaire et la sensibilisation aux avantages de l'énergie propre. L'étude recommande d'améliorer le programme PFES en augmentant les plafonds de paiement, en ajustant les politiques de tarification de l'électricité pour les participants PFES et en intégrant la sensibilisation et l'éducation sur la transition vers une énergie propre.

Mots-clés

Paiement pour les services écosystémiques ; transition énergétique ; théorie de l'accumulation d'options énergétiques ; Province de Lam Dong ; Vietnam

Remerciements

Cette recherche s'inscrit dans le programme GEMMES Viet Nam 2 (projet C3-WP3) et a bénéficié du soutien financier de l'Agence française de développement. Le Dr Cecilia Poggi a assuré une supervision significative du processus analytique et de rédaction. Nous remercions M. Ramaholimihaso pour son role d'assistant à la recherche, qui a apporté des contributions précieuses à la révue de la littérature et à l'analyse de l'article. Nous remercions également Eva Tène et deux membres du panel d'experts pour leurs précieux commentaires.

Classification JEL

Q56; Q41; D12

Version originale

Anglais

Acceptée

juillet 2025

Introduction

Vietnam has committed to achieving net-zero emissions by 2050, making the energy transition an essential task. The Vietnamese government is promoting the use of renewable energy sources such as solar and wind power by issuing various supportive policies, including investment incentives and energy efficiency improvements. In the context of global climate change, sustainable energy transition remains one of the major challenges that Vietnam faces. This transition requires not only technological and infrastructural changes, but also environmental policies that incentivize household shifts.

The Payment for Forest and Environmental Services (PFES) program plays an important role in the energy transition in Vietnam. PFES is a policy mechanism that provides financial incentives to individuals or communities for protecting and ensuring sustainable forest management. PFES program aims to reduce deforestation, protect water resources, conserve biodiversity, and sequester carbon (McElwee et al., 2020; Nguyen et al., 2022).

PFES provides additional earnings to many households, especially those living near protected forests. With increased income, people may be able to access and switch to cleaner energy sources, instead of relying on traditional energy sources. Research by Kolinjivadi et al. (2014) shows that the PFES program has brought numerous economic, social, and environmental benefits to forest-adjacent communities. In Cat Tien National Park, Pham, T.T et. al. (2021) find PFES payments contribute 16% to 74% of ethnic minority household income. Among poor households participating in PFES, 22% relied solely on PFES for earnings, and 81.4% reported escaping poverty thanks to PFES, though monitoring and data reliability remain concerns. In Dak Lak, PFES makes up 6% to 18% of household income and encourages forest protection (Pham, T.T. et al., 2021). Pham, V.T. & Roongtawanreongsri, S. (2022) confirm PFES participants have significantly higher incomes than those not participating—with an average increase of VND12.84 million and PFES contributes about 15% of total income. PFES enables investments in agriculture to further improve livelihoods. Duc et al. (2023) shows that PFES enhances environmental benefits and livelihoods in Bắc Kạn province.

However, questions remain about how and to what extent the PFES program contributes to household income in different regions, and how this, in turn, supports the rural energy transition. In this study, we empirically test the hypotheses elaborated from the theories of Energy Ladder and Fuel Stacking: PFES increases the adoption and consumption of less carbon-intensive energy sources (hypothesis 1); and the effect of PFES on energy behaviour is mediated by income (hypothesis 2). To examine these hypotheses, this research investigates if PFES enhances income of participating households in Lâm Đồng province via a qualitative analysis and if such income enhancement leads towards more sustainable energy consumption by testing data from Vietnam Living Standard Survey (VHLSS).

1. Literature review

1.1. Payment for Forest Ecosystem Services (PFES)

1.1.1. Definition and objectives of PFES

Payment for Ecosystem Services (PES) is usually defined as a voluntary transaction where an environmental service is being ‘bought’ by a minimum of one buyer from a minimum of one provider, if and only if the environmental service provider secures an environmental service provision (Wunder, 2005).

PES is expected to have a double objective of environmental conservation and improving economic and social welfare (Börner et al., 2017). However, Jayachandran (2023) argues that conservation and anti-poverty goals of PES inherently conflict with each other. PES often has two components: compensation for the change in behaviour and an additional amount, which is a pure transfer. The environmental benefits are maximized when the pure transfer equals zero. If the compensation is sufficiently high to induce participation, then any additional funds should be used to reach more people, as higher compensation does not lead to more conservation. The economic benefit of PES (pure transfer) is negatively correlated with the cost of compliance. Those who have lower opportunity costs, generally poorer households, exhibit higher economic benefits from PES (Alix-Garcia et al., 2015; Jayachandran, 2023).

Studies suggest that worldwide PES has a positive impact on income (Snilsveit et al., 2019) and reduces deforestation (Busch & Ferretti-Gallon, 2023; Snilsveit et al., 2019). However, these results must be interpreted with caution as they may be limited by several biases in their estimation and are inherently context dependent. Additionally, the available qualitative and quantitative evidence supporting the impact of PES policies is still scarce (Samii et al., 2014; Snilsveit et al., 2019). Recent literature suggests that PES programmes significantly reduce tree cover loss and deforestation (Alix-Garcia et al., 2015; Jayachandran et al., 2017) and minimize burning (Jack et al., 2022). The positive environmental effects persist in the long term, even after the cessation of payments (Hayes et al., 2022).

1.1.2. Economic and environmental effects of PFES

Evaluating the environmental impact of PFES presents challenges, including data deficiencies (Thuy et al., 2013). Available data may be inconsistent and unreliable, particularly regarding forest cover, forest conditions, carbon sequestration, and watershed protection. In addition, local government agencies often face capacity constraints, limiting their ability to effectively collect, analyse, and monitor this data (Thuy et al., 2013). Overall, comprehensive evaluations of PFES impacts in Vietnam remain limited (Gallemore et al., 2023).

PFES is globally associated with less deforestation (Busch & Ferretti-Gallon, 2023). In Vietnam, two years after the implementation of the pilot programme in 2008, promising environmental outcomes were observed in Lâm Đồng. Between 2005 and 2010, illegal logging decreased notably (Ly, 2013), and the programme improved environmental awareness and education on forest protection (Ly, 2013; Phan et al., 2018). It also shifted responsibility from the government to users, fostering a better understanding of forests' value (Ly, 2013). From 2011 to 2014, forest cover in Lâm Đồng rose from 57.7% to 62.6%, and illegal logging fell by 60% (Phan et al., 2018). However, intensive land clearing is still observed in communes like Đa Nhim where local authorities distributed forestland certificates for coffee plantations, aiming to alleviate livelihood pressures in less ecologically vulnerable areas (Trædal & Vedeld, 2017). Similar positive results of PFES are observed in other provinces: Quảng Nam's forest cover grew from 457,200 ha in 2008 to 680,300 ha in 2017, and Thừa Thiên Huế from 293,200 ha to 311,900 ha (Do & NaRanong, 2019). Annual forest area growth nearly doubled and even increased sevenfold compared to the pre-PFES period, while forest loss due to fires and natural causes declined. However, forest loss from cutting rose from 2002 to 2016, partly due to land demands for eight hydropower plants in Quảng Nam (Do & NaRanong, 2019).

Thuy et al. (2021) estimate that, without PFES, the risk of deforestation would be much more critical. Even if deforestation still happens in PFES areas, they are less likely to occur (Tran Quoc et al., 2023). Bảo et al. (2020) show that forest violations decreased over time in Tà Đùng National Park, Đắk Nông Province, after PFES was put into implementation. Moreover, the programme helps reduce the deforestation rate compared to non-PFES areas (Gallemore et al., 2023). Forest loss began declining three years after the program started, with positive impact growing over time (Gallemore et al., 2023).

PFES has been found to positively impact income (Pham et al., 2020; Pham et al., 2021). In Đắk Lắk and Kon Tum, PFES participants have more income sources and higher total income than non-participants (Pham et al., 2021). PFES payments enable households to acquire or rent productive land and invest more in livelihood activities, resulting in higher income per labourer, per land area, and per production cost (Pham et al., 2021). In Sơn La, average income from forestry, including PFES, is 2.31 times higher in villages with PFES than in control villages (Pham et al., 2020). PFES provides a stable income, though the lack of pre- and post-programme income data hinders a proper evaluation (Pham et al., 2020). Overall, the effectiveness of PFES in improving livelihood depends on the forest area managed, the opportunity costs of land use, the local context, and the capacity of local agencies to handle the distribution of PFES payments (Pham et al., 2015).

Evidence on the transformative effects of PES on livelihoods in Vietnam remains mixed. Evaluation of PFES impact tend to lack methodological rigor, and available data is insufficient to accurately quantify its effects (Thuy et al., 2021). Although there is generally positive perception of PFES schemes (Ly, 2013), the programme implementation encounters certain limitations and concerns.

Several studies find no significant impact of PES on local livelihoods. To et al., (2012) find that the pilot PES schemes in Lâm Đồng and Sơn La provinces failed to accomplish the objective of enhancing local livelihoods and reducing poverty. Land tenure issues and related conflicts induced unequal distribution of benefits (To et al., 2012). The PFES failed to reach the poor, especially newly established households and migrants lacking access to land but strongly reliant on forestland and forest resources. In the pilot phase, households without a prior contract with the state forest were excluded from the PFES scheme. The capture of the benefits by the local elite and the exclusion of poor households is also observed in other provinces (Mohammed, 2011; Thuy et al., 2013; To & Dressler, 2019). Low-income people often struggle to access PFES due to lack of land titles and unequal power dynamics (McElwee, 2012; Thuy et al., 2013). Even when they possess land certificates, their plots are typically smaller, reducing their engagement in PES schemes (McElwee, 2012).

On the other hand, the success of the PFES scheme is limited by opportunity costs (Thuy et al., 2013; To et al., 2012). PFES compensation is considered too low to outweigh the potential gains from other land uses. In Sơn La province, firewood and timber revenue can surpass PFES income by four times, while bamboo and bamboo shoots generate 7.34 times more income (Pham et al., 2020). After the pilot phase, poor and landless households saw their income shrink since their primary income sources were restricted (Nguyen et al., 2022). In an interview, one village head reported that "the payment is too low while patrol activity is dangerous if you meet illegal loggers" (Nguyen et al., 2022).

1.1.3. Success factors and participation in PFES programs

Characteristics related to the design, implementation, and context might explain a PES scheme's success or failure. Snilsveit et al. (2019) suggest that targeting the most relevant participants is essential for the success of a programme. Successful PES schemes rely on targeted approaches that considers the participant's social, economic, and environmental factors, and must be in line with its main objective (Snilsveit et al., 2019). For instance, if the programme aims at reducing deforestation and improving livelihoods, it should target vulnerable participants in areas that are likely to be deforested. Furthermore, strong governance structures should be ensured to establish a relationship of trust between the implementer and the beneficiaries. Snilstveit et al. (2019) shows that, the success of the programme requires full understanding and adhesion to the programme of the participants. Otherwise, it could create distrust and dropout from the programme (Snilstveit et al., 2019).

PES programme uptake is influenced by factors such as income, land size, labour, opportunity costs, social norms, capital, and the state of the ecosystem service. Snilsveit et al., (2019) indicate that people with higher incomes, diversified livelihoods, and larger land are more likely to engage in PES initiatives, while those reliant on natural resources face higher opportunity costs and are less inclined to enrol—especially in community-level schemes. Policy makers should identify a contextual level of compensation that is sufficient to maximize participation. Still, it should not be set too high if it would not result in more conservation (Jayachandran, 2023). PES effectiveness can also improve with complementary policies that encourage innovation in the market for alternatives to charcoal as a source of energy or wood as a building material and thereby reduce people's forgone income from protecting the forest (Jayachandran, 2023).

During the pilot phase in Lâm Đồng, payments were based on household participation rather than the quality of forest services (To et al., 2012; Trædal & Vedeld, 2017). A uniform payment rate was applied (K=1), meaning that all participants in the same watershed received equal payment regardless of efforts (Ly, 2013). As PFES payments were low and could not support livelihoods, participants were not encouraged to improve the forest quality (Lượng, 2018).

Implementers face high transaction costs in identifying beneficiaries and payment levels (Nguyen et al., 2022; To et al., 2012). In Sơn La province, the pilot programme involved allocating small land plots to thousands of households. The weak capacity of the state to conduct inventories and track changes in forestland titles, along with costly inventory and complex computation of payment levels, induced delays in setting contracts and disbursing payments (To et al., 2012).

Despite the claims of success around PFES, To and Dressler (2019) emphasizes that the lack of credible data undermines the ability to affirm that PFES have actually benefited the poor, given that some studies have shown the persistence of elite capture. Moreover, the unresolved land tenure problem may have impeded the PFES implementation and resulted in the exclusion of the poor from accessing the scheme (To & Dressler, 2019). Thus, results must be interpreted with caution. Most impact evaluation studies acknowledge that with the methodologies used as well as the quality of the data, caution must be applied, as the findings might not be robust and accurate enough (Pham et al., 2020; Thuy et al., 2013; Thuy et al., 2021; To & Dressler, 2019).

1.2. The PFES in Vietnam and in Lâm Đồng province

1.2.1 Introduction to the PFES scheme in Vietnam

In Vietnam, PFES payment are set by the government via its provincial authorities, making it different from the conventional market-based approach which consists of voluntary transactions between users and providers (Suhardiman et al., 2013; Thuy et al., 2013).

The Vietnamese government first mentioned PES as part of the country's Forestry Development Strategy in 2006 (To & Dressler, 2019). In 2007, the Vietnamese Ministry of Agriculture and Rural Development (MARD) accompanied by the Winrock's Asia Regional Biodiversity Conservation Program (ARBCP), developed a pilot policy on PFES (Chiramba et al., 2011). Pilot testing activities were launched in Lâm Đồng and Sơn La provinces in 2008 and then implemented between January 2009 and December 2010. The pilots included environmental services such as water regulation and provision, soil erosion reduction and watershed protection, ecotourism services, and scenic landscape amenities. The ARBCP managed the implementation in Lâm Đồng province, while the German bilateral cooperation agency (GIZ) supported the implementation in Sơn La Province. The commune of Đa Nhim (Lâm Đồng) was the first pilot site that entered into forest protection.

In 2010, the Prime Minister announced a national decree to scale up the PES scheme. 36 provinces quickly adopted the programme between 2011 and 2013 (Office of Government, 2014). This expansion covered approximately 40.5% of Vietnam's natural forest areas by 2013 (Cochard et al., 2020). In 2016, PFES scheme had substantial coverage in provinces with abundant natural forest resources that face a constant threat of illegal logging and robust hydroelectric production capabilities. This was particularly evident in the northern regions and those closer to the coast, where large forestland areas were included in the scheme (Cochard et al., 2020). PFES communities tend to exhibit high levels of poverty, a substantial rural population, and often have significant proportions of ethnic minorities. These areas have relatively smaller labour contributions to the official agricultural sector (Cochard et al., 2020). Currently, the PFES policy has been implemented nationwide, in most provinces.

The policy allowed payment for five different types of ecosystem services and identified different kinds of service buyers, including soil erosion prevention, watershed protection for hydropower plants and water suppliers, carbon sequestration, landscape and biodiversity protection for tourism purposes, and water regulation for aquaculture (McElwee et al., 2020; Nguyen et al., 2022).

The payment to forestry service providers was based on the K-coefficients (Suhardiman et al., 2013). The K-coefficients encompass various dimensions: three categories of forest status (rich, medium, poor); forest type (based on the state's system of classification of special use, protection, and production forest); forest origin, which includes natural forest and plantation; and a measure of difficulty in protecting and patrolling the forest (To & Dressler, 2019). However, as the calculations with the K-coefficients appeared to be complex, the idea was denied. Instead, some provinces used a uniform payment (K=1) or only applied one or two coefficients – mainly the K3 on the origin of the forest (Đức et al., 2020; McElwee et al., 2020). Hydropower companies had to pay VND20 per kilowatt as purchasers of environmental services, while water supply companies incurred a charge of VND40 per cubic meter, and tourism companies contributed 1% of their annual gross revenues. These funds served as compensation to households for the environmental services they rendered (Suhardiman et al., 2013). In 2009, average household payments ranged from VND 8.1 to 8.7 million to VND 10.5 to 12 million (Chiramba et al., 2011), and total PFES revenue reached VND 77 billion (To et al., 2012).

The management of PFES fund vary across provinces (Suhardiman et al., 2013). Each province can decide its benefit distribution mechanisms, leading to a multitude of local collective action models. These span from communities with collective forest land titles receiving community-wide PES payments, organized kin and clan groups managing forests to receive payments, or communities without land titles providing collective patrols for protection of state forest lands and receiving a collective payment (Nguyen et al., 2022).

1.2.2. PFES implementation in Lâm Đồng

The PFES forest area in 2023 was 400,000 ha, accounting for more than 75% of the total forest area of the province. Of which, the acreages classified by forest use purposes are listed as: protection forest: 132,658.19 ha, special-use forest: 81,085.07 ha, and production forest: 185,406.50 ha; and by forest origin: natural forest: 355,655.08 ha, and planted forest: 43,494.68 ha (Lam Dong PPC, 2024a).

The PFES programme is jointly supervised by several government agencies, with the Lâm Đồng Forest Protection and Development Fund (FPDF) acting as a coordinator. The PFES system involves a forest leasing model where households, either individually or together, are contracted by state or private forest owners to manage forested areas. "Forest protection groups" jointly oversee and safeguard the forestland. These arrangements are more akin to labour contracts rather than performance-based agreements, with payments tied to participation rather than results (Trædal & Vedeld, 2017). Forest owners enter into forest protection contracts with local farmers, especially those with prior experience in forest protection and participation in forestry programs. These local farmers are the actual providers of ecosystem service (Trædal & Vedeld, 2017). The FPDF collects payments from the ecosystem service buyers and distributes them among the forest owners based on their forest area. The forest owners, in turn, pay the local farmers every three months (Phan et al., 2018).

Unlike other government agencies, the Lâm Đồng FPDF does not have representatives at district or communal levels. They work directly with forest owners and FES users. Similar to other provinces, until 2017, Lâm Đồng did not employ the K coefficient (i.e., K=1). From 2018 to 2022, the province applied the K3 to forest origin (K3 = 1.00 for natural forests, K3 = 0.9 for planted forests). Between 2009 and 2022, the total PFES collected was VND 3,245 billion (an average of VND 216 billion per year), with hydropower plants accounting for roughly 95% of the revenue. The total expenditure for 2009-2022 was 3,092 billion VND (Lam Dong FPDF, 2023a). The FPDF retains management fee of no more than 10% of the total collected amount to operate the Fund, carry out propaganda activities, and provide protective clothing and forest protection equipment. From 2020, tourism companies pay FES directly to forest owners. In 2022, forest owners in the Đồng Nai River basin were paid 1,214,000 VND/ha/year, while those in the Serepok River basin got 936,000 VND/ha/year (Lam Dong FPDF, 2023a).

Beginning in 2023, PFES in Lâm Đồng has been implemented based on individual user's supply basins, with full application of the four K coefficients established in Decree No. 156/2018/ND-CP. The FPDF has worked out and agreed on the payment area for each FES user and the K coefficients for each forest basin. Each year, the FPDF produces a map of the supply basin and sets the unit price for each user. In 2023, the total PFES collected was 347,786 million VND. The FPDF kept 6.91% of total revenue for management, and 93.09% of the total was allocated to the FES suppliers (Lam Dong PPC, 2024b). In 2024, Lâm Đồng FPDF got authorization to pay for forest environmental services from 67 production entities, including 54 hydropower plants, 12 clean water production factories, and 01 industrial manufacturing facilities. PFES forest owners consisted of 164 organizations (forest protection management boards and national parks: 15; forestry companies: 08; other forest owners: 147), 1457 households and individuals, 03 village communities, and 04 communal people's committees (Lam Dong PPC, 2024b).

The Lâm Đồng FPDF pays directly to forest owners in quarterly instalments, in which the 1st, 2nd, and 3rd instalments are advances. To set the basis for acceptance and settlement of the PFES contract, FPDF coordinates with the Lâm Đồng Forest Protection Department, a state agency, to conduct inspections and determine the forest area eligible for payment compared to the forest quality determined since 2014.

1.3. Fuel Stacking Theories

Energy plays a vital role in human life as well as the development of each nation. The abundance and quality of energy are considered a measure of the people's wealth and society's progress (Ado & Darazo, 2016). While in developed countries, the use of cleaner and more environmentally friendly energy such as gas and electricity has become popular, in developing countries, people still depend on various traditional energy sources such as biomass, firewood, coal, and kerosene for daily use for cooking, heating, and agricultural production purposes. The main reason for this choice is that traditional fuels such as firewood and biomass are often available, especially in rural areas (Vo & Ho, 2024). In addition, people in rural areas have difficulty accessing modern fuels, especially regarding their income constraints. In other words, energy costs significantly influence households' decision to switch to cleaner energy sources because increased fuel quality is accompanied by higher fuel costs (Das et al., 2014).

According to FAO’s report, about 2.6 billion people worldwide relied on biomass to meet their energy needs in 2015; this number is expected to increase to 2.7 billion by 2030 (Ado & Darazo, 2016). Reliance on biomass comes with many costs for households and society. These costs include deforestation, environmental pollution and climate change due to emissions from energy combustion, serious health burdens in the form of respiratory diseases that women and their children suffer from when cooking, and the cost of collecting biomass that takes up a lot of women's time (Elias & Victor, 2005). Therefore, switching to clean energy consumption, and reducing the use of firewood and solid fuels is inevitable for countries to move towards sustainable growth and development, and improving people's health and lives (Vo & Ho, 2024).

Up to now, there is no widely accepted definition of energy transition. Still, commonly, energy transition is understood as a change towards increasing access to and use of clean energy (such as gas and electricity) and reducing reliance on traditional energy (such as coal and biomass fuel) (Berkhout et al., 2012). Throughout history, the world has witnessed many changes in energy use. Some typical examples include the shift from traditional energy sources such as biomass to fossil fuels such as coal and then from fossil fuels to cleaner energy sources such as electricity (Fouquet, 2010). Theoretically, there are two main hypotheses related to the energy transition: energy ladder and energy stacking (Nguyen et al., 2019).

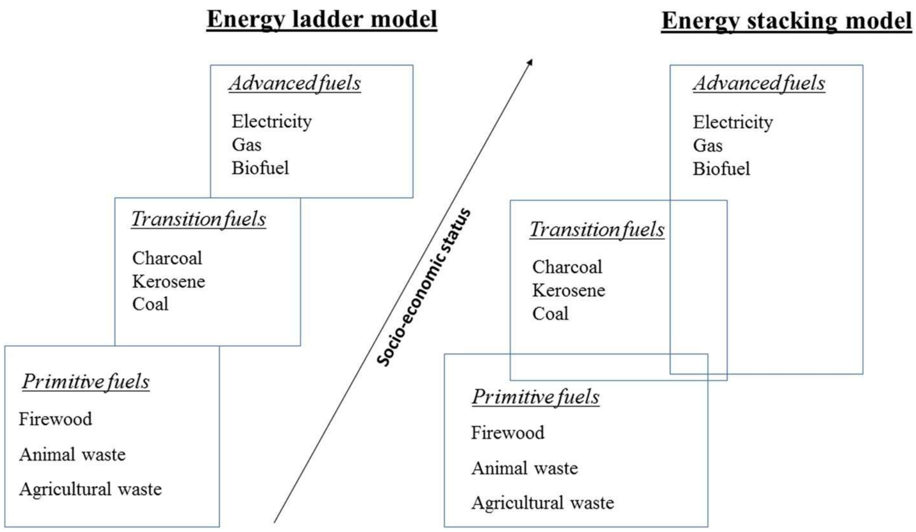


Fig. 1. Framework for Energy ladder and Energy stacking models

Sources: Hosier and Dowd (1987) and Han et al., (2018)

1.3.1 Energy ladder

The concept of the energy ladder takes the differences in energy use between households of different economic statuses as its starting point. Households are assumed to behave consistently with neoclassical consumers, moving to more efficient energy sources as their income increases. In contrast to firewood and crop waste used by the poor, wealthier households use electricity and petroleum products (Song et al., 2018).

The energy ladder model suggests that an energy transition consists of three stages. The first stage is marked by widespread household dependence on biomass energy. In the second stage, households switch to "transitional" fuels such as kerosene, coal, and charcoal. In the third stage, households switch to liquefied petroleum gas and electricity consumption as their incomes increase (Barnes et al., 2002). In other words, according to the energy ladder theory, household energy choices shift from primitive fuels to transitional fuels, then to modern fuels, as incomes increase. Primitive fuels are dirtier and less efficient but cheaper, while modern fuels are more energy efficient and cleaner but also more expensive. Poor households are constrained by income and, therefore, use more affordable and dirtier fuels, while wealthier households can afford more costly and cleaner fuels. Household income has been identified as the most crucial factor in determining fuel choice (Arnold et al., 2006; Cooke et al., 2008; Heltberg, 2005). Switching to a new fuel is also a switch away from a previously used fuel (Heltberg, 2005). Fuels on the energy ladder are ranked according to household preferences based on physical characteristics, including cleanliness, ease of use, cooking speed, and efficiency (Horst G & AJ, 2008).

1.3.2 Energy stacking

The Energy Ladder theory assumes that household energy choices and transitions are determined exclusively by household income. However, research in many developing countries shows that households switching to modern energy sources do not entirely abandon traditional energy sources (Masera et al., 2000). In other words, households, especially in rural areas, do not simply switch fuels but also expand their fuel portfolio, using multiple fuels at the same time, taking advantage of the benefits that each fuel brings to ensure energy security and minimize costs (Gupta & Köhlin, 2006; Masera et al., 2000; Nansaior et al., 2011). Even advanced fuel users may continue to use traditional fuels such as firewood and charcoal (Song et al., 2018). Therefore, the Energy Ladder theory fails to explain actual household behaviour, which has given rise to the energy stacking theory that contradicts the energy ladder concept.

The key determinants of the energy stacking hypothesis include preferences, needs, costs, and income (Masera et al., 2000). This energy-stacking behaviour can be seen as a livelihood strategy through which households cope with erratic income flows, protect themselves from unstable energy markets, and maintain their cultural activities while benefiting to some extent from modern fuels (Kroon et al., 2013).

In Vietnam, along with rapid economic growth, households gradually switch from using traditional fossil energy in their daily lives to cleaner and more efficient energy, such as gas and electricity (Son & Yoon, 2020). Research on energy transition in Vietnamese households in recent years also confirms the “energy stacking” theory because increasing income does not lead to switching from inferior energy sources such as biomass to superior energy sources (Nguyen et al., 2019; Vo & Ho, 2024). Therefore, in the next section, the paper will summarize the factors affecting households' “energy stacking”.

1.3.3. Factors affecting energy choices

One of the shortcomings of the “energy ladder” theory is that it focuses only on income to determine households’ energy choices, ignoring other possible factors. Masera et al. (2000) found that other socioeconomic factors also influence households’ fuel choices. On the other hand, the energy ladder theory assumes that the energy transition is linear; that is, as income increases, households switch to modern energy sources (Heltberg, 2004). However, Masera et al. (2000) study found that the transition is not one-way, modern energy sources (LPG and electricity) do not entirely replace traditional energy sources (firewood and charcoal), but they become part of households' fuel stacking behaviour. Therefore, the fuel stacking model explains some factors influencing household energy choices more accurately.

According to Kroon et al. (2013), factors affecting household choices for energy consumption can be divided into three groups: (i) factors within the household such as age, gender, education level of the household head, income, number of household members, housing area, number of electrical appliances, production and business sectors, culture and religion, etc; (ii) factors outside the household such as ability to access to electricity, LPG or firewood, and the price of these fuels; (iii) macro factors such as living area. However, to simplify the analysis, this paper focuses on dividing the factors affecting household energy choices into two groups: the group inside the household and the group outside the household.

1.3.4 Inside household factors

As mentioned above, according to the Energy Ladder theory, income is the most important factor related to household energy transition. Therefore, the relationship between income and energy transition is mentioned in all studies (Kroon et al., 2013). According to Heltberg (2005), household income is an essential factor that encourages the demand for LPG and electricity while at the same time discouraging the use of biomass energy (Waweru et al., 2022). Especially for households in rural areas, many studies in China have shown that increasing household income plays a vital role in enabling households to consume cleaner and more efficient energy as well as reducing energy poverty (Han et al., 2018; Song et al., 2018). In another study, Mekonnen and Köhlin (2008) used a multinomial logit model and found that total household expenditure significantly affects fuel stacking behaviour.

In addition to income, inside household factors that explain fuel stacking behaviour include preferences, familiarity with traditional fuels, and the tendency to establish a state of energy security to avoid being vulnerable to fluctuations in energy prices or services (Alem et al., 2016). Furthermore, modern fuels are considered imperfect substitutes for traditional fuels because traditional fuels are associated with some cultural and traditional aspects of the household's lifestyle; according to Ruiz-Mercado and Masera (2015), these factors also influence household energy choices.

Tradition, custom and religion have shaped specific consumption patterns in societies. The social group to which a household belongs can play a significant role in its behaviour. For example, indigenous ethnic groups in urban Guatemala have a significantly different fuel portfolio than non-indigenous groups, resulting in a much higher likelihood of using only firewood (Heltberg, 2005). In India, rural Muslim households are less likely to use LPG than firewood. Muslims are a minority group in India, which can be a barrier to accessing modern forms of energy (Kroon et al., 2013).

Celik and Oktay (2019) used three types of choices (solid/non-solid/combined) to model household fuel stacking behaviour in Turkey and found that factors influencing household energy choices included gender, occupation, income, and education level of the household head; household size; housing type; heating system type; number of rooms in the house. For example, higher-income and higher-educated households were more likely to use only modern fuels. In contrast, larger households were more likely to choose only traditional fuels.

Studies have shown a positive impact of education level on the likelihood of households using modern fuels such as LPG and Kerosene. This can be explained by the increasing opportunity cost of fuel collection time at higher levels of education and the growing awareness of the negative health impacts of wood and charcoal use (Heltberg, 2004).

The increasing family size suggests that there is more labour available for fuel collection, which limits the need to switch to modern fuels purchased on the market. Rao and Reddy (2007) mention that larger households in developing countries are often associated with lower incomes, thus explaining their limited ability to purchase modern fuels.

The age of the household head has been found to have two trends influencing energy consumption choices. In multigenerational households with wealthy heads, financial abundance leads to the choice of consuming expensive fuels. In contrast, older heads may be more conservative in abandoning traditional energy consumption habits. Mekonnen and Köhlin (2008) found a positive relationship between age and the use of solid fuels as the primary fuel for cooking. Similarly, other studies found no evidence of a negative relationship between age and the use of solid fuels.

Housing area measured by the number of rooms was found to be associated with the switch from firewood to LPG (Heltberg, 2005). This is an indicator of how wealth influences fuel switching. In addition, wealth is also reflected in assets, energy-consuming equipment such as cars, motorbikes and machinery for production. The more modern equipment a household owns, the more likely it is to rely on modern energy (Ma et al., 2019).

Regarding the occupational factor, some research results show that households are simultaneously involved in different agricultural sectors, leading to different access to multiple energy sources. Households involved in crop, forestry and livestock activities are more likely to choose coal, firewood and biomass as their main energy sources for production and daily use. In contrast, households with non-agricultural occupations often have higher incomes, increasing the likelihood of choosing cleaner energy for production and daily use (Ma et al., 2019; Vo & Ho, 2024).

1.3.5 Outside household factors

In general, household fuel stacking behaviour has been studied using a variety of methods in many different countries, especially in developing countries. In addition to internal household factors, fuel choice is influenced by other external factors such as fuel accessibility, fuel prices, and energy scarcity. For example, access to electricity was positively associated with switching fuels for cooking (Heltberg, 2004, 2005). Access to electricity here is understood as physical access or the availability of infrastructure and technology (Ado & Darazo, 2016). In urban areas, easy access to electricity leads to a lower proportion of households choosing to use firewood. In rural areas, limited access to electricity also makes households significantly more likely to consume only LPG (Heltberg, 2005). Barnes et al. (2002) offer two explanations for the relationship between electricity and LPG: (i) where access to electricity is easy, other modern fuels are also limited, and (ii) the availability of lighting and other appliances encourages people to adopt more modern fuels for their modern life (Kroon et al., 2013).

In addition to physical access, fuel prices can influence market access to fuels. Prices influence fuel switching to some extent (Mekonnen & Köhlin, 2008). Notably, Alem et al. (2016) in Ethiopia found that electricity prices positively influence the choice of using a mix of different energy sources. Similarly, high LPG prices increase firewood consumption in rural areas. Likewise, in urban areas, where LPG is dominant for cooking, high LPG prices make firewood an additional option; conversely, high firewood prices increase the likelihood of using LPG alone (Heltberg, 2005). This illustrates the impact of prices on household fuel choice behaviour (Kroon et al., 2013).

In addition to price, resource scarcity also causes accessibility issues, leading to higher energy purchase costs or greater opportunity costs in terms of time spent searching for fuel. In forest areas, fuelwood scarcity is a driving force for households to use fuels other than firewood. Firewood scarcity makes households spend more time collecting firewood, so they switch to other fuels that are more easily accessible. In addition, fuelwood scarcity impacts households' perceptions of pressure to protect the forest environment, which was also found to influence fuel switching (Kroon et al., 2013).

A household's location is also considered an important external factor influencing energy choice. Households in urban areas are more likely to use higher-quality energy sources than their rural counterparts (Heltberg, 2005). Heltberg (2004) found that fuel switching rates were lower in rural areas, while larger cities were found to provide a more favourable environment for modern fuels. Heltberg's (2005) study in Guatemala found that the proportion of urban households using each fuel type in the respective order was electricity, LPG, firewood, charcoal, and kerosene. While for rural households, the order was firewood, electricity, kerosene, LPG, and charcoal. Results from the multinomial logit model showed that higher costs were associated with switching from firewood to LPG in urban areas; high LPG prices increase the likelihood of using only firewood in rural areas, while high fuelwood prices increase the possibility of using only LPG in urban areas. Similarly, Mekonnen and Köhlin (2008) found that households residing in the capital city of Ethiopia were more likely to choose non-solid fuels than households in smaller towns. They attributed this finding to better access to electricity and kerosene.

Households' decision to shift from complete dependence on biomass fuels to partial or total dependence on commercial fuels takes place in a complex and multidimensional context. In addition to factors from inside and outside the household, the political context and economic policies also have significant impacts. In addition to policies affecting fuel prices that directly affect household energy transition, as mentioned above, fuel-related policies such as electricity planning, coal mining planning, forest protection policies, forest environmental service payment policies, etc., also have impacts on household energy consumption choices (Nguyen et al., 2019; Song et al., 2018). In the following content, the study will discuss the relationship between household energy conversion and policies related to forest protection.

1.3.6 Energy transition and PFES

Access to fuelwood and other affordable energy sources is essential for the livelihoods of rural households in developing countries. However, reliance on fuelwood and other biomass fuels (e.g., crop residues, charcoal) has impacts on climate (Ramanathan & Carmichael, 2008), environmental sustainability (Bailis et al., 2015), and human health (Martin et al., 2014). Switching from fuelwood to modern fuels can also lead to ecosystem restoration by reducing pressure on forest resources (Wang et al., 2012). Due to both the environmental and health benefits associated with using modern fuels instead of firewood, many governments have policies to promote rural households to switch from biomass to modern fuels, but these often have limited impact (Arnold et al., 2006; Madubansi & Shackleton, 2007). These policies include protecting forests or increasing household income through payment for forest environmental services.

In China, Song et al. (2018) conducted a study on the effects of the Conversion of Cropland to Forest Program (CCFP) and the Ecological Welfare Forest Program (EWFP) along with several other factors on household energy consumption choices. The study's results showed similarities with many other scholars that most households that have adopted advanced fuels have not yet abandoned firewood, but instead are making a gradual transition through expanding fuel options. The most critical factor determining fuel choice is household income. In contrast, CCFP and EWFP were found to play a much smaller role in household fuel use. CCFP has little direct influence on fuel choice or the amount of firewood used, which may be due to small areas, but households with more EWFP areas tend to rely more on firewood. EWFP area also significantly increased per capita fuelwood use, which can be considered a proxy for access to upland forest land.

These findings suggest that dependence on a crucial livelihood source such as fuelwood is unlikely to change rapidly under the influence of external policies such as CCFP and EWFP. If fuelwood use is to be reduced, new policies that specifically promote or facilitate the use of modern fuels by rural households are needed (Song et al., 2018).

Also related to forest protection policies, another study in China conducted to investigate the impact of forest ecosystem compensation policies on household energy use found that although this policy helped address deforestation and promoted the transition of forest-based livelihoods to more diversified forms, it affected household energy poverty (Geng et al., 2020; Liu et al., 2022). Traditionally, households in forest communities rely heavily on burning biomass energy, especially firewood, for cooking and heating (D'emurger & Fournier, 2011). However, the implementation of such compensation policies forces local people to change their traditional energy use patterns due to significantly reduced access to firewood and significantly increased energy consumption costs (Zeb, 2019). Therefore, forest ecological compensation can affect local energy poverty and contribute to broader concerns about social inequality (Markkanen & Anger-Kraavi, 2019).

Like many other countries in South and Southeast Asia, ecosystem compensation policies in China impose restrictions on logging and non-timber products, which directly impact the incomes of households whose livelihoods depend on forests (Busch et al., 2021). In response, these households have had to shift to alternative agricultural livelihoods that are less dependent on forest resources, such as crop and livestock farming (Schreckenberg & Luttrell, 2009). On the one hand, diversification of income sources reduces dependence on forests, but on the other hand, it can increase total household income because compensation provides additional income sources for low-income households (Neudert et al., 2015; Wei et al., 2016). However, many other studies have shown that ecosystem compensation policies can lead to reduced household income due to restricted access to natural resources (Geng et al., 2020).

Ecosystem compensation policies and livelihood change impacts have both been shown to influence household energy consumption. On the one hand, households lose access to forests for firewood collection (Njenga et al., 2021). On the other hand, improved incomes can increase affordability and promote the use of clean and modern energy (Nguyen et al., 2020). All these factors contribute to a shift in local energy consumption towards more modern energy, characterized by less reliance on traditional energy sources and a larger share of modern energy (Gao & Yu, 2024).

In Vietnam, research on the energy transition has only been conducted in the last 10 years. Studies agree that the majority of low-income households and ethnic minority households still use firewood every day. They have difficulty accessing electricity and gas due to the lack of professional management by local authorities and agencies, and energy prices, especially electricity prices in remote areas, are often pushed higher than market prices. To limit this, the Vietnamese Government has introduced several support policies to promote electricity use in rural and mountainous areas. In the "Regulation on the structure of retail electricity prices," the state will allocate a part of the budget to support low-income households in paying their monthly electricity bills. In addition, the Government has issued the "Strategic Orientation for Vietnam's Energy Development to 2030, with a Vision to 2045" to direct the energy sector to ensure national energy security firmly; provide sufficient, stable, high-quality energy for rapid and sustainable socio-economic development; ensure national defence and security; improve people's living standards; and contribute to energy conservation and ecological environment protection. To encourage renewable energy development, the Government of Vietnam has issued a Decision on "Vietnam's Renewable Energy Development Strategy to 2030, with a Vision to 2050". This Decision aims to establish a Sustainable Energy Development Fund using funds from the state budget, revenue from environmental protection fees for fossil fuels, financial sources, contributions from domestic and foreign organizations and individuals, and other legal capital sources to provide financial support for activities to promote growth in the energy sector nationwide (Vo & Ho, 2024).

In contrast to the lack of access to modern energy sources, households in rural and mountainous areas of Vietnam are more likely to engage in agroforestry activities, which gives them easier access to firewood for daily use. This is also part of the reason why firewood is still widely used for cooking and agricultural production activities. A study in Vietnam showed that households' participation in different agricultural and forestry sectors will affect their ability to choose energy for daily use and production activities. Households living in rural areas combine crop and livestock farming activities, so they rely on both charcoal and firewood, while families living in mountainous regions tend to be more involved in forestry activities, have easier access to forests, and use firewood more commonly (Vo & Ho, 2024).

In addition to the agroforestry production factor, research in Nepal has found that the very low opportunity cost of labour time (usually female and child labour) is the reason why firewood collection is widespread in rural areas, even in places where firewood is severely scarce. At the same time, off-farm labour opportunities increase the opportunity cost of labour time, thereby motivating households with higher incomes from off-farm employment to reduce firewood use, contributing to forest protection. In other words, increased labour costs are considered a factor that can effectively adjust the supply of firewood from forests (Randall, 1995).

The above analysis shows that studies on the relationship between PFES and energy transition in households all emphasize that the energy transition of households is due to income changes from participating in PFES. Moreover, families participating in forest protection policies are often limited in fuelwood access, so they change their energy consumption behavior towards more modern directions.

2. Data

In this section, we describe the information and data used for the qualitative and quantitative analyses.

2.2. Focus group discussions and key informant interviews

To serve the qualitative analysis, we exploit information from focus group discussions (FDGs) and key informant interviews in Lâm Đồng Province to understand the PFES implementation, evaluate PFES's impacts on forest protection awareness and household income, and explores the link between economic conditions and energy consumption.

Lâm Đồng was one of the two provinces that piloted the PFES since 2009. As of 2023, the forest-covered rate was 54.37% (Lam Dong PPC, 2024a). The province is home to two crucial river basins: the Serepok River basin of 86,105 hectares, and the Đồng Nai River basin of 313,044 hectares (Lam Dong PPC, 2024a).

The two districts chosen for field survey were Đức Trọng and Lạc Dương, both located upstream of the Đồng Nai River Basin. Most forest owners in these two districts include private firms and state-run Protection Forest Management Boards (PFMBs). There is only one community and a few households operating as independent forest owners. Therefore, we opted to interview workers and managers of private firms and PFMBs.

To reach the interviewees, we sent written requests for support to the two districts' People's Committees, and they connected us with district forest ranger units. The forest rangers contacted forest owners around the district, who then arranged their workers to engage in group discussions. During a five-day fieldwork in July 2024, we conducted seven interviews and group discussions, including three groups of forest protection laborers, one group of private forest owners, one interview with PFMB staff, and two interviews with district forest rangers.

In addition, we conducted interviews with officials from the Lâm Đồng Forest Protection and Development Fund (FPDF) and the Lâm Đồng Department of Industry and Trade to learn about the PFES condition as well as provincial energy production and consumption patterns. The interviews are summarized in Table 1.

Table 1. Focus group discussions and key informant interviews

No.	Focus groups and key informant interviews	Number of participants	Venue
1	Forest protection laborers of one state-owned protection forest management board	7	Ninh Gia Commune, Đức Trọng District
2	Forest protection laborers of one private enterprise	7	Đa Nhim Commune, Lạc Dương District
3	Forest protection laborers of one state-owned protection forest management board	6	Đạ Sar Commune, Lạc Dương District
4	Forest owners – private enterprises	2	Ninh Gia Commune, Đức Trọng District
5	Đa Nhim Protection Forest Management Department	1	Đạ Sar Commune, Lạc Dương District
6	Forest ranger at the district level	2	Đức Trọng District
7	Forest ranger at the district level	2	Lạc Dương District
8	Forest Protection and Development Fund of Lâm Đồng	1	Đà Lạt City
9	Industry and Commerce Department of Lâm Đồng	2	Đà Lạt City

No.	Focus groups and key informant interviews	Number of participants	Venue
	Total	30	

Participants of the two FDGs in Ninh Gia commune (Đức Trọng district) and Đạ Sar commune (Lạc Dương district) are forest protection laborers contracted by PFMBs. The FDG in Đa Nhim (Lạc Dương district) consists of specialized forest protection workers from a private firm.

According to the Lâm Đồng Portal (https://lamdong.gov.vn), all three communes—Đa Nhim, Đạ Sar, and Ninh Gia—are rural areas where agriculture and forestry are the primary sources of incomes. Đa Nhim and Đạ Sar feature a vast forest area, high forest coverage, and a high concentration of ethnic minorities in the overall population (about 80%). Ninh Gia has a lesser forest cover and only 18% ethnic minorities in total population. Nevertheless, most of the participants (18/20 persons) in the FDGs are ethnic minorities and reside near the forest.

Table 2. Background information of the studied commune

District	**Lạc Dương**		**Đức Trọng**
Forest area (ha)	113,911.68		45,049
Forest coverage (%)	86		50
Population (persons)	35,635		220,697
Commune	**Đa Nhim**	**Đạ Sar**	**Ninh Gia**
Forest area (ha)	23,944	20,178	3,211
Forest coverage (%)	90	80	22
Population (persons) (as of 2022)	5,654	6,528	13,845
Ethic minority rate (%)	78	80	18
Poor households (in 2023)	33	11	16

Source: Lâm Đồng Portal (https://lamdong.gov.vn)

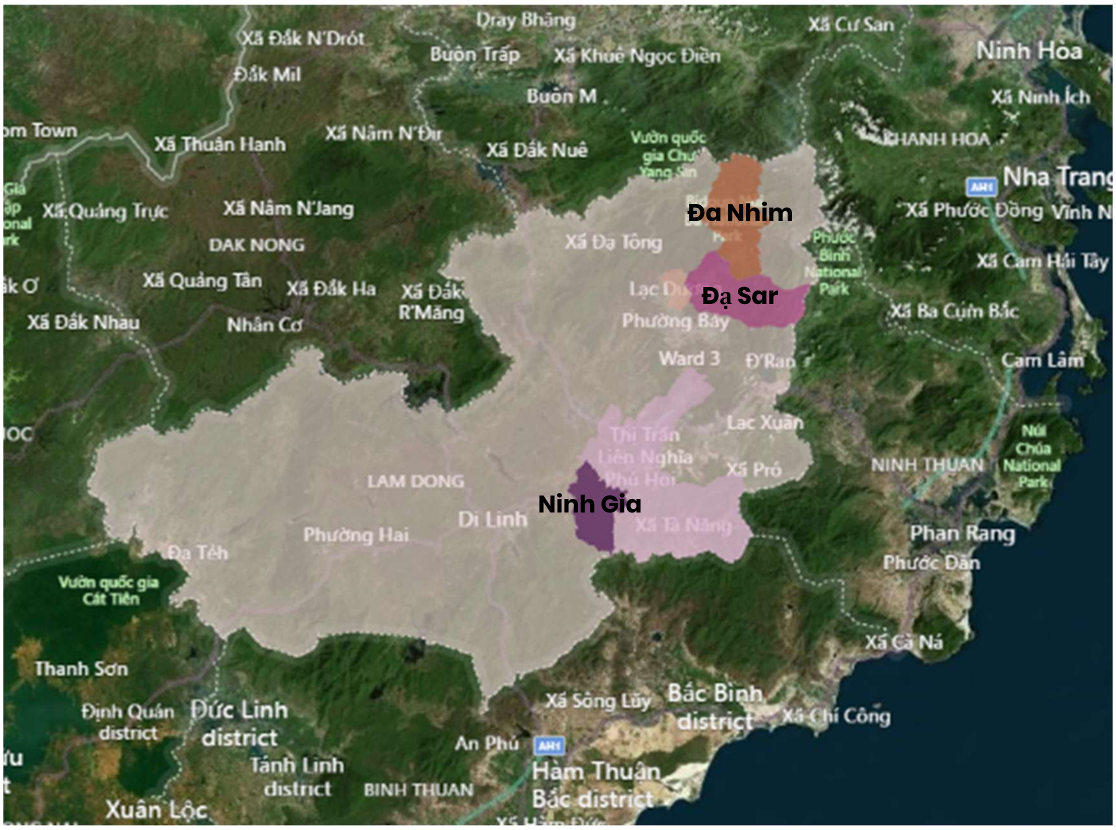


Fig. 2. Survey sites - Đa Nhim, Đạ Sar, and Ninh Gia communes in Lâm Đồng Province

2.3. Vietnam Household Living Standard Survey data

Secondary data from the Vietnam Household Living Standard Survey (VHLSS) in 2010 and 2020 are exploited for regression models to analyse how income interacts with households' energy consumption trajectories.

Data from 2010 is considered a baseline for investigating changes in energy patterns over time. VHLSS is an annual national survey conducted by the General Statistics Office (GSO) to systematically monitor and supervise the living standards of different population groups in Viet Nam. The VHLSS has been organized and implemented with high-level statistical information. Its stratified sampling method ensures regional representative, covering all 63 provinces of Vietnam. Each year, the survey includes approximately 9000 households with detailed information on income and expenditure, as well as basic demographic characteristics related to living standards, housing, and electricity, among others.

Since the number of observations for Lam Đồng is limited (n=141) and PFES recipients are not directly identifiable in the VHLSS, we use national data instead and restrict our data analysis to rural regions where most PFES recipients reside. The national data also support the generalization of the research results.

3. Method

This study aims to examine the relationship between PFES and household energy transition. Fig. 3 illustrates our proposed conceptual framework for impact of PFES on energy transition, highlighting the pathway from forest protection funds through household involvement to improved socio-economic outcomes and ultimately influencing energy use and transition.

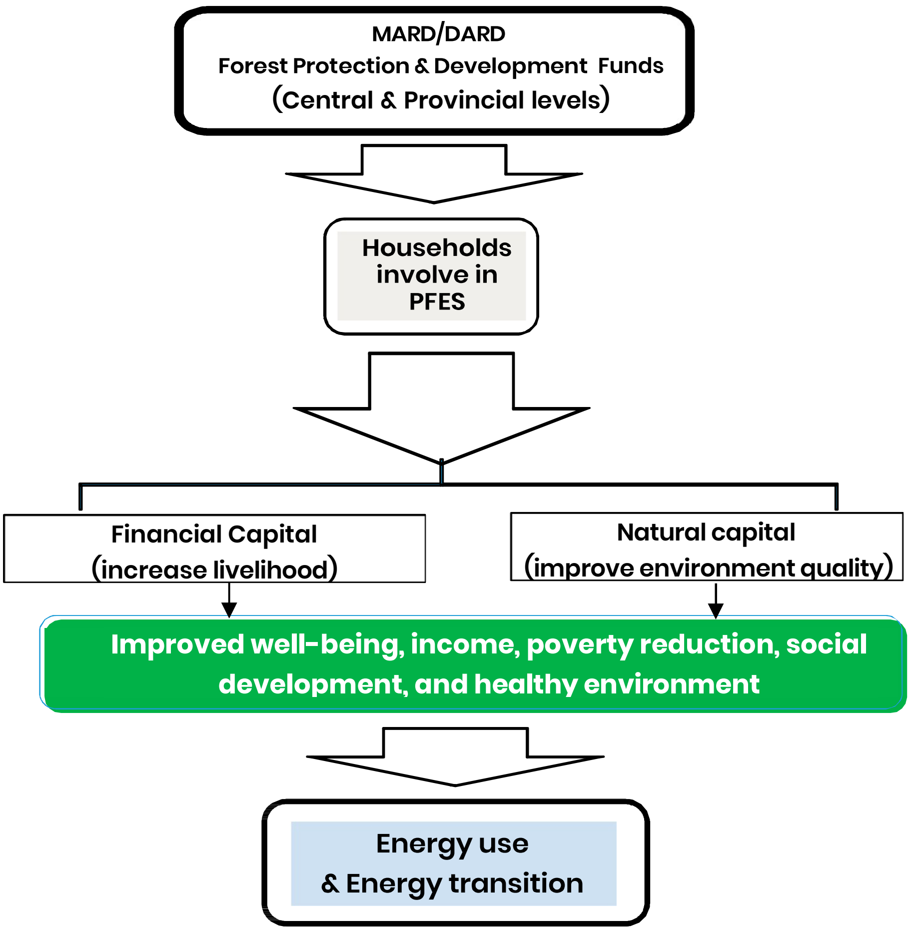


Fig. 3. Conceptual Framework for impact of PFES on Energy transition

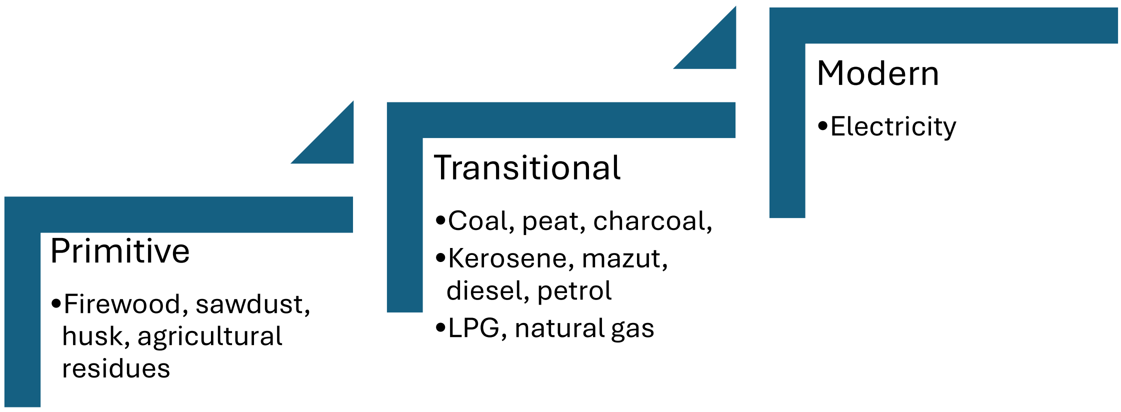
Source: Adopt from Do and NaRanong (2019)

However, due to the lack of data for a quantitative analysis, we are not able to investigate the direct impact of PFES on energy transition. Instead, we employ a mixed method research design which combines qualitative and quantitative study. In the qualitative analysis, we exploit information from focus group discussions (FDGs) and key informant interviews to evaluate how PFES helps households improve their income. Then, in the quantitative analysis we use data from Vietnam Living Standard Surveys to assess the impact of household income improvement on energy transition.

In the first stage, the study uses qualitative analysis—drawing on focus group discussions and key informant interviews—to assess how the PFES program improves forest protection awareness, supports household income improvement, and discover the correlation between economic condition and energy consumption in Lâm Đồng Province. In the second stage, quantitative analysis explores the relationship between household income and energy consumption patterns. A key limitation of the study is that it does not directly assess the impact of PFES on the energy transition.

Since 2018, all communes and 99% of households in Vietnam have access to electricity (EVN, 2019). According to the VHLSS 2020 statistics, 99.33% of homes utilize power from the national grid, combined with other forms of energy.

We classify the energy types into different categories based on the energy ladder proposed by Han et al. (2018). In this study, primitive energy includes firewood, sawdust, husk, and agricultural residues. Transitional energy encompasses coal, kerosene, mazut, diesel, petrol, liquefied petroleum gas (LPG) and natural gas. Modern energy includes electricity from the national grid. The energy ladder is described in Fig. 4.



Fig, 4. Energy ladder for Vietnam

As households use various types of energy, the fuel choice is a categorical variable to provide evidence on whether households tend to follow the fuel stacking theory. The seven categories are described in Table 3.

Table 3. Fuel choice categories for household energy consumption

Fuel choice categories	Primitive	Transition	Modern
7			Yes
6		Yes	Yes
5	Yes		Yes
4	Yes	Yes	Yes
3		Yes	
2	Yes	Yes	
1	Yes		

In the quantitative analysis, we employ several types of regression models, including ordinal logistic, multinomial logistic and ordinary least square, using the general equation as follows:

$$Ei = \beta Xi + \varepsilon i \quad (1)$$

The dependent variable (Ei) is an ordinal variable reflecting the household fuel choice for consumption and for production (i.e., planting, forestry, fishery, and non-agricultural, non-forestry, non-fishery). In addition, the percentage of each energy source in total energy expenditure is used for OLS regression. The vector of independent variables Xj encompasses households' characteristics that might affect fuel choice (Table 4).

Table 4. The summary of descriptive statistics

Variables	**2010**	**2020**
Demographics of household head		
Educational level (%)		
- *No degree*	16.52	14.73
- *Primary school*	27.15	26.83
- *Secondary school*	44.90	47.03
- *University*	11.43	11.41
Male (%)	74.10	72.50
Age	50.36	50.95
Married (%)	62.40	67.20
Poor (%)	14.20	4.80

Household characteristics		
Income (thousand VND/person/month)	1387.10	4249.80
HH size (number of persons)	3.90	3.60
Employed (%)		
- Farm	4.50	3.80
- Non-farm	34.10	49.50
Self-employed in agri & forestry (%)	41.30	25.80
Self-employed in non-agri & forestry (%)	20.10	20.90
House area (m^2)	68.14	91.65

We adopt several variables extracted from literature that might impact household's use of energy, including demographics (age, gender, ethnicity and education level of household head, who is often responsible for decision-making in household consumption, and household size) (Nguyen et al., 2019; Song et al., 2018), livelihoods (wage earners, on-farm and off-farm employment) (Chang et al., 2024; Masuku, 2024), endowments (income, assets, areas of different land types) (Ai et al., 2021; Zheng et al., 2024), and communal features (region, urbanization) (Ai et al., 2021; Chadwick et al., 2022; Li et al., 2024; Selvakkumaran & Ahlgren, 2019). To explore the influence of PFES policy, we employ information on payment of forest protection services and forest land area. Song et al. (2018) found that engagement in the Ecological Welfare Forest Program and income are the main factors promoting the adoption of modern fuels.

4. Results

4.2. PFES implementation, revenues, and expenditure

In our interviews, the forest owners and contracted households stated that the amount payable to them was reasonable. However, the FPDF officer argued that this income allocation method was heavily egalitarian and did not promote forest quality improvement.

The K-coefficient design aims to adjust the distribution of benefits (Le et al., 2016). However, the implementation of K-coefficients creates difficulties for relevant parties. The calculation of unit prices becomes complicated and requires agreements among FES suppliers, users, and the FPDF. The interview with the Lâm Đồng FPDF's staff indicates the potential inequality in PFES distribution: downstream families could receive less remuneration than upstream ones, even if their efforts to protect the forests are similar. In 2023, the payments for 1 hectare of PFES forest vary greatly, ranging from VND445,000/ha to VND2,723,000/ha. Some households benefit from greater payment prices, but others suffer from reduced rates. This significant shift generates disparities in PFES allocation and limits forest owners' acceptability. Additionally, the PFDF must clearly explain to numerous PFES users to make them accept higher compensation.

In the in-depth interviews, the forest owners believe that the forest status sways significantly, so the forest inventory conducted every ten years does not keep pace with the changes in forest quality over time. The forest map was built based on the forest inventory results from 2014 and has been adjusted through annual field inspections using GIS technology since 2016. However, the forest owners state that the forest maps have many shortcomings and do not fully reflect reality.

Forest owners register their planned service provision area annually, and PFES purchasers estimate how much they will pay. The PFDF prepares a revenue and expenditure plan and sends it to relevant stakeholders, including PFES buyers, sellers, and forest rangers. According to the Lâm Đồng FPDF representative, planning is usually on schedule, but the cost appraisal is time-consuming and often causes delays. Before 2022, payments were quite on time, although it took time for contracted households to receive money in cash. From 2023, payments are made via bank accounts and mobile transfers; the payment process is simple, and forest owners and contracted households do not encounter difficulties. Currently, only a few elderly workers in remote areas still receive cash.

The FPDF regularly coordinates with the Forest Ranger Department at the provincial level and forest ranger units at the district level to inspect forest quality and supervise PFES payments. Our interviews with both parties indicate that this collaboration works smoothly and harmoniously. Forest Ranger is a state agency that inspects and supervises forest protection. They match up with the provincial FPDF to check areas' payment eligibility and participate in accepting PFES payments.

In addition, the FPDF works with district authorities, forest owners, and related units to organize propaganda and dissemination of the Forestry Law (Law number 16/2017/QH14 dated 15 November 2017) and other government regulations in a variety of formats, including newsletters and articles in newspapers, television, radio, the Lâm Đồng Fund's website, and propaganda billboards. They also offer patrolling equipment (e.g., forest tents, calendars, notebooks, bags, backpacks, caps, raincoats, brochures, folders, flags, and garbage cans) and arrange communication propaganda in general schools and families, particularly those with PFES contracts or who live near woods. The FPDF collaborates with the Fatherland Front Committee, Provincial Youth Union, Farmers' Association, Provincial Labor Federation, and Women's Union to organize conferences and seminars, and distributes propaganda materials to forest owners, forestry management boards of communes, wards and towns.

4.3. Impacts of PFES

4.3.1 Impact on awareness of forest protection

Our field survey examines impact of PFES on local people's awareness of forest protection in Lâm Đồng province. A decade ago, deforestation was severe. During 2001 - 2012, Lâm Đồng suffered 453 forest fires. In five years, from 2008 to 2012, the Lâm Đồng Ranger Department (2012) recorded 3,325 violations on 1,409 hectares, including 2,743 cases of illegal logging of 11,386 m3 round wood. In 2014, 1,841 cases were reported for confiscating more than 2,006 m3 of wood, 254 million VND worth of non-timber forest products and 245 kg of wild animal meat (Minh Dao, 2015). In 2015, the Dai Ninh and Ta Nang Protection Forests saw severely destruction, with over 300,000 m2 lost in Đức Trọng district (Dang Tuan, 2015). Fortunately, in the last ten years, forest violations has decreased sharply. In the first 11 months of 2023, there were only 194 cases, with 14.16 hectares destroyed, 1,382 m3 forest products damaged, and 85 wild animals lost. Compared to the same period in 2022, violations fell by 25% (62 cases) and deforestation area declined by 46% (11.89 hectares).

The focus group discussions estimate a 70-80% reduction in deforestation and a 30-40% reduction in forest encroachment over the past ten years. Interviewees attribute this improvement to intensified monitoring and residents' awareness, which are supposed to be the results of PFES program. Participants of the Đa Nhim group patrol their forest daily. In Ninh Gia and Đạ Sar, forest owners use 24-hour surveillance. In addition, they prioritize contracting households with farmland adjacent to the forest. As part of PFES, the forest owners receive support from the FPDF to undertake propaganda and push families to sign annual commitments to protect the forests. The forest protection workers in Ninh Gia disclose that many villagers, like themselves, were illegal loggers ten years ago and have now become protection workers of the PFES scheme. They note that as many villagers join PFES, people are becoming more conscious of the importance and regulation of forest conservation. Similar observations are reported in Đạ Sar and Đa Nhim groups. These findings align with studies by Gondwe et al. (2022) and Onnoghen et al. (2023), which emphasize the role of co-management in mitigating deforestation and raising societal awareness in forest conservation. As noted by Pagdee et al. (2006), high community participation significantly enhances the success of forest management programs.

4.3.2 Impact on income and livelihoods

In the early stages of PFES implementation, the Vietnamese Government stipulated that ethnic minority households, poor Kinh households and communities in certain areas were beneficiaries. Since 2022, PFES participants have been expanded to households, individuals and communities in areas where forests need to be protected (Decree No. 75/2015/ND-CP; Decision No. 1719/QD-TTg; Circular No. 12/2022/TT-BNNPTNT). In Lâm Đồng province, forestry firms and state-owned organizations received 99% of PFES, with 90% going to subcontracted households (Lam Dong PPC, 2024b). PFES has improved livelihoods, increased income, and stabilized the living standard of 13,059 households participating in forest protection contracts (including 10,885 ethnic minority households, which account for more than 80% of the total number of PFES contracted households) (Lam Dong FPDF, 2023b).

According to the FDGs and key informant interviews, the average annual PFES income was 25 million VND per household. Local authorities report that, in 2023, the average yearly income per person was 61 million VND in Lạc Dương district and 64 million VND in Đức Trọng district (Lac Duong DPC, 2024; Duc Trong DPC, 2024). If we suppose a typical household has two income earners, then PFES profit is equivalent to one-fifth of the average household income per year, which is a significant contribution to household incomes. Although planting is often the primary source of revenue for the contracted laborers in the FDGs, they appreciate PFES for its additional earnings, accounting for 10% - 20% of their average family income. The FDGs state that PFES income is the primary source for a few poor households. However, the Đa Nhim Protection Forest Management Board state that the selection of laborers prioritizes those who are healthy and live locally (primarily ethnic minorities); they do not intentionally select poor households.

Specialized workers who get paid monthly from a private firm in Đa Nhim group receive an average of 5.7 million VND/month to carry out daily forest protection (12 hours/day) in an area of about 40 hectares/worker. The salary from forest protection is their primary source of income. In addition to PFES, forest protection may bring other incomes to households. In Đức Trọng and Lạc Dương, people collect firewood for cooking and graze livestock in the forest. In Đạ Sar commune, about 50% of households graze livestock in the forest, while the remaining 50% raise cattle in barns.

The contracted workers report that the PFES has altered their livelihoods. "Previously, we were illegal loggers and collected resin (turpentine). Now, we protect the forest under the PFES scheme. We patrol the forest for six days each month. The rest of the time, we work on coffee, pepper, and avocado plantations", some people of FDG in Ninh Gia said. They convey their joy at this development as their life become better.

The workers often work in teams of 10 people to protect an area of 300 hectares. They often patrol in pairs and use their own motorbikes to go through the pine forest. Sometimes, they stay overnight in the forest to prevent and detect violations. The FPDF and the forest management boards provide guidance and training on patrolling and protecting the forest.

Some families had participated in the contract to protect prior to the PFES scheme. In such agreements, they also received a payment for protection work, but the amount received was lower than the PFES.

In Đắk Lắk and Kon Tum provinces, Roongtawanreongsri et al. (2021) find that many ethnic minority communities have limited awareness of PFES and its benefits, restricting their involvement. However, in Lâm Đồng, the knowledge constraint affects the participation of ethnic minorities in a different way. Most protection workers are contracted by organizations; they do not get 100% of the PFES as if they were paid directly from the FPDF. In addition, they do not actively join in meetings with the FPDF and have less voice over policy execution. This hinders household participation in implementing and monitoring PFES collection and payment.

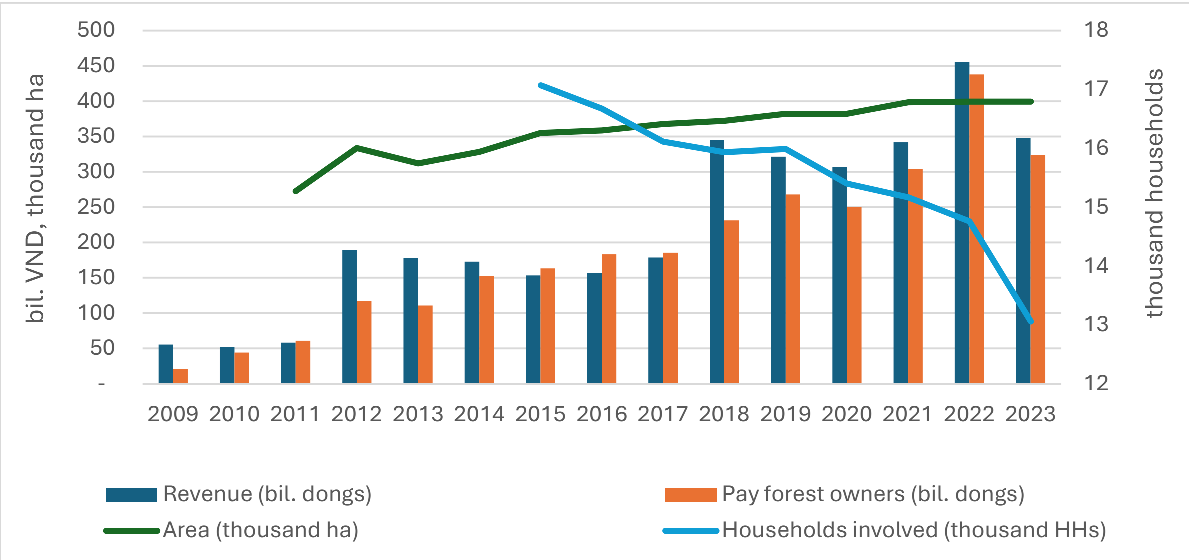


Fig. 5. PFES revenues and payments, areas, and number of households

Source: Data collected from Lâm Đồng FPDF reports from 2012 to 2024

The forest area that received PFES payments expanded gradually, from 272.53 ha in 2011 to 399.74 ha in 2023. The PFES revenues climbed dramatically from 55 billion dongs in 2009 to 456 billion dongs in 2022 before falling to 348 billion dongs in 2023. The decline in 2023 was due to the new application of PFES after Decree 156. Meanwhile, the number of households receiving PFES has shrunk from 17,073 in 2015 to 13,059 in 2023. Decree 168/2016/ND-CP dated December 27, 2016 stipulates that the contracted area is not more than 30 hectares per household. In 2015, each household safeguarded 20.78 ha on average. By 2023, this figure rose to 30.06 ha per household. In our meeting with the FPDF official, he states that the contraction of families and expansion of forest area per household have improved forest conservation's effectiveness while also bringing better income to the contracted households. He proposes to raise the patrol cap.

There are several reasons for the shrinkage of households participating in PFES in Lâm Đồng. Before 2022, only ethnic minorities, poor Kinh households, or poor communes are eligible for this scheme. The number of communities and households enjoying this policy has decreased along with socio-economic development. In 2023, the beneficiaries have been expanded, and families living in areas with forests that need protection are allowed to participate in the contracts. However, due to projected changes in PFES unit prices, Lâm Đồng province have substantial delays in making advance payments, and the payment amount have not been determined. The number of households willing to participate in the contract has decreased significantly.

In areas with a low PFES rate (i.e. 445,000 VND/ha), families may receive less than 13 million VND annually. This amount discourages household participation. Newspapers claim in several regions like Khanh Hoa and Lai Chau provinces, residents are unwilling to sign a protection contract due to the low compensation of 400,000 dongs/ha (Huong & Hao, 2023; Nhan, 2023).

4.3.3 Energy consumption in survey areas

During the focus group discussions, we also seek to get insights on economic conditions and local energy consumption in the three communes. All areas rely primarily on electricity from the national grid, supplemented by firewood, gas, diesel, petrol and limited solar power. No small hydropower or solar plant exist in the region.

Ninh Gia is a large commune with 3,805 households; of which only 18% are ethnic minorities. However, all FDG participants are minor ethnic, and they seem to be worse off than the Kinh residents. Pepper and coffee are their main sources of income. The electricity grid in Ninh Gia commune has been around since 1999-2000, replacing kerosene and firewood. Today, all villagers use electricity for lighting, fans, televisions, and mobile phones. Air-conditioners are not popular since the climate is cool and this equipment is not an urgent need. Some households with better economic conditions use refrigerators. The FDG in Ninh Gia commune reports that firewood remains the major fuel for cooking and water heating, especially for contracted households., while non-contracted households may use gas as they have less access to firewood. A few households use electric rice cookers. Petrol and diesel are utilized for transportation. In Dai Ninh Protection Forest, the workers switched from oil and batteries to solar panels since 2020. Private enterprise forest owners equip solar-powered surveillance to quickly detect forest fires or illegal loggers. According to the interviewees, a few remote households use rooftop solar power. However, the initial investment is quite costly (approximately 60 million VND) and the capacity is weak and unreliable in the rainy season. Grid electricity is preferred for its stability and lower cost.

In Đạ Sar, economic conditions of FDG participants are somewhat better since high-tech agriculture is more common. Most families use gas for cooking, and nearly 30% of households use electric stoves. Only some households use firewood to cook food for husbandry. A few households in the food business use coal stoves. All households use electric rice cookers and electric kettles. People in Đạ Sar commune explain that firewood makes smoke and dust, so they prefer gas and electricity for daily energy consumption. Households use grid electricity in greenhouses. Most households start using solar water tanks since 2006-2013, although the initial cost of a solar water heater is relatively high (about VND 15 million). Still, each tank can be used for ten years, making it cheaper than an electric water heater (estimated electricity cost is about VND 1 million/month).

Đa Nhim residents use gas stoves, electric rice cookers and kettles to avoid dust from firewood. Few people use solar water heaters due to high initial cost and space requirement. In both Đạ Sar and Đa Nhim communes, solar lights have been widely used since 2020 to illuminate gardens thanks to their reasonable price although the light is weak for indoor lighting.

Unlike Dai Ninh Forest, watchtowers in Đa Nhim use solar LEDs and batteries for lighting. Firewood or flashlights are preferred over solar panels and kerosene since they do not catch too much notice of illegal loggers. A few remote vegetable gardens use diesel power generators for watering and irrigation. They do not use biogas because livestock manure is reserved for fertilizer, which is more effective.

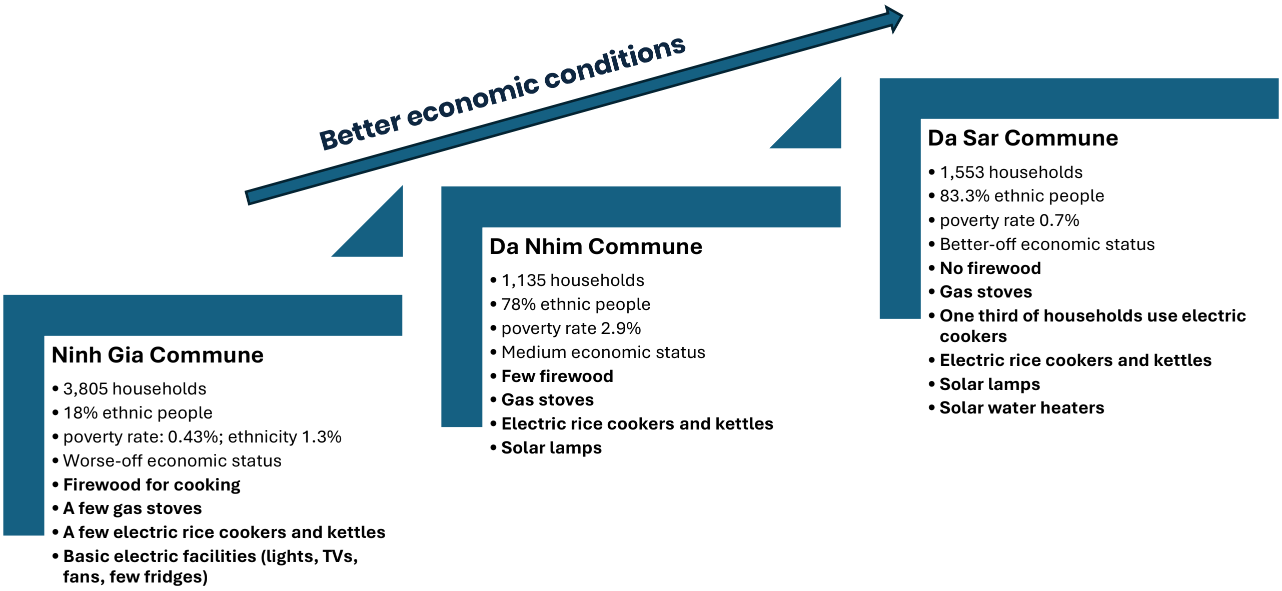


Fig. 6. Shifting energy sources in the surveyed communes

Although FDGs' participants show their awareness of energy transition, especially in Đạ Sar and Đa Nhim, high costs limit adoption. In Đạ Sar commune, people prefer less polluting energy, but the price of solar power is still too high. The motivating factor for switching to solar energy (garden lights, water heaters) is that these devices help save money compared to grid electricity. Energy use reflects stacking fuel theory—households use multiple types of energy simultaneously rather than fully switching to cleaner options.

In low economic condition area like Ninh Gia, people use cheap but polluting forms of energy, such as firewood. In better economic area like Đa Nhim, they switch to less polluting fuel such as gas and electricity. For more favorable economic condition area like Đạ Sar, people are willing to spend a high initial investment to use renewable energy such as solar power. Households participating in PFES are more likely to use firewood to cook in worse-off communes but not evidenced in better-off communes.

Energy use also aligns with forest protection needs—solar panels are used in watchtowers for lighting and surveillance. This practice will encourage people to use more solar power when the investment cost gradually becomes cheaper.

Overall, the use of renewable energy is still limited, with firewood playing a major role in poorer communities. The use of solar power is in its early stages. Firewood still plays a vital role in daily energy consumption in Ninh Gia commune. There is still room for transition toward modern and renewable energy.

4.4. Income effect on household's energy shifts

Qualitative analysis from the case of Lâm Đồng Province suggests that PFES contributes to improving household income, although its impact may be limited in certain areas where the PFES rate has decreased since the application of full K-coefficients. Data from VHLSS do not provide information of PFES. Therefore, this section only focuses on examining where income have positive effect on household energy transition, neglected PFES participation.

4.4.1 Energy transition for living purposes

Table 5. Household energy consumption for living purposes in 2010 and 2020, Lâm Đồng Province

Type of energy	N	% of HHs use this energy	Proportion in total energy expenditure			
			Mean	Standard Deviation	Min	Max
VHLSS 2010						
Electricity	141	97.9%	20.7%	14.9%	0.0%	100.0%
Petrol	141	90.1%	46.1%	22.3%	0.0%	94.6%
LPG	141	73.0%	19.0%	15.5%	0.0%	61.5%
Diesel	141	0.0%	0.0%	0.0%	0.0%	0.0%
Firewood	141	31.9%	9.3%	18.6%	0.0%	100.0%
Agricultural residue	141	17.7%	3.8%	9.4%	0.0%	42.9%
Kerosene	141	6.4%	0.6%	3.1%	0.0%	31.3%
Peat, charcoal	141	1.4%	0.5%	5.7%	0.0%	67.8%
VHLSS 2020						
Electricity	141	↑ 100.0%	↑ 37.3%	15.0%	4.8%	83.7%
Petrol	141	↑ 94.3%	↓ 40.4%	18.6%	0.0%	92.3%
LPG	141	↑ 91.5%	~ 19.2%	12.2%	0.0%	84.4%
Diesel	141	↑ 1.4%	↑ 0.1%	1.3%	0.0%	15.2%
Firewood	141	↓ 13.5%	↓ 2.7%	8.5%	0.0%	58.8%
Agricultural residue	141	↓ 3.5%	↓ 0.3%	2.0%	0.0%	16.7%
Kerosene	141	↓ 0.0%	↓ 0.0%	0.0%	0.0%	0.0%
Peat, charcoal	141	↓ 0.7%	↓ 0.0%	0.2%	0.0%	2.6%

Note: ↑ increased, ~ equal, ↓ decreased in 2020 compared to 2010.

Source: Authors' own calculations. Original.

In 2020, households in Lâm Đồng relied on electricity for daily energy needs. Petrol was an essential energy source, used in 91.5% households, especially for vehicles (motorbikes and automobiles). Households had various cooking fuel options, in addition to electricity: LPG (91.5%), firewood (13.5%), agricultural residue (3.5%), and peat/charcoal (0.7%).

There was a significant shift toward clean energy after 10 years since 2010. More households used electricity (from 97.9% households in 2010 to 100% in 2020), petrol (90.1% to 94.3%), and LPG (73% to 91.5%). Fewer families used firewood (31.9% to 13.5%, agricultural residue (17.7% to 3.5%), kerosene (6.4% to 0%), and peat and charcoal (1.4% to 0.7%). Changes in the proportion of expenditure on energy sources followed the similar pattern.

Because there are almost no substitutes for gasoline and diesel for transportation, we overlook these fuels in our energy transition analysis.

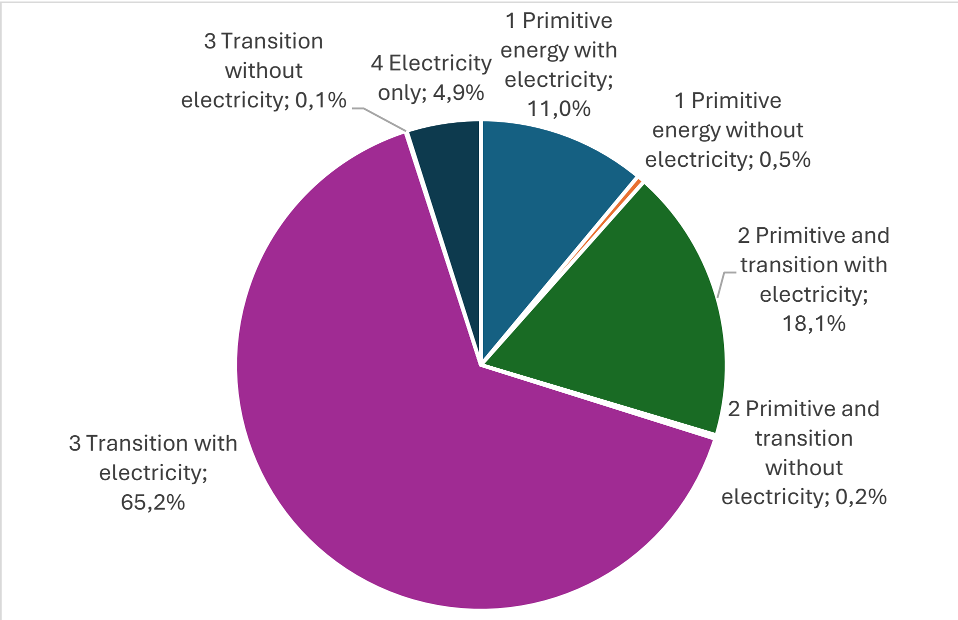


Fig. 7. Energy consumption pattern for living purposes in rural Vietnam, 2020

The fraction of households who do not utilize electricity is modest. Therefore, we create a household energy stacking index with four values:

1. Primitive energy (mainly firewood and some agricultural residue), with or without electricity
2. Primitive and transitional energy (mostly LPG) with or without electricity.
3. Transitional energy with or without electricity
4. Electricity only.

Table 6 and Table 7 provide regression results, indicating factors influencing the energy transition pattern of rural households for living purposes in 2020 and 2010. The model results show that several factors (with statistical significance) influence household energy choices for living purposes including: income, education level, occupation, household size, housing area, forest area, poor households and ethnic minority households. The level of influence of each factor will be presented specifically in the discussion section.

Table 6. Regression results, energy consumption for living purposes, rural Vietnam households in 2020

	OLS	Ordinal regression	Multinominal regression (base group: transition + electricity)			OLS		
Dependent variable	**HH stacking index**	**HH stacking index**	**Primitive**	**Primitive+ transition**	**Electricity only**	**% of primitive in energy exp.**	**% of transition in energy exp.**	**% of electricity in energy exp.**
lnIncome	0.026***	0.098***	-0.243***	-0.085***	0.090*	0.021	-0.014	-0.043**
	(0.006)	(0.021)	(0.050)	(0.028)	(0.047)	(0.013)	(0.011)	(0.017)
lnIncome square						-0.001**	0.000	0.002**
						(0.001)	(0.001)	(0.001)
Educational level	0.023***	0.095***	-0.305***	-0.114***	-0.042	-0.006***	-0.002**	0.004***
	(0.005)	(0.019)	(0.054)	(0.028)	(0.042)	(0.001)	(0.001)	(0.001)
Male	-0.017	-0.023	0.334*	0.029	0.224	0.005	-0.012**	-0.015**
	(0.025)	(0.098)	(0.199)	(0.127)	(0.197)	(0.005)	(0.005)	(0.007)
Age	0.000	-0.001	-0.009*	0.006*	-0.015***	0.000	0.001***	0.002***
	(0.001)	(0.002)	(0.005)	(0.003)	(0.005)	(0.000)	(0.000)	(0.000)
Married	-0.013	-0.082	-0.285	-0.006	-0.428**	-0.001	-0.001	0.012
	(0.028)	(0.110)	(0.213)	(0.141)	(0.213)	(0.006)	(0.005)	(0.008)
Poor	-0.314***	-1.050***	1.597***	0.605***	1.674***	0.139***	-0.030***	-0.064***
	(0.036)	(0.127)	(0.191)	(0.187)	(0.228)	(0.007)	(0.007)	(0.010)
Kinh	0.517***	1.473***	-2.638***	-1.082***	-1.501***	-0.141***	0.048***	0.095***
	(0.023)	(0.081)	(0.138)	(0.104)	(0.164)	(0.005)	(0.004)	(0.006)
HH size	-0.020***	-0.056**	0.104**	-0.019	-0.088	0.003**	-0.005***	-0.007***
	(0.006)	(0.024)	(0.048)	(0.030)	(0.056)	(0.001)	(0.001)	(0.002)
Employed	0.039***	0.124***	-0.456***	-0.045	-0.217***	-0.013***	-0.011***	-0.030***
	(0.010)	(0.035)	(0.070)	(0.045)	(0.084)	(0.002)	(0.002)	(0.003)
Self-employed in agri & forestry	-0.123***	-0.489***	0.705***	0.641***	0.112	0.020***	-0.010***	-0.015***
	(0.008)	(0.032)	(0.066)	(0.041)	(0.073)	(0.002)	(0.002)	(0.002)
Self-employed in non agri & forestry	0.038***	0.152***	-0.468***	-0.176***	-0.247**	-0.012***	-0.004*	0.010***
	(0.012)	(0.044)	(0.112)	(0.059)	(0.105)	(0.002)	(0.002)	(0.003)

	OLS	Ordinal regression	Multinominal regression (base group: transition + electricity)			OLS		
Dependent variable	HH stacking index	HH stacking index	Primitive	Primitive+ transition	Electricity only	% of primitive in energy exp.	% of transition in energy exp.	% of electricity in energy exp.
Forest area	-0.077***	-0.222***	0.385***	0.319***	-0.120	0.016***	-0.006***	-0.011***
	(0.009)	(0.034)	(0.062)	(0.055)	(0.159)	(0.002)	(0.002)	(0.002)
House area	0.001***	0.003***	-0.012***	-0.003***	0.002	0.000***	0.000***	0.000***
	(0.000)	(0.001)	(0.002)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)
_cons	2.094***		2.923***	-0.181	-1.181*	0.103	0.242***	0.557***
	(0.075)		(0.606)	(0.365)	(0.627)	(0.071)	(0.062)	(0.093)
/cut1		-0.973						
		(0.284)						
/cut2		0.806						
		(0.284)						
/cut3		5.421						
		(0.296)						
Observations	5,878	5,878		5,878		5878	5878	5878
(Adjusted) R^2	0.2774	0.1506		0.2117		0.3625	0.157	0.16517

Note: standard errors in parentheses, *** p<0.001; ** p<0.05; * p<0.1
Source: Authors' own calculations. Original.

Table 7. Regression results, energy consumption for living purposes, rural Vienam households in 2010

	OLS	Ordinal regression	Multinominal regression (base group: transition + electricity)			OLS		
Dependent variable	**HH stacking index**	**HH stacking index**	**Transition only**	**Primitive+ transition**	**Electricity only**	**% of primitive in energy exp.**	**% of transition in energy exp.**	**% of electricity in energy exp.**
lnIncome	0.292***	0.766***	0.675***	1.232***	0.776***	-0.260**	0.184**	-0.214***
	(0.027)	(0.071)	(0.091)	(0.120)	(0.192)	(0.124)	(0.082)	(0.077)
lnIncome square						0.006	-0.007*	0.010***
						(0.006)	(0.004)	(0.004)
Educational level	0.020*	0.052**	0.081**	0.097**	-0.024	-0.011***	0.004**	0.001
	(0.010)	(0.025)	(0.037)	(0.041)	(0.077)	(0.003)	(0.002)	(0.002)
Male	-0.074	-0.203	-0.187	-0.307	0.109	0.014	-0.015	-0.014
	(0.054)	(0.133)	(0.182)	(0.207)	(0.370)	(0.017)	(0.011)	(0.010)
Age	-0.001	-0.002	0.002	-0.001	-0.014	0.001*	0.001***	0.001***
	(0.001)	(0.003)	(0.004)	(0.005)	(0.009)	(0.000)	(0.000)	(0.000)
Married	-0.001	0.060	0.154	0.198	-0.478	-0.011	-0.017	-0.025**
	(0.063)	(0.158)	(0.207)	(0.246)	(0.415)	(0.019)	(0.013)	(0.012)
Poor	-0.111***	-0.368***	-0.257*	-0.767***	-0.447	0.113***	-0.021**	-0.020**
	(0.043)	(0.120)	(0.134)	(0.259)	(0.323)	(0.013)	(0.009)	(0.008)
Kinh	0.288***	0.780***	0.657***	1.676***	0.138	-0.138***	0.063***	0.055***
	(0.035)	(0.092)	(0.107)	(0.187)	(0.233)	(0.011)	(0.007)	(0.007)
HH size	-0.005	-0.027	-0.074*	-0.164***	0.080	0.007*	-0.005*	0.001
	(0.013)	(0.032)	(0.040)	(0.055)	(0.082)	(0.004)	(0.003)	(0.002)
Employed	-0.024	-0.087**	-0.136***	-0.065	-0.093	-0.016***	-0.009***	-0.004
	(0.016)	(0.042)	(0.051)	(0.070)	(0.110)	(0.005)	(0.003)	(0.003)
Self-employed in agri & forestry	-0.119***	-0.262***	0.017	-0.576***	-0.344***	0.033***	-0.020***	-0.018***
	(0.014)	(0.036)	(0.045)	(0.064)	(0.098)	(0.004)	(0.003)	(0.003)
Self-employed in non agri & forestry	0.047**	0.112**	0.071	0.169*	0.100	-0.022***	0.009**	0.009**
	(0.022)	(0.053)	(0.073)	(0.089)	(0.146)	(0.007)	(0.004)	(0.004)

	OLS	Ordinal regression	Multinominal regression (base group: transition + electricity)			OLS		
Dependent variable	**HH stacking index**	**HH stacking index**	**Transition only**	**Primitive+ transition**	**Electricity only**	**% of primitive in energy exp.**	**% of transition in energy exp.**	**% of electricity in energy exp.**
Forest area	0.000*	0.000***	0.000*	0.000***	0.000	* 0.000	0.000	0.000*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
House area	0.002***	0.003***	0.001	0.007***	0.004	0.000***	0.000	0.000**
	(0.000)	(0.001)	(0.002)	(0.002)	(0.003)	(0.000)	(0.000)	(0.000)
_cons	-1.145***		-7.583***	-13.787***	-9.315***	2.405***	-1.017**	1.334***
	(0.265)		(0.876)	(1.192)	(1.867)	(0.648)	(0.429)	(0.406)
/cut1		7.593						
		(0.694)						
/cut2		9.304						
		(0.703)						
/cut3		11.541						
		(0.715)						
Observations	2,780	2,780	2,780			2,777	2,777	2,777
(Adjusted) R^2	0.2283	0.1226	0.1619			0.3962	0.183	0.1328

Note: standard errors in parentheses, *** p<0.001; ** p<0.05; * p<0.1

Source: Authors' own calculations. Original.

4.4.2. Energy transition for production purposes

Table 8. Household energy consumption for production purposes, Lâm Đồng province

Type of energy	N	% of HHs use this energy	Proportion in total energy expenditure			
			Mean	Standard Deviation	Min	Max
VHLSS 2010						
Petrol	100	70.0%	44.8%	42.0%	0.0%	100.0%
Electricity	100	57.0%	28.5%	38.9%	0.0%	100.0%
Diesel	100	32.0%	20.8%	34.9%	0.0%	100.0%
LPG	100	4.0%	0.5%	2.9%	0.0%	22.0%
Mazut	100	0.0%	0.0%	0.0%	0.0%	0.0%
Kerosene	100	2.0%	0.3%	3.0%	0.0%	29.5%
Firewood	100	8.0%	3.1%	13.5%	0.0%	90.9%
Peat	100	4.0%	1.2%	10.1%	0.0%	100.0%
Coal	100	1.0%	0.8%	8.3%	0.0%	83.3%
VHLSS 2020						
Petrol	95	↑ 74.7%	↓ 38.8%	38.6%	0.0%	100.0%
Electricity	95	↑ 68.4%	↑ 35.8%	40.5%	0.0%	100.0%
Diesel	95	↑ 35.8%	~ 20.0%	31.9%	0.0%	100.0%
LPG	95	↑ 6.3%	↑ 3.0%	13.6%	0.0%	93.3%
Mazut	95	↑ 3.2%	↑ 1.0%	9.1%	0.0%	88.5%
Kerosene	95	↓ 0.0%	↓ 0.0%	0.0%	0.0%	0.0%
Firewood	95	↓ 2.1%	↓ 1.0%	8.7%	0.0%	84.2%
Peat	95	↓ 1.1%	↓ 0.1%	0.5%	0.0%	5.1%
Coal	95	~ 1.1%	↓ 0.4%	4.2%	0.0%	41.4%

Note: ↑ increased, ~ equal, ↓ decreased in 2020 compared to 2010.

Source: Authors' own calculations. Original.

In 2020, 74.7% and 68.4% of rural households relied on petrol and electricity to meet their energy production demands, respectively. While 35.8% of household businesses used diesel, 6.3% LPG, 3.2% mazut, 2.1% firewood, 1.1% peat and 1.1% coal.

Similar to the energy transition for living purposes, we observed the positive change for production over 10 years from 2010 to 2020. Household businesses employed more electricity (from 57.0% to 68.4%), petrol and diesel rose from 70.0% to 74.7% and 32.0% to 35.8% respectively, firewood dropped to 2.1% in 2020 from 8% in 2010.

We utilize the production energy stacking index with four values as follows:

1: Primitive energy (firewood) only

2: Primitive and transitional energy. The most essential parts of transitional energy are petrol and diesel.

3: Transitional energy only

4: Primitive, transitional energy, and electricity

5: Primitive energy and electricity

6: Transitional energy and electricity

7: Electricity only.

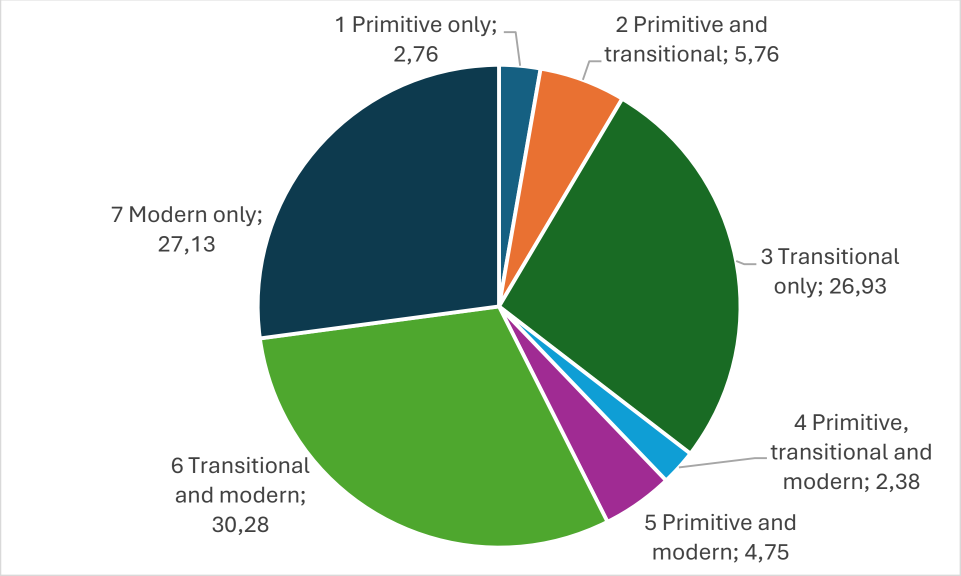


Fig. 8. Energy consumption pattern for production purposes in rural Vietnam, 2020

Table 9 provides regression results, indicating factors influencing the energy transition pattern of rural households for production purposes. The quantitative impact of each factor will be presented specifically in the discussion section.

Table 9. Regression results, energy consumption for production purposes in Vietnam rural households, 2020 and 2010

	OLS (2020)	Ordinal regression (2020)	OLS (2020)			OLS (2010)	Ordinal regression (2010)	OLS (2010)		
Dependent variable	Production stacking index	Production stacking index	% of primitive in energy exp.	% of transition in energy exp	% of electricity in energy exp.	Production stacking index	Production stacking index	% of primitive in energy exp.	% of transition in energy exp	% of electricity in energy exp.
lnRevenue	-1.038***	-1.241***	0.216***	0.059	-0.275***	2.303**	3.496***	-0.513**	0.400	0.113
	(0.289)	(0.330)	(0.037)	(0.075)	(0.072)	(1.052)	(1.171)	(0.227)	(0.261)	(0.197)
lnRevenue square	0.044***	0.049***	-0.009***	-0.002	0.011***	-0.080*	-0.128***	0.016*	-0.011	-0.004
	(0.012)	(0.014)	(0.002)	(0.003)	(0.003)	(0.044)	(0.049)	(0.009)	(0.011)	(0.008)
Education level	0.095***	0.107***	0.002	-0.033***	0.031***	0.115***	0.126***	0.004	-0.026***	0.022***
	(0.019)	(0.022)	(0.002)	(0.005)	(0.005)	(0.030)	(0.032)	(0.006)	(0.007)	(0.006)
Male	-0.266***	-0.243**	-0.011	0.053**	-0.042*	-0.232	-0.309*	-0.007	0.051	-0.044
	(0.094)	(0.108)	(0.012)	(0.024)	(0.023)	(0.158)	(0.173)	(0.034)	(0.039)	(0.030)
Age	0.014***	0.018***	0.000	-0.004***	0.004***	0.024***	0.026***	-0.001*	-0.003***	0.004***
	(0.002)	(0.003)	(0.000)	(0.001)	(0.001)	(0.003)	(0.004)	(0.001)	(0.001)	(0.001)
Married	0.211*	0.129	-0.008	-0.011	0.019	0.332 *	0.356 *	-0.046	0.032	0.014
	(0.108)	(0.127)	(0.014)	(0.028)	(0.027)	(0.187)	(0.210)	(0.040)	(0.046)	(0.035)
Poor	-0.441***	-0.527***	0.065***	0.010	-0.075**	-0.004	-0.077	0.054**	-0.073**	0.019
	(0.127)	(0.153)	(0.016)	(0.033)	(0.032)	(0.122)	(0.139)	(0.026)	(0.030)	(0.023)
Kinh	1.568***	1.887***	-0.127***	-0.162***	0.289***	1.242***	1.285***	-0.246***	0.093***	0.153***
	(0.079)	(0.100)	(0.010)	(0.020)	(0.020)	(0.094)	(0.103)	(0.020)	(0.023)	(0.018)
HH size	-0.072***	-0.086***	-0.003	0.022***	-0.018***	-0.071**	-0.095***	-0.007	0.019**	-0.012**
	(0.021)	(0.024)	(0.003)	(0.005)	(0.005)	(0.032)	(0.035)	(0.007)	(0.008)	(0.006)
Employed	0.084***	0.108***	0.000	-0.024***	0.023***	0.004	-0.014	0.001	-0.007	0.006
	(0.033)	(0.038)	(0.004)	(0.008)	(0.008)	(0.042)	(0.047)	(0.009)	(0.010)	(0.008)
Self-employed in agri-forest	-0.110***	-0.154***	0.023***	0.008	-0.031***	-0.212***	-0.240***	0.071***	-0.043***	-0.028***
	(0.030)	(0.034)	(0.004)	(0.008)	(0.008)	(0.037)	(0.041)	(0.008)	(0.009)	(0.007)
	0.056	-0.072*	0.012**	0.026***	-0.038***	0.334***	0.299***	0.022*	-0.058***	0.036***

	OLS (2020)	Ordinal regression (2020)	OLS (2020)			OLS (2010)	Ordinal regression (2010)	OLS (2010)		
Dependent variable	**Production stacking index**	**Production stacking index**	**% of primitive in energy exp.**	**% of transition in energy exp**	**% of electricity in energy exp.**	**Productio n stacking index**	**Productio n stacking index**	**% of primitive in energy exp.**	**% of transition in energy exp**	**% of electricity in energy exp.**
Self-employed in non agri-forest	(0.036)	(0.040)	(0.005)	(0.009)	(0.009)	(0.054)	(0.057)	(0.012)	(0.013)	(0.010)
Forest Area	-1.601	-1.452	0.524*	0.329	-0.854	0.000	0.000	0.000	0.000	0.000
	(2.504)	(2.792)	(0.317)	(0.647)	(0.623)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
House Area	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)
_cons	9.439***		-1.111***	0.324	1.787***	-13.597**		4.275***	-2.574*	-0.701
	(1.668)		(0.211)	(0.431)	(0.415)	(6.231)		(1.342)	(1.545)	(1.168)
/cut1		-10.112					23.002			
		(1.924)					(6.969)			
/cut2		-8.838					23.527			
		(1.920)					(6.970)			
/cut3		-6.495					24.890			
		(1.917)					(6.973)			
/cut4		-6.235					25.394			
		(1.917)					(6.973)			
/cut5		-6.111					25.958			
		(1.917)					(6.973)			
/cut6		-4.574					27.234			
		(1.916)					(6.974)			
Observations	3608	3608	3608	3608	3608	1,938	1,938	1,938	1,938	1,938
(Adjusted) R^2	0.2236	0.0808	0.1056	0.0745	0.1557	0.335	0.113	0.3014	0.1021	0.168

Note: standard errors in parentheses, *** p<0.001; ** p<0.05; * p<0.1

Source: Authors' own calculations. Original.

4.5. Discussion

All regression results presented above confirm the energy stacking theory. Households do not shift directly from traditional to modern energy for living purposes but instead employ multiple energy sources as their economic and social conditions evolve. There are several determinants of household energy usage and transition patterns.

Income improvement is a key driver of the energy transition, since higher-income households prefer to switch from traditional biomass fuels to cleaner cooking fuels such as gas and electricity. The income and income square coefficients indicate that wealthier people have a lower proportion of primitive energy and a higher share of electricity, validating that affordability is a significant barrier to energy transition in lower-income groups. This finding is consistent with the results found in Vietnam by (Vo & Ho, 2024) and (Nguyen et al., 2023), that household income positively influences the likelihood of choosing oil for daily use. This evidence confirms the plausibility of the "energy stacking" hypothesis in which households do not entirely switch from poorer to higher quality energy sources as income increases.

Poor households are more reliant on primitive energy sources like firewood and agricultural residue. Their limited financial resources hinder their capacity to shift to modern energy, resulting in continuous reliance on a combination of primitive and transition fuels. The findings emphasize the necessity of targeted measures that enhance energy cost and availability for disadvantaged families in breaking the cycle of energy poverty. In a similar vein, Nguyen et al. (2019), using the VHLSS from 2004 to 2016, found that while income poverty, consumption poverty, and electricity poverty have declined in many regions of Vietnam, energy cost poverty has increased. This implies that energy costs are growing relatively faster than income, representing an increasing burden on poor households.

The educational attainment of the household head has a substantial impact on energy choices. Higher levels of education are associated with a better understanding of the health and environmental benefits of clean energy, resulting in greater use of electricity and less consumption of biomass fuels, even less transition fuels like charcoal and gas. This result is consistent with Y. Liu et al. (2022) findings in Brazil, Russia, India, and China that a positive change in education contributes to increasing clean energy consumption.

Ethnic minority families often utilize more biomass fuels and less transitional or modern energy. In addition to poor economic status and low educational attainment that usually adhere to ethnic minorities, geographic limits, cultural preferences, and structural hurdles to accessing modern energy infrastructure may contribute to this pattern. This emphasizes the importance of inclusive energy policies that address regional imbalances and incorporate excluded populations into national electrification and renewable energy projects.

Larger families had lower rates of energy transition, most likely due to greater energy use and higher expenses associated with modern energy adoption that prevent them from utilizing contemporary alternatives. This implies that actions supporting inexpensive energy solutions must take into account household size dynamics. By another approach, Vo and Ho (2024) replaced household size by using the number of children, adults and elders for their model, so they discovered that increasing the number of children and adults in a family is associated with more demand for energy for various purposes, especially cooking. Elders have a low demand for energy, especially in Vietnam, where older adults tend to save more than expend. It explains the positive association between the number of elders, the probability of consuming coal-biomass and oil, and the negative link between them and the likelihood of consuming electricity and gas.

The regression findings show that age, gender, and marital status have no significant impact on energy transition. However, these characteristics are related to complex spending patterns. Female-headed families tend to prioritize gas and electricity, which may reflect their closer attention to health and energy security. This result contradicts findings in Nigeria that female-headed households are more likely to choose dirty fuels like biomass and kerosene (Nwaka et al., 2020) or in Bhutan, where female-headed households have significantly lower clean energy use compared to male-headed households (Aryal et al., 2019).

Furthermore, single-person households are more likely to use a mix of transition fuels and electricity rather than relying solely on electricity. Older-headed households tend to spend more on transition fuels and electricity, but they prefer to blend the two energy sources rather than counting on electricity alone. This demonstrates that social demographic characteristics influence energy decisions in addition to economic constraints.

The occupation of household members has an impact on energy consumption. Households with more employed workers use more of a combination of transition and electricity and less primitive energy. In contrast, self-employed people in the agriculture and forestry industries rely on firewood and agricultural residue due to the accessibility and cost-effectiveness of biomass from agricultural production. Self-employed workers outside the agriculture and forestry sectors are more likely to switch to modern energy. A similar result was found in a previous Vietnamese study (Vo & Ho, 2024) that a household with self-employment activities uses more energy and electricity. This finding is also consistent with the research result of Ma et al. (2019) in China, which found that households with non-agricultural occupations often choose cleaner energy for their daily use. This finding implies that economic diversity helps to accelerate the energy transition.

Households with larger forest areas indicate more reliance on firewood, lowering their cleaner energy usage. This finding confirms that access to free or low-cost biomass hinders energy transition. Households with larger house areas use more transition and electricity, most likely owing to higher energy demand for home appliances.

Regarding the use of energy for production purposes, the regression models imply that the energy stacking index is quadratic in relation to the magnitude of production revenue. Households do not have to rely on primitive energy sources to cut expenses when revenue is low. They tend to consume cheaper energy when their revenue increases. Nonetheless, businesses often employ cleaner energy for higher-quality, safer, and more automated production when the production scale is sufficiently great. Larger, poorer, and ethnic minority families utilize less electricity for production and more transitional and primitive energy. They are at the lower side of the energy stacking theory.

Age and educational attainment have comparable effects on energy transition patterns in manufacturing as they do on energy transition patterns in living. Households with older heads use less transitional energy and more contemporary energy. This is contrary to the results found by Mekonnen and Kohlin (2008) that the higher age of household heads, the more use of solid fuels for production. Higher-educated household heads spend more on electricity and less on transitional energy. This finding is similar to what Vo & Ho (2024) found in their study: household heads with a high education level are less likely to choose fossil fuels such as coal and biomass for production activities. This result confirms the efficiency of education in Vietnam, as well-educated heads tend to use more clean and environmentally friendly energy sources. Households in the forestry and agriculture sectors spend less on electricity and more on firewood. In contrast, households in the non-forestry and agriculture sectors spend less on electricity and more on firewood and transitional energy due to the availability of firewood. This result is contrary to the finding of Vo & Ho (2024) that households participating in the cropping industry will likely choose electricity and oil for production activities. Those households participating in the agricultural services, fisheries, and forestry sectors will likely be the oil group. These productions also use oil-powered engines, like the cropping industry.

According to Vo & Ho (2024), households in forestry-related production activities also increase the probability of choosing coal-biomass because of the enormous availability of firewood and biomass fuels in the forestry sector. This is also consistent with previous studies in neighboring countries such as Laos and Cambodia, saying that a household with forest extraction uses more coal and biomass (Nguyen et al., 2019). However, forest areas have no discernible impact on the energy transition for production

5. Conclusions

This study analyzes the role of PFES in Vietnam's energy transition from economic, social, and environmental perspectives. It provides an insightful look into PFES and its role in household energy consumption in Lam Dong province by examining how households have leveraged income from PFES to improve energy use patterns.

The study results indicate that PFES does contribute to energy transition, but not significantly, as it does not substantially increase people's income, and the local people continue to rely on various available energy sources because of multiple factors other than income.

The results of the limited contribution of PFES to energy transition are shown in three manifestations as follows. First, this study shows that the income from PFES is not large enough and the number of households receiving income from PFES had fallen due to the socio-economic development situation in Lam Dong. Before 2022, the decrease in the number of households participating in PFES was due to its eligibility criteria, limiting participation to ethnic minorities, poor Kinh households, or disadvantaged communes. Households with better economic conditions were not allowed to participate. Second, the choice of energy type does not depend entirely on income. Households in the study area rely on readily available and accessible energy sources such as wood, coal, and grid electricity. Access to and use of renewable energy sources is difficult due to high investment costs and lack of technical support. Third, although PFES mainly focuses on reducing illegal logging and protecting forest resources and helps to increase community participation in forest management and protection, the program does not directly support behavior change in energy use. These issues reduce the effectiveness of PFES in promoting sustainable energy transition. On the other hand, this study confirms that income has an impact on shift in energy use. In the case study in Lam Dong, although people did not consider the energy transition process important, households switched to less polluting energy when economic conditions were better and when the initial access cost was not too high, or when there was a combination of different types of energy to optimize costs.

This study also found that, other than income, factors such as education and occupation have influence on energy use transition. The study confirmed that education level, not age, tended to have a decisive influence on the use of clean and environmentally friendly energy. Occupation was also a decisive factor in energy use decisions. Households in the forestry and agricultural sectors spent less money on electricity and more money on firewood. In contrast, households in the non-forestry and agricultural sectors spent less money on electricity and more money on firewood and transitional energy due to the availability of firewood.

Because low-carbon development offers a faster, cheaper, and smarter pathway to sustainable energy and economic development, it is essential to enhance programs like PFES to contribute to this objective. Specifically, increasing PFES payments and providing financial and technical support to households are necessary steps to enable more efficient access to and use of renewable energy sources.

To increase the impact of PFES on income improvement, the Ministry of Agriculture and Environment (MAE) in coordination with provincial FPDFs should steadily increase the patrol cap, a feasible option with expected impactful outcomes for provinces with a majority of state-run Protection Forest Management Boards among beneficiaries, like Lâm Đồng.

To foster energy transition, Ministry of Industry and Trade (MOIT), Ministry of Finance (MOF), and Vietnam Electricity (EVN), with support from MAE and local authorities should offer preferential electricity prices to PFES households, especially in hydropower areas, to boost electricity use. Funding can come from hydropower, EVN cross-subsidies, and government or international climate funds.

In addition, MAE, MOIT, MOF, and Ministry of Construction, in coordination with Ministry of Foreign Affairs, should provide training programs to raise awareness and promote low-emission energy with support from local authorities, NGOs, EVN, and the Ministry of Education and Training. Funding can come from government budget allocations, private CSR, and carbon credit revenues, and international climate finance like REDD+.

The limitation of this study is that we have not yet examined the direct causal relationship between PFES and energy transition, due to the unavailability in nationally representative surveys of specific questions regarding household (or community) participation to said program. This study thus provides a rationale to suggest for testing in the future the inclusion of said question into the VHLSS. Future research could incorporate primary surveys to provide more reliable empirical evidence for testing this relationship.

Bibliography

ADO, A., & **DARAZO, I. R.** (2016). Determinants of fuels stacking behaviour among households in Bauchi Metropolis. *The Business & Management Review*, *7*(3), 84.

AI, X.-N., **DU, Y.-F.**, **LI, W.-M.**, **LI, H.**, & **LIAO, H.** (2021). The pattern of household energy transition. *Energy*, *234*, 121277.

ALEM, Y., **BEYENE, A.**, **KÖHLIN, G.**, & **MEKONNEN, A.** (2016). Modeling household cooking fuel choice: A panel multinomial logit approach, Ethiopia. *Energy Economics*, *59*(C), 129–137.

ALIX-GARCIA, J. M., **SIMS, K. R. E.**, & **YAÑEZ-PAGANS, P.** (2015). Only One Tree from Each Seed? Environmental Effectiveness and Poverty Alleviation in Mexico's Payments for Ecosystem Services Program. *American Economic Journal: Economic Policy*, *7*(4), 1–40. https://doi.org/10.1257/pol.20130139

ARNOLD, J. E. M., **KÖHLIN, G.**, & **PERSSON, R.** (2006). Wood fuels, livelihoods, and policy interventions: changing perspectives. *World Dev*, *34*(3), 596–611.

ARYAL, J. P., **MOTTALEB, K. A.**, & **ALI, A.** (2019). Gender and household energy choice using exogenous switching treatment regression: evidence from Bhutan. *Environmental Development*, *30*, 61–75.

BAILIS, R., **DRIGO, R.**, **GHILARDI, A.**, & **MASERA, O.** (2015). The carbon footprint of traditional wood fuels. *Nat. Clim. Chang*, *5*(3), 266–272.

BẢO, T. Q., **LONG, K. T.**, & **HẢI, N. H.** (2020). Tác động của chính sách chi trả dịch vụ môi trường rừng đến bảo vệ rừng tại Vườn quốc gia Tà Đùng, tỉnh Đắk Nông. *Tạp chí Khoa học và Công nghệ Lâm nghiệp*(5), 061–072. https://www.researchgate.net/publication/351094995_Tac_dong_cua_chinh_sach_chi_tra_dich_vu_moi_truong_rung_den_bao_ve_rung_tai_Vuon_Quoc_gia_Ta_Dung_tinh_Dak_Nong

BARNES, D. F., **KRUTILLA, K.**, & **HYDE, W.** (2002). The urban energy transition—Energy, poverty, and the environment: two decades of research. *Forthcoming book.*

BERKHOUT, F., **MARCOTULLIO, P.**, & **HANAOKA, T.** (2012). Understanding energy transitions. *Sustain. Sci*, *7*, 109–111.

BÖRNER, J., **BAYLIS, K.**, **CORBERA, E.**, **EZZINE-DE-BLAS, D.**, **HONEY-ROSÉS, J.**, **PERSSON, U. M.**, & **WUNDER, S.** (2017). The Effectiveness of Payments for Environmental Services. *World Development*, *96*, 359–374. https://doi.org/10.1016/j.worlddev.2017.03.020

BUSCH, J., & **FERRETTI-GALLON, K.** (2023). What Drives and Stops Deforestation, Reforestation, and Forest Degradation? An Updated Meta-analysis. *Review of Environmental Economics and Policy*, *17*(2), 217–250. https://doi.org/10.1086/725051

BUSCH, J., **RING, I.**, **AKULLO, M.**, **AMARJARGAL, O.**, **BORIE, M.**, **CASSOLA, R. S.**, **CRUZ-TRINIDAD, A.**, **DROSTE, N.**, **HARYANTO, J. T.**, **KASYMOV, U.**, **KOTENKO, N. V.**, **LHKAGVADORJ, A.**, **PAULO, F. L.**, **MAY, P. H.**, **MUKHERJEE, A.**, **MUMBUNAN, S.**, **SANTOS, R.**, **TACCONI, L.**, **SELVA, L. V.**, . . . **ZHOU, K.** (2021). A global review of ecological fiscal transfers. *Nat. Sustain*, *4*(9), 756–765.

CELIK, A. K., & **OKTAY, E.** (2019). Modelling households' fuel stacking behaviour for space heating in Turkey using ordered and unordered discrete choice approaches. *Energy and Buildings*, *204*, 109466.

CHADWICK, K., **RUSSELL-BENNETT, R.**, & **BIDDLE, N.** (2022). The role of human influences on adoption and rejection of energy technology: A systematised critical review of the literature on household energy transitions. *Energy Research & Social Science*, *89*, 102528.

CHANG, H., HEERINK, N., ZHANG, J., & HE, K. (2024). Off-farm employment and household clean energy transition in rural China: A study based on a gender perspective. *Energy*, *287*, 129551.

CHIRAMBA, T., MOGOI, S., MARTINEZ, I., & JONES, T. (2011). Payment for Forest Ecosystem Services (PFES): Pilot implementation in Lam Dong Province, Vietnam.

COCHARD, R., NGUYEN, V. H. T., NGO, D. T., & KULL, C. A. (2020). Vietnam's forest cover changes 2005–2016: Veering from transition to (yet more) transaction? *World Development*, *135*, 105051. https://doi.org/10.1016/j.worlddev.2020.105051

COOKE, P., KÖHLIN, G., & HYDE, W. F. (2008). Fuelwood, forests and community management evidence from household studies. *Environ. Dev. Econ*, *13*(1), 103–135.

D'EMURGER, S., & FOURNIER, M. (2011). Poverty and firewood consumption: A case study of rural households in northern China. *China Econ. Rev*, *22*(4), 512–523.

DANG TUAN. (2015). Rừng phòng hộ Dai Ninh bị tàn phá với tốc độ "chóng mặt". *Vietnam Plus.* https://www.vietnamplus.vn/rung-phong-ho-dai-ninh-bi-tan-pha-voi-toc-do-chong-mat-post347115.vnp

DAS, S., GROOTE, H., & BEHERA, B. (2014). Determinants of household energy use in Bhutan. *Energy*, *69*, 661–672. https://doi.org/10.1016/j.energy.2014.03.062

DO, D., & NARANONG. (2019). Livelihood and Environmental Impacts of Payments for Forest Environmental Services: A Case Study in Vietnam. *Sustainability*, *11*(15), 4165. https://doi.org/10.3390/su11154165

DUC, V. T., TRUONG, S. C., THANH, L. N., HAI, V. D. T., THU, H. L. T., & CASSE, T. (2023). Integrated Effect of the Payment for Forest Environmental Services (PFES) in Vietnam. In *Land-Use Management-Recent Advances, New Perspectives, and Applications*. IntechOpen.

ĐỨC, N. M., HÀ, Q. Đ., DIỆP, Đ. T., HUYỀN, Đ. T. T., THỊ, N., & PHƯƠNG, T. (2020). Chi trả dịch vụ môi trường rừng ở Việt Nam: Lý thuyết, thực hiện, bài học kinh nghiệm và hàm ý chính sách. *Phát triển kinh tế Việt Nam trong bối cảnh biến đổi toàn cầu*, 32.

DUC TRONG DPC. (2024). Report on the results of implementing new rural areas in Duc Trong district.

ELIAS, R. J., & VICTOR, D. G. (2005). Energy Transition in Developing Countries: Review of Concepts and Literature. *PESD Working Paper*(40).

EVN. (2019). *EVN Annual Report.*

FOUQUET, R. (2010). The slow search for solutions: lessons from historical energy transitions by sector and service. *Energy Policy*, *38*, 6586–6596.

GALLEMORE, C. T., PHAM, T. T., HAMILTON, M., & MUNROE, D. K. (2023). Vietnam's Payments for Forest Ecosystem Services Scheme's Role in Protecting Longstanding Forests as Deforestation Rates Rise.

GAO, Y., & YU, L. (2024). Understanding the impacts of ecological compensation policies on energy poverty: insights from forest communities in Zhejiang, China. *Land Use Policy*, *142*, 107144.

GENG, Y., SUN, S., & YEO-CHANG, Y. (2020). Impact of forest logging ban on the welfare of local communities in northeast China. *Forests*, *12*(1), 3.

GONDWE, M., CHIRWA, P., CHO, M., GELDENHUYS, C., & TSHIDZUMBA, R. (2022). Key drivers of LULCC in co-managed and government managed forest reserves in Malawi (1999–2018). *International Forestry Review*, *24*(1), 1-14.

GUPTA, G., & KÖHLIN, G. (2006). Preferences for domestic fuel: analysis with socio-economic factors and rankings in Kolkata, India. *Ecol. Econ*, *57*(1), 107–121.

HAN, H., WU, S., & ZHANG, Z. (2018). Factors underlying rural household energy transition: A case study of China. *Energy Policy*, *114*, 234–244.

HAYES, T., **MURTINHO, F.**, **WOLFF, H.**, **LÓPEZ-SANDOVAL, M. F.**, & **SALAZAR, J.** (2022). Effectiveness of payment for ecosystem services after loss and uncertainty of compensation. *Nature Sustainability*, *5*(1), 1. https://doi.org/10.1038/s41893-021-00804-5

HELTBERG, R. (2004). Fuel switching: Evidence from eight developing countries. *Energy Economics, 26*(5), 869–887.

HELTBERG, R. (2005). Factors determining household fuel choice in Guatemala. *Environ. Dev. Econ, 10*(3), 337–361.

HORST G, H.-V., & **AJ, H.** (2008). Reassessing the "energy ladder": household energy use in Maun, Botswana. *Energy Policy*, *36*, 3333–3344.

HUONG, C., & **HAO, S.** (2023). Bảo vệ rừng từ chính sách cho người nhận khoán: Tiếp tục giữ định mức cũ (Bài 1). *Dân tộc và Phát triển.*

JACK, B. K., **JAYACHANDRAN, S.**, **KALA, N.**, & **PANDE, R.** (2022). Money (Not) to Burn: Payments for Ecosystem Services to Reduce Crop Residue Burning.

JAYACHANDRAN, S. (2023). The inherent trade-off between the environmental and anti-poverty goals of payments for ecosystem services. *Environmental Research Letters, 18*(2), 025003. https://doi.org/10.1088/1748-9326/acb1a7

JAYACHANDRAN, S., **LAAT, J.**, **LAMBIN, E. F.**, **STANTON, C. Y.**, **AUDY, R.**, & **THOMAS, N. E.** (2017). Cash for carbon: A randomized trial of payments for ecosystem services to reduce deforestation. *Science, 357*(6348), 267–273. https://doi.org/10.1126/science.aan0568

KROON, B., **BROUWER, R.**, & **BEUKERING, P. J.** (2013). The energy ladder: Theoretical myth or empirical truth? Results from a meta-analysis. *Renewable and Sustainable Energy Reviews, 20*, 504–513.

LAC DUONG DPC. (2024). *Report on the results of implementing new rural areas in Lac Duong district.*

LAM DONG FOREST RANGER DEPARTMENT. (2012). *Forest Ranger Report.*

LAM DONG FOREST RANGER DEPARTMENT. (2023). *Forest Ranger Report.*

LAM DONG FPDF. (2023a). *Lam Dong Forest Protection and Development Fund. Annual results of payment for forest environmental services in Lam Dong Province.*

LAM DONG FPDF. (2023b). *Results of 2023 tasks and 2024 plan. Report No. 548/BC-QBVR.*

LAM DONG PPC. (2024a). *Decision No. 337/QD-UBND dated 29 Feb 2024 on announcement of the forest status of Lam Dong Province in 2023.*

LAM DONG PPC. (2024b). *Decision No. 1663/QD-UBND dated 14 Oct 2024 on Approval of adjustment of plan for revenue and expenditure of forest environmental services in Lam Dong province in 2023.*

LE, N. D., **LOFT, L.**, **TJAJADI, J. S.**, **PHAM, T. T.**, & **WONG, G. Y.** (2016). Being equitable is not always fair: An assessment of PFES implementation in Dien Bien, Vietnam (Working Paper 205).

LI, L., **XIA, H.**, **CHEN, Z.**, **DUAN, M.**, & **PEI, J.** (2024). Spatiotemporal characteristics and driving mechanisms of household energy transition in rural China: Micro-evidence from 2005 to 2017. *Science of The Total Environment*, *909*, 168554.

LIU, F., **FENG, C.**, **ZHOU, Y.**, **ZHANG, L.**, **DU, J.**, **HUANG, W.**, **LUO, J.**, & **WANG, W.** (2022). Effectiveness of functional zones in National Nature Reserves for the protection of forest ecosystems in China. *J. Environ. Manag*, *308*, 114593. https://doi.org/10.1016/j.jenvman.2022.114593

LƯỢNG, P. H. (2018). Chi trả dịch vụ môi trường rừng ở Việt Nam: Thực trạng và giải pháp. *Tạp chí Khoa học và Công nghệ Lâm nghiệp*(1), 198–202.

LY, N. T. Y. (2013). Evaluating the pilot implementation of payment for forest environmental services in Lam Dong, Vietnam. *In.*

MA, W., **ZHOU, X.**, & **RENWICK, A.** (2019). Impact of off-farm income on household energy expenditures in China: Implications for rural energy transition. *Energy Policy*, *127*, 248–258.

MADUBANSI, M., & **SHACKLETON, C. M.** (2007). Changes in fuel wood use and selection following electrification in the Bushbuckridge Lowveld, South Africa. *J. Environ. Manag*, *83*(4), 416–426.

MARKKANEN, S., & **ANGER-KRAAVI, A.** (2019). Social impacts of climate change mitigation policies and their implications for inequality. *Climate Policy*, *19*(7), 827–844. https://doi.org/10.1080/14693062.2019.1596873

MARTIN, W. J., **HOLLINGSWORTH, J. W.**, & **RAMANATHAN, V.** (2014). Household air pollution from cook stoves: impacts on health and climate. *Global Climate Change and Public Health, Respiratory Medicine*, *7*(Springer), 237–255.

MASERA, O. R., **SAATKAMP, B. D.**, & **KAMMEN, D. M.** (2000). From linear fuel switching to multiple cooking strategies: A critique and alternative to the Energy Ladder model. *World Development*, *28*(12), 2083–2103.

MASUKU, B. (2024). Rethinking South Africa's household energy poverty through the lens of off-grid energy transition. *Development Southern Africa*, 1–24.

MCELWEE, P., **HUBER, B.**, & **NGUYỄN, T. H. V.** (2020). Hybrid Outcomes of Payments for Ecosystem Services Policies in Vietnam: Between Theory and Practice. *Development and Change*, *51*(1), 253–280. https://doi.org/10.1111/dech.12548

MCELWEE, P. D. (2012). Payments for environmental services as neoliberal market-based forest conservation in Vietnam: Panacea or problem? *Geoforum*, *43*(3), 412–426. https://doi.org/10.1016/j.geoforum.2011.04.010

MEKONNEN, A., & **KÖHLIN, G.** (2008). Determinants of household fuel choice in major cities in Ethiopia. In *Environment for Development Discussion Paper Series EfD DP 08-18*. Environment for Development Initiative.

MINH DAO. (2015). Bảo tồn đa dạng sinh học: Thách thức và hành động. *Lam Dong Online*. https://baolamdong.vn/khoahoc/201505/bao-ton-da-dang-sinh-hoc-thach-thuc-va-hanh-dong-2457811/

MOHAMMED, E. (2011). Pro-poor benefit distribution in REDD+: Who gets what and why does it matter? *In*.

NANSAIOR, A., **PATANOTHAI, A.**, **RAMBO, A. T.**, & **SIMARAKS, S.** (2011). Climbing the energy ladder or diversifying energy sources? The continuing importance of household use of biomass. *Biomass Bioenergy*, *35*(10), 4180–4188.

NEUDERT, R., **GOETTER, J. F.**, **ANDRIAMPARANY, J. N.**, & **RAKOTOARISOA, M.** (2015). Income diversification, wealth, education and well-being in rural south-western Madagascar: Results from the Mahafaly region. *Dev. South. Afr*, *32*(6), 758–784. https://doi.org/10.1080/0376835X.2015.1063982

NGUYEN, L. T., **RATNASIRI, S.**, & **WAGNER, L.** (2023). Does income affect climbing the energy ladder? A new utility-based approach for measuring energy poverty. *The Energy Journal*, *44*(4), 123–146. https://doi.org/10.5547/01956574.44.4.lngu

NGUYEN, T. T., **NGUYEN, T. T.**, & **GROTE, U.** (2020). Multiple shocks and households' choice of coping strategies in rural Cambodia. *Ecol. Econ*, *167*, 106442. https://doi.org/10.1016/j.ecolecon.2019.106442

NGUYEN, T. T., **NGUYEN, T. T.**, **HOANG, V. N.**, **WILSON, C.**, & **MANAGI, S.** (2019). Energy transition, poverty and inequality in Vietnam. *Energy Policy*, *132*, 536–548. https://doi.org/10.1016/j.enpol.2019.06.001

NGUYEN, V. T. H., **MCELWEE, P.**, **LE, H. T. V.**, **NGHIEM, T.**, & **VU, H. T. D.** (2022). The challenges of collective PES: Insights from three community-based models in Vietnam. *Ecosystem Services*, *56*, 101438. https://doi.org/10.1016/j.ecoser.2022.101438

NHAN, T. (2023). Khánh Hòa: Người dân không mặn mà nhận khoán bảo vệ rừng. *Dân tộc và Phát triển*. https://baodantoc.vn/khanh-hoa-nguoi-dan-khong-man-ma-nhan-khoan-bao-ve-rung-1682502322108.htm

NJENGA, M., GITAU, J. K., & MENDUM, R. (2021). Women's work is never done: Lifting the gendered burden of firewood collection and household energy use in Kenya. *Energy Res. Soc. Sci, 77*, 102071. https://doi.org/10.1016/j.erss.2021.102071

NWAKA, I. D., UMA, K. E., & IKE, G. N. (2020). Determinants of household fuel choices among Nigerian family heads: are there gender-differentiated impacts? *Environmental Science and Pollution Research, 27*(34), 42656-42669.

OFFICE OF GOVERNMENT. (2014). Conclusion of Deputy Prime Minister Hoang Trung Hai at the online conference reviewing 3 years of implementing the policy on payments for forest environmental services (2011-2013). Hanoi

ONNOGHEN, N. U., SYLVANUS, U. U., IPUOLE, D. O., ANTHONY, E. A., & OHAMBASSEY, S. (2023). Social Awareness Creation and Farmers' Forest Conservation Practices in Obudu Local Government Area, Cross River State. *Journal of Institute of Africa Higher Education Research and Innovation (IAHERI), 1*(001).

PAGDEE, A., KIM, Y.-S., & DAUGHERTY, P. J. (2006). What makes community forest management successful: a meta-study from community forests throughout the world. *Society and Natural Resources, 19*(1), 33-52.

PHAM, T. T., CHAU, N. H., CHI, D. T. L., LONG, H. T., & FISHER, M. R. (2020). The politics of numbers and additionality governing the national Payment for Forest Environmental Services scheme in Vietnam: A case study from Son La province. *Forest and Society*, 379–404. https://doi.org/10.24259/fs.v4i2.10891

PHAM, T. T., LOFT, L., BENNETT, K., PHUONG, V. T., DUNG, L. N., & BRUNNER, J. (2015). Monitoring and evaluation of Payment for Forest Environmental Services in Vietnam: From myth to reality. *Ecosystem Services, 16*, 220–229. https://doi.org/10.1016/j.ecoser.2015.10.016

PHAM, V. T., ROONGTAWANREONGSRI, S., HO, T. Q., & TRAN, P. H. N. (2021). Can payments for forest environmental services help improve income and attitudes toward forest conservation? Household-level evaluation in the Central Highlands of Vietnam. *Forest Policy and Economics, 132*, 102578. https://doi.org/10.1016/j.forpol.2021.102578

PHAN, T.-H. D., BROUWER, R., HOANG, L. P., & DAVIDSON, M. D. (2018). Do payments for forest ecosystem services generate double dividends? An integrated impact assessment of Vietnam's PES program. *PLOS ONE, 13*(8), 0200881. https://doi.org/10.1371/journal.pone.0200881

RAMANATHAN, V., & CARMICHAEL, G. (2008). Global and regional climate changes due to black carbon. *Nat. Geosci, 1*(4), 221–227.

RANDALL, B. (1995). The effect of labor market performance on deforestation in developing countries under open access: an example from rural Nepal. *Journal of Environmental Economics and Management, 29*, 42-63.

RAO, M. N., & REDDY, B. S. (2007). Variations in energy use by Indian households: an analysis of micro level data. *Energy, 32*, 143–153.

ROONGTAWANREONGSRI, S., HO, T. Q., & TRAN, P. H. N. (2021). Can payments for forest environmental services help improve income and attitudes toward forest conservation? Household-level evaluation in the Central Highlands of Vietnam. *Forest Policy and Economics, 132*, 102578.

RUIZ-MERCADO, I., & MASERA, O. (2015). Patterns of stove use in the context of fuel–device stacking: Rationale and implications. *EcoHealth, 12*(1), 42–56.

SAMII, C., **LISIECKI, M.**, **KULKARNI, P.**, **PALER, L.**, **CHAVIS, L.**, **SNILSTVEIT, B.**, **VOJTKOVA, M.**, & **GALLAGHER, E.** (2014). Effects of Payment for Environmental Services (PES) on Deforestation and Poverty in Low and Middle Income Countries: A Systematic Review. *Campbell Systematic Reviews*, *10*(1), 1–95. https://doi.org/10.4073/csr.2014.11

SCHRECKENBERG, K., & **LUTTRELL, C.** (2009). Participatory forest management: a route to poverty reduction? *Int. For. Rev*, *11*(2), 221–238.

SELVAKKUMARAN, S., & **AHLGREN, E. O.** (2019). Determining the factors of household energy transitions: A multi-domain study. *Technology in Society*, *57*, 54-75.

SNILSVEIT, B., **STEVENSON, J.**, **LANGER, L.**, **SILVA, N.**, **RABATH, Z.**, **NDUKU, P.**, **FERRARO, J. P.**, **POLANIN, J.**, **SHEMILT, I.**, & **EYERS, J.** (2019). International Initiative for Impact Evaluation (3ie).

SON, H., & **YOON, S.** (2020). Reducing energy poverty: characteristics of household electricity use in Vietnam. *Energy for Sustainable Development*, *59*, 62–70. https://doi.org/10.1016/j.esd.2020.08.007

SONG, C., **BILSBORROW, R.**, **JAGGER, P.**, **ZHANG, Q.**, **CHEN, X.**, & **HUANG, Q.** (2018). Rural household energy use and its determinants in China: how important are influences of payment for ecosystem services vs. other factors? *Ecological Economics*, *145*, 148-159.

SUHARDIMAN, D., **WICHELNS, D.**, **LESTRELIN, G.**, & **THAI HOANH, C.** (2013). Payments for ecosystem services in Vietnam: Market-based incentives or state control of resources? *Ecosystem Services*, *5*, 94–101. https://doi.org/10.1016/j.ecoser.2013.06.001

THUY, P. T., **BENNETT, K.**, **PHUONG, V. T.**, **BRUNNER, J.**, **DUNG, L. N.**, & **TIEN, N. D.** (2013). Payments for forest environmental services in Vietnam: From policy to practice. In.

THUY, P. T., **HAMILTON, M.**, & **GALLEMORE, C.** (2021). Preliminary results of assessments on the impacts of Payments for Forest Environmental Services (PFES) on forest networks and governance, household income and forest loss in Vietnam. In.

TO, P., & **DRESSLER, W.** (2019). Rethinking 'Success': The politics of payment for forest ecosystem services in Vietnam. *Land Use Policy*, *81*, 582–593. https://doi.org/10.1016/j.landusepol.2018.11.010

TO, P. X., **DRESSLER, W. H.**, **MAHANTY, S.**, **PHAM, T. T.**, & **ZINGERLI, C.** (2012). The Prospects for Payment for Ecosystem Services (PES) in Vietnam: A Look at Three Payment Schemes. *Human Ecology*, *40*(2), 237–249. https://doi.org/10.1007/s10745-012-9480-9

TRÆDAL, L. T., & **VEDELD, P. O.** (2017). Livelihoods and Land Uses in Environmental Policy Approaches: The Case of PES and REDD+ in the Lam Dong Province of Vietnam. *Forests*, *8*(2). https://doi.org/10.3390/f8020039

TRAN QUOC, C., **TRAN NAM, T.**, **KULL, C. A.**, **NGUYEN VAN, L.**, **DINH, T. T.**, **COCHARD, R.**, **SHACKLETON, R.**, **NGO, D. T.**, **NGUYEN HAI, V.**, & **PHUONG THAO, P. T.** (2023). Factors associated with deforestation probability in Central Vietnam: A case study in Nam Dong and A Luoi districts. *Journal of Forest Research*, *28*(3), 159–167. https://doi.org/10.1080/13416979.2023.2182259

VO, D. H., & **HO, C. M.** (2024). Understanding the characteristics of the household energy transition in a developing country. *Heliyon*, *10*(1). https://doi.org/10.1016/j.heliyon.2024.e23977

WANG, C., **YANG, Y.**, & **ZHANG, Y.** (2012). Rural household livelihood change, fuelwood substitution, and hilly ecosystem restoration: evidence from China. *Renewable and Sustainable Energy Reviews*, *16*(5), 2475–2482.

WAWERU, D., **MOSE, N.**, & **OTIENO, S.** (2022). Household energy choice in Kenya: An empirical analysis of the energy ladder hypothesis. *Journal of Energy Research and Reviews*, *10*(4), 12–19.

WEI, D., **CHAO, H.**, & **YALI, W.** (2016). Role of income diversification in reducing forest reliance: Evidence from 1838 rural households in China. *Journal of Forest Economics, 22*, 68–79. https://doi.org/10.1016/j.jfe.2015.12.002

WUNDER, S. (2005). Payments for Environmental Services: Some nuts and bolts. In.

ZEB, A. (2019). Spatial and temporal trends of forest cover as a response to policy interventions in the district Chitral, Pakistan. *Applied Geography*, *102*, 39–46.

ZHENG, J., **DANG, Y.**, & **ASSAD, U.** (2024). Household energy consumption, energy efficiency, and household income–Evidence from China. *Applied Energy*, *353*, 122074.

Agence française
de développement
5, rue Roland Barthes
75012 Paris l France
www.afd.fr

What is AFD?
Éditions Agence française de développement publishes analysis and research on sustainable development issues. Conducted with numerous partners in the Global North and South, these publications contribute to a better understanding of the challenges faced by our planet and to the implementation of concerted actions within the framework of the Sustainable Development Goals.
With a catalogue of more than 1,000 titles and an average of 80 new publications published every year, Éditions Agence française de développement promotes the dissemination of knowledge and expertise, both in AFD's own publications and through key partnerships. Discover all our publications in open access at editions.afd.fr.
Towards a world in common.

Publication Director Rémy Rioux
Editor-in-Chief Thomas Melonio

Legal deposit 3rd quarter 2025
ISSN 2492 - 2846

Graphic design MeMo, Juliegilles, D. Cazeils
Layout PUB
Printed by the AFD reprography service

To browse our publications:
https://www.afd.fr/en/ressources-accueil