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Article

# From Two Birds to Two Loops: Electric Cooking and the Reinvention of Energy Systems

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## Abstract

This paper examines how the body of research and innovation on electric cooking for low and middle income countries has evolved to the extent that electric cooking is now influencing energy system performance. **Methods:** The paper synthesises recent evidence from pilots, market developments, and system-level analysis across Africa and Asia, focusing on demand patterns, utility economics, carbon finance mechanisms, and emerging digital and financing models. **Results:** Electric cooking is increasingly acting as a system-strengthening demand, rather than a system stressor. Two reinforcing mechanisms are identified: (i) an electricity revenue loop, in which increased consumption improves utility and mini-grid viability and supports further investment; and (ii) a carbon finance loop, enabled by metered methodologies and measurable emissions reductions, which can improve household affordability and accelerate adoption. The analysis also highlights the importance of diversified demand (household, commercial, and institutional), which improves load factors and aligns demand with generation. However, a persistent planning blind spot remains, with cooking demand largely excluded from energy models. **Conclusions:** Electric cooking is moving from proof of concept toward system integration, but scale is constrained by affordability, reliability, tariff design, fuel stacking, institutional fragmentation, and carbon market uncertainty. The findings suggest that electric cooking should be treated as a core component of energy system design, requiring coordinated policy, planning, and financing to realise its full potential.

**Keywords:** biomass cooking; SDG 7; grid extension; off-grid electricity; renewable energy; climate change policies; integrated planning; urbanisation; Africa; developing Asia

## 1. Introduction

In “Two Birds, One Stone—Reframing Cooking Energy Policies in Africa and Asia” [1], the central proposition was both simple and disruptive: cooking should be treated not as a marginal, household-level issue, but as an integral component of energy systems. The paper argued that a large share of the global population already possessed some form of electricity access, and that this latent and underutilised electricity infrastructure could be leveraged to achieve simultaneous gains in clean cooking, energy access, and broader development outcomes. In doing so, it challenged a long-standing paradigm that had focused heavily on incremental improvements to biomass use, instead proposing a transition toward modern energy—particularly electricity—as a route to deliver “two birds with one stone.”

Three years later, “Mutual Support—Modern Energy Planning Inclusive of Cooking—A Review of Research into Action in Africa and Asia since 2018” [2] took stock of how this reframing was beginning to translate into practice. The emphasis had shifted from conceptual possibility to empirical validation. Across a growing body of field studies, pilot programmes, and system modelling exercises, the evidence suggested that electric cooking—especially through efficient appliances such as electric pressure cookers—was not only technically viable but increasingly

compatible with a range of energy systems, including weak grids, mini-grids, and solar home systems [3] [4]. The “mutual support” framing captured a key insight: rather than competing with electrification efforts, modern cooking demand could reinforce them—improving load factors, strengthening utility revenues, and enhancing the economics of distributed energy systems [5] [6].

This paper begins from that trajectory and asks a more pointed question: what has changed since 2022 and how far has the trajectory, that of eCooking as a part of planning for electricity access and clean cooking, been realised in practice?

## 2. Materials and Methods

This paper adopts a narrative, literature-informed synthesis approach. It draws on recent evidence from peer-reviewed publications, programme reports, and emerging grey literature, alongside insights from pilots and market developments across Africa and Asia. The analysis focuses on four interrelated domains: demand patterns, utility and mini-grid economics, carbon finance mechanisms, and emerging digital and financing models.

The review is not systematic. Rather, literature and evidence were identified through an iterative “snowball” process, informed by ongoing engagement with researchers, practitioners, utilities, and market actors. This engagement was primarily facilitated through the UK Aid-funded Modern Energy Cooking Services (MECS) programme, a research and innovation programme led by Loughborough University that aims to accelerate the transition to modern energy cooking across low- and middle-income countries [7] [8] [9] [10]. The programme works across technology development, market systems, policy engagement, and field-based pilots, providing a broad evidence base and practitioner network that informs this synthesis.

As such, the paper combines published evidence with practitioner-informed insights, aiming to identify emerging system dynamics rather than provide exhaustive coverage. The findings should therefore be interpreted as indicative and hypothesis-generating, reflecting patterns observed across multiple contexts rather than statistically representative conclusions. Appendix A lays out the limitations and tensions of this approach.

Generative artificial intelligence (GenAI) has been used to generate graphics, and for superficial text editing.

## 3. Results

### 3.1. From Opportunity to Partial System Embedding

The period between 2019 and 2022 was characterised by proof of concept. Since 2022, the transition has entered a more complex phase of partial system embedding. In several countries, electric cooking is no longer confined to pilots or niche programmes but is beginning to appear, albeit unevenly, in national energy strategies, utility planning discussions, and market development initiatives. [11] [12] [13] The language of “eCooking” has moved from the periphery toward the mainstream of SDG7 discourse.

However, this embedding remains incomplete. While the technical case for electric cooking is now well established [3] [4], its integration into planning frameworks, financing structures, and supply chains is still evolving. In many contexts, cooking demand is not yet systematically incorporated into load forecasting, tariff design, or infrastructure investment decisions [14]. As a result, the system-level benefits identified in both earlier papers—particularly around load growth and asset utilisation are only partially realised.

### 3.1.2. Mini-Grids and Weak Grids: From Constraint to Conditional Opportunity

One of the most important areas of progress—and tension—lies in the role of mini-grids and weak grids. In *Two Birds*, these systems were identified as potential platforms for modern energy cooking, but with limited empirical backing. By the time of *Mutual Support*, modelling and early

field evidence suggested that, under certain conditions, mini-grids could support significant levels of electric cooking without prohibitive system upgrades. [4] [7].

Subsequent experience has both reinforced and qualified this conclusion. It is now clearer that mini-grids can accommodate cooking loads, but only under specific technical and operational configurations. [7] [8] These include the presence of:

- high-efficiency appliances (notably electric pressure cookers),
- load management strategies (implicit or explicit),
- sufficient generation capacity or storage (often battery-supported), and
- tariff structures that align operator incentives with increased consumption.

Where these conditions are met, cooking demand can improve system economics by increasing load factors and reducing the relative cost of delivered electricity. [5] [6] Where they are absent, cooking loads can expose system constraints—particularly around peak demand and generation adequacy. [7]

This duality marks an important evolution in understanding. Electric cooking is no longer seen simply as an additional load, but as a structural variable in system design—capable of either strengthening or destabilising energy systems depending on how it is integrated.

### 3.1.3. The Emergence of Load as an Asset

A further development since 2022 is a growing recognition that demand itself—particularly cooking demand—can be treated as an asset. This represents a subtle but significant shift from earlier framings.

In both *Two Birds* and *Mutual Support*, the focus was on how existing energy infrastructure could enable cleaner cooking. Increasingly, the perspective is reversing: how cooking demand can enable better energy systems. This is most evident in three areas:

- Utility economics: Regular, predictable cooking loads—especially for staple foods—can contribute to more stable revenue streams and improved asset utilisation. [5]
- Mini-grid viability: Increased demand density can improve the financial sustainability of systems that would otherwise struggle with low consumption levels. [6] [7]
- Planning justification: Anticipated cooking loads can strengthen the case for grid extension or system upgrades, particularly where they displace costly or subsidised fuels such as LPG. [15,16]

This reframing aligns closely with broader shifts in energy planning, where demand stimulation is increasingly recognised as critical to infrastructure viability. [6]

### 3.1.4. Persistent Frictions: Affordability, Behaviour, and System Coordination

Despite these advances, several of the frictions identified in earlier work remain unresolved, albeit in more nuanced forms.

- Affordability continues to be shaped less by lifetime cost advantages and more by upfront barriers and financing constraints. While the economic case for electric cooking is often favourable, particularly for energy-intensive dishes, access to appliances remains a limiting factor. [10] [17]
- Behaviour and fuel stacking persist as central dynamics. Even where electric cooking is adopted, it is rarely exclusive. This complicates both impact assessment and system planning, as partial adoption does not translate cleanly into proportional reductions in traditional fuel use. [18] [19]
- System coordination remains perhaps the most underdeveloped dimension. The integration of cooking into energy systems requires alignment across multiple actors—utilities, regulators, appliance suppliers, financiers, and carbon market actors. In practice, these systems are often fragmented, with no single actor responsible for orchestrating the transition. [14] [12].

### 3.1.5. From Reframing to Realignment

Taken together, the trajectory from *Two Birds* (2019) through *Mutual Support* (2022) to the present suggests a shift from reframing to realignment.

- The original reframing—positioning cooking as an energy system issue—has largely been accepted within the research and policy community.
- The current challenge is one of realignment: adjusting institutions, markets, and infrastructure to reflect that insight. [14] [11]

This paper builds on that foundation by examining how far this realignment has progressed across different contexts, and where the remaining gaps and opportunities lie.

### 3.2. From Load Problem to Revenue Engine

In earlier framings of electrification—implicit in both *Two Birds*, *One Stone—Reframing Cooking Energy Policies in Africa and Asia* and, to a lesser extent, *Mutual Support—Modern Energy Planning Inclusive of Cooking—A Review of Research into Action in Africa and Asia since 2018*—electric cooking was often treated as a potential stressor on energy systems. The concern was intuitive: cooking is energy-intensive, time-bound, and concentrated in morning and evening peaks. For utilities and mini-grid operators already managing constrained systems, the prospect of widespread cooking loads appeared, at best, a planning challenge and, at worst, a risk to system stability.

This perception is now beginning to shift. Emerging evidence from pilots, utility observations, and system modelling suggests that, under the right conditions, electric cooking is not simply an additional load to be managed, but a revenue-generating demand that can materially strengthen the financial performance of energy systems. [5] [6]

At the heart of this shift is a simple but underappreciated characteristic of cooking: it is daily, essential, and relatively inelastic. [3] Unlike many household electricity uses—lighting, phone charging, or entertainment—cooking is not discretionary. Households cook every day, often multiple times per day, and the energy required to do so is substantial. When delivered through efficient electric appliances, this translates into consistent, repeat consumption of electricity, often at levels significantly higher than those associated with basic access tiers.

This has two important implications for utilities and mini-grid operators.

First, electric cooking increases average revenue per user (ARPU). [10] In many low-consumption systems, the core challenge is not connection but utilisation: customers are connected to electricity networks but consume very little, limiting revenue and constraining the ability of operators to recover costs or invest in system improvements. [11] The introduction of electric cooking can shift households from low-consumption to moderate- or high-consumption categories, increasing monthly electricity spend in a way that is both predictable and sustained. In this sense, cooking represents a transition from access to use—a deepening of electrification rather than its expansion.

Second, cooking demand can improve load factors. [11] [15] While cooking is often associated with peak demand, it also introduces a more substantial and structured load profile into systems that might otherwise be characterised by short-duration, low-intensity usage. In mini-grids in particular, where underutilisation of generation assets is a persistent challenge, the addition of cooking loads can increase the proportion of energy generated that is actually consumed and paid for. Even where peaks are accentuated, the overall effect can be a more economically efficient use of installed capacity—especially when combined with high-efficiency appliances and, increasingly, battery storage.

However, focusing solely on household cooking risks missing an important and increasingly well-evidenced dimension of this transition: the role of commercial and institutional cooking loads. These forms of demand exhibit markedly different temporal characteristics from domestic cooking and, in doing so, introduce a further layer of system value. [20]

Commercial food vendors—ranging from small street food enterprises to larger informal or semi-formal kitchens—typically operate during daytime hours, often with extended cooking periods that span late morning through the afternoon. While the exact profile varies by cuisine and business model, the resulting electricity demand is generally flatter and more sustained than the pronounced evening peaks associated with household cooking. Early field evidence suggests that this type of load can contribute to daytime demand filling, improving utilisation of generation assets that might otherwise be underused outside evening hours—particularly in solar-dominated systems.

A similar pattern is observed in institutional settings, including schools, hospitals, and other public or private facilities. School feeding programmes, for example, often involve concentrated cooking activity in the morning and at midday, creating predictable, high-volume demand outside traditional peak periods. Unlike household adoption, which may be gradual and partial due to fuel stacking, institutional transitions can involve step changes in demand, as entire kitchens shift from biomass or LPG to electricity. [14]

Taken together, these non-household cooking segments introduce an important form of load diversification. [15] Where domestic cooking tends to concentrate demand in the evening, commercial and institutional cooking can extend and flatten the overall load curve, reducing the degree of temporal concentration and improving the alignment between generation and consumption. In systems with significant solar penetration, this alignment is particularly valuable, as it increases the proportion of locally generated energy that is directly consumed rather than curtailed or stored. [13]

These effects point toward a reframing of electric cooking as a form of ‘anchor demand’ across multiple user segments. [11] Just as productive uses of energy—such as milling, refrigeration, or small enterprises—are often promoted to improve the economics of rural electrification, cooking may represent the most widespread and reliable form of demand available. It is geographically ubiquitous, culturally embedded, and temporally consistent. Unlike many productive loads, it does not depend on market development or entrepreneurial activity; it already exists, currently served by other fuels.

In this sense, commercial and institutional electric cooking begin to blur the boundary between “household energy use” and “productive use of energy”, with implications for how such demand is prioritised within electrification strategies. [11]

This reframing has important implications. If cooking demand can be captured within electricity systems, it effectively converts an existing, external energy expenditure—on charcoal, firewood, LPG, or kerosene—into internalised electricity revenue. From the perspective of the energy system, this is not merely an increase in load, but a reallocation of household energy spending toward the electricity sector. [21]

The consequences of this reallocation extend beyond immediate revenue gains. Increased and more reliable income streams can improve the financial standing of utilities and mini-grid operators, strengthening their ability to maintain infrastructure, service debt, and justify further investment. [6] In this sense, electric cooking begins to exhibit the characteristics of a reinforcing economic loop:

increased cooking demand → higher electricity consumption → improved revenue → greater system viability → increased investment → improved service → further adoption of electric cooking

While this loop is not yet fully realised in most contexts, early evidence suggests that elements of this loop are already emerging. [7] [8] Importantly, the loop does not rely on universally high tariffs or rapid behavioural change; rather, it depends on the gradual alignment of appliance efficiency, service reliability, and affordability.

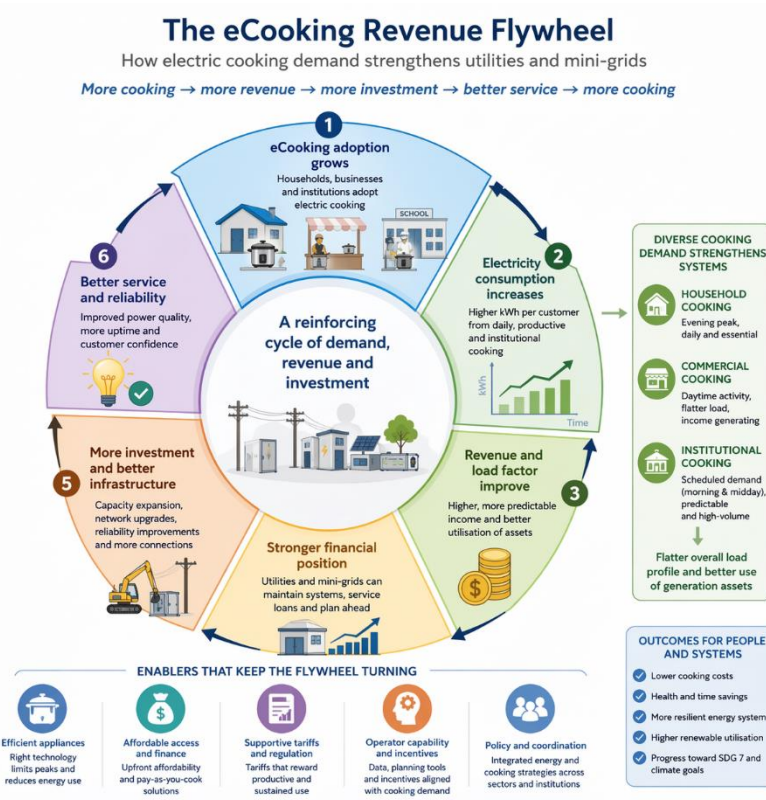
However, this shift from “load problem” to “revenue engine” is not automatic. It is contingent on several conditions. Appliances must be efficient enough to keep peak demand within manageable bounds. Tariff structures must allow operators to capture increased consumption without discouraging use. Systems must be sufficiently reliable to support regular cooking practices. And households must be able to access the appliances required to make the transition. [6] [8] [10]

Where these conditions are met, electric cooking has the potential to move from the margins of energy planning to its centre—not only as a means of delivering clean cooking, but as a foundational component of financially viable energy systems. [14]

Electric cooking is therefore not a single, uniform load, but a portfolio of demand types:

- household (evening-peaked, daily, essential),
- commercial (daytime, income-generating, often extended), [20]
- institutional (scheduled, high-volume, predictable). [14]

This diversity strengthens its role within energy systems. Rather than amplifying a single peak, electric cooking—when considered across these segments—can contribute to a more balanced and economically productive load profile. [7] [13]



**Figure 1.** Representing the eCooking Revenue flywheel (Generative AI construct from Authors prompts).

### 3.3. From Fragility to Conditional Opportunity

In *Two Birds, One Stone* [1], mini-grids and weak grids were positioned as potential platforms for modern energy cooking, but with limited empirical grounding. By the time of *Mutual Support* [2], this position had evolved: modelling and early field evidence suggested that electric cooking could be accommodated within such systems under certain conditions. [4] [7] The intervening years have provided a clearer, and more nuanced, picture.

Mini-grids and weak grids are no longer best understood simply as constraints to cooking adoption, but neither are they universally enabling environments. Rather, they represent conditional opportunities—systems whose ability to support electric cooking depends on how demand, technology, and system design are aligned. [7] [8]

#### 3.3.1. The Structural Challenge: Low Demand, not Just Limited Supply

The traditional narrative around mini-grids has focused on supply-side limitations: insufficient generation capacity, reliance on diesel back-up, voltage instability, and the risks associated with peak

demand. [6] While these constraints remain real, a growing body of operational experience suggests that an equally important, and often more binding, challenge lies on the demand side.

Many mini-grids operate with low levels of consumption per customer, resulting in underutilised assets and fragile financial performance. [6] Systems are built with a degree of excess capacity to ensure reliability, yet much of that capacity remains unused for large portions of the day. In such contexts, the absence of sufficient demand—not the presence of excessive demand—is often the primary constraint on viability.

Electric cooking directly engages with this challenge. [7] By introducing substantial, regular energy demand, it has the potential to increase utilisation of existing generation assets and improve the economics of service provision. [3] However, this potential is not automatically realised and depends on how cooking loads interact with system characteristics. [8]

### 3.3.2. When Cooking Strengthens the System

Where certain conditions are met, electric cooking can act as a system-strengthening load within mini-grids and weak grids. [7]

First, the use of high-efficiency appliances, particularly for energy-intensive cooking tasks, limits the extent to which peak demand increases. Devices such as electric pressure cookers shift a significant portion of energy use into controlled, lower-power phases, reducing instantaneous load while maintaining total energy consumption. [4] [8] This distinction—between energy and power—is critical for system compatibility.

Second, as discussed in Section 2, cooking demand is not monolithic. The presence of commercial and institutional loads, often occurring during daytime hours, can complement household demand patterns. In solar-based systems, this creates a closer alignment between generation profiles and consumption, increasing the share of locally generated electricity that is directly used rather than curtailed or stored. [7] [13]

Third, even where cooking contributes to evening peaks, the overall increase in energy sales can improve financial performance sufficiently to justify incremental investments—such as additional generation capacity or battery storage—that mitigate these peaks. [6] In this sense, cooking demand can help unlock the very investments needed to accommodate it.

Taken together, these dynamics suggest that electric cooking can, under the right conditions, move mini-grids from a state of chronic underutilisation toward more balanced and economically viable operation.

### 3.3.3. When Cooking Exposes System Limits

At the same time, there are contexts in which the introduction of electric cooking can expose or exacerbate system constraints. [8]

In systems with very limited generation capacity, or where appliance efficiency is low, cooking loads can lead to overloading during peak periods, resulting in voltage drops, outages, or the need for increased reliance on expensive diesel generation. Similarly, where tariff structures do not allow operators to recover the costs associated with higher consumption, increased demand may not translate into improved financial performance. [6]

Reliability also plays a central role. Households and commercial users are unlikely to depend on electricity for cooking if supply is inconsistent, particularly for time-sensitive cooking tasks. In such cases, fuel stacking persists, and the potential system benefits of electric cooking are only partially realised. [19]

These challenges underline an important point: electric cooking is not a plug-and-play solution for mini-grid viability. It interacts with existing system characteristics in ways that can be either reinforcing or destabilising.

### 3.3.4. Designing for Cooking, Rather than Accommodating It

A key implication of recent experience is that mini-grids and weak grids are most successful in supporting electric cooking when they are designed with cooking demand in mind, rather than attempting to accommodate it retrospectively. [7] [14]

This includes:

- Generation sizing that anticipates not only basic access loads but also higher-consumption uses such as cooking;
- Integration of storage, particularly in solar-based systems, to manage temporal mismatches between generation and demand;
- Appliance strategies that promote efficient devices and shape load profiles;
- Tariff design that balances affordability with cost recovery and encourages sustained use.

In this context, cooking demand becomes a planning parameter, not an externality. Its inclusion alters optimal system design, potentially leading to different choices around generation mix, capacity margins, and investment timing. [8] [14]

### 3.3.5. From Edge Case to Design Case

The evolution from Two Birds to Mutual Support framed electric cooking in mini-grids as a plausible extension of electrification. The current evidence suggests a further shift: in some contexts, cooking is moving from being an edge case—a demand to be cautiously accommodated—to a design case—a demand that can shape system architecture and economics.

This does not imply that all mini-grids should prioritise cooking, nor that the transition is straightforward. However, it does suggest that excluding cooking from system design may lead to suboptimal outcomes, both in terms of service provision and financial viability.

The implication for planners and operators is therefore not simply to assess whether their systems can support cooking, but to consider how cooking demand—across household, commercial, and institutional segments—can be actively integrated into system design to enhance overall performance.

In this light, mini-grids and weak grids are neither barriers nor guaranteed enablers of electric cooking. They are adaptive systems, whose performance depends on how effectively demand and supply are co-designed. Electric cooking, once viewed as a risk to these systems, is increasingly emerging as one of the most significant opportunities to improve their long-term viability.

## 4. Discussion

### 4.1. The Planning Blind Spot: Cooking Still Missing from Energy Models

Despite the conceptual shift introduced in Two Birds, One Stone [1] and the growing empirical base synthesised in Mutual Support [2], a notable disconnect persists: cooking demand remains largely absent from formal energy planning models and processes. [14] [22]

This omission is not always explicit. In many cases, cooking is not deliberately excluded; rather, it is implicitly assumed away—either embedded within low baseline consumption estimates or treated as a future, uncertain load that does not materially affect near-term planning decisions. The result is that one of the most significant and predictable forms of energy use in low- and middle-income countries is systematically underrepresented in the models that shape infrastructure investment.

#### 4.1.1. How Cooking Disappears in Practice

In national electrification plans, least-cost models, and mini-grid sizing tools, demand is typically constructed from a combination of:

- household tier-based consumption assumptions (often aligned with Multi-Tier Framework levels),
- projected uptake of productive uses,
- and, in some cases, anchor loads such as telecom towers or agro-processing.

Within this structure, household electricity use is frequently characterised by low initial consumption, dominated by lighting, phone charging, and small appliances. [6] Cooking is either excluded or represented by highly conservative assumptions that do not reflect the potential for transition to modern energy cooking. [14]

This leads to a structural distortion. Systems are designed around a view of demand that is artificially suppressed, particularly at the household level. As a result:

- generation capacity is sized conservatively,
- network investments are staged cautiously,
- and the economic case for electrification is evaluated against a low-demand baseline.

In effect, planning frameworks assume a future in which households remain low consumers of electricity, even where the underlying energy demand—currently met by biomass, charcoal, or LPG—is substantial. [18]

#### 4.1.2. The Consequence: Underbuilt and Underutilised Systems

The exclusion of cooking demand has two interrelated consequences.

First, it contributes to the development of underbuilt systems. By not anticipating higher levels of consumption associated with electric cooking, planners may undersize generation and distribution infrastructure, creating systems that are technically capable of delivering basic access but struggle to accommodate growth in demand without subsequent upgrades.

Second, and perhaps more critically, it reinforces underutilisation. Where systems are built to meet low demand expectations, and where no concerted effort is made to stimulate higher consumption, operators may find themselves with assets that are insufficiently used to generate sustainable revenue. This dynamic is particularly evident in mini-grids, where financial viability is closely tied to consumption levels.

These outcomes are mutually reinforcing. Low expectations of demand lead to conservative system design, which in turn constrains the ability to support higher-demand uses such as cooking, thereby validating the original assumption of low consumption.

#### 4.1.3. A paradox in Energy Planning

This dynamic gives rise to a broader paradox:

*Energy systems are being planned on the basis of current electricity consumption, rather than total energy demand.*

In many contexts, households already expend significant amounts of energy on cooking, albeit through non-electric fuels. When this demand is excluded from planning models, electrification is effectively treated as an end in itself, rather than as a means of serving the full spectrum of household energy needs.

The consequence is a misalignment between what energy systems are designed to deliver and what households actually require. Cooking, as one of the largest and most time-critical energy uses, sits at the centre of this misalignment.

#### 4.1.4. Emerging Attempts to Integrate Cooking

There are, however, early signs of change. Some recent planning exercises and modelling efforts have begun to explore the inclusion of cooking demand, either through scenario analysis or through explicit integration into demand projections. These approaches often reveal that:

- the inclusion of cooking demand significantly alters load forecasts,
- higher demand can improve the economic case for grid extension or system upgrades,

- and system designs that incorporate cooking from the outset may differ materially from those based on low-consumption assumptions.

In mini-grid contexts, similar insights are emerging. Where operators consider the potential for electric cooking—particularly across household, commercial, and institutional segments—they may adopt different strategies around capacity sizing, storage integration, and tariff design.

However, these approaches remain the exception rather than the norm. In most cases, cooking is still treated as an add-on rather than a core planning variable.

#### 4.1.5. From Omission to Integration

The persistence of this blind spot suggests that the challenge is not solely technical, but also institutional. Planning frameworks, tools, and assumptions have evolved over time in ways that prioritise access metrics—connections, coverage, and basic service levels—over depth of use. Integrating cooking into these frameworks requires a shift in perspective:

- from access to utilisation,
- from marginal loads to core demand,
- and from incremental upgrades to system-level design choices.

This shift has implications across multiple domains. It affects how demand is forecast, how investments are prioritised, how tariffs are structured, and how success is measured.

Evidence from Latin America and developing Asia suggests that the relevance of electric cooking extends beyond low-access contexts. In highly electrified systems, the challenge is often not connection but utilisation, with cooking representing a significant untapped source of demand. [20] [21] In countries with surplus renewable generation, particularly hydropower-dominated systems such as Ecuador and Bhutan, electric cooking is increasingly positioned as a demand-stimulation strategy, both to absorb excess generation and to reduce reliance on imported fuels. [24] [25] [16] At the same time, in contexts where LPG remains dominant, policy alignment across fuels becomes critical, as transitions to electricity interact with existing subsidy structures and fuel markets. [26] [27] Evidence from Nepal further highlights how electric cooking is being explored not only at household level but also for enterprise and institutional use, reinforcing its role as a broader demand category within electrified systems. [28] [21]

Taken together, these cases reinforce the central argument of this paper: that electric cooking is not only a household technology transition, but a system-level variable whose value depends on how it is integrated into energy planning, pricing, and infrastructure.

#### 4.1.6. Reframing the Planning Question

If Two Birds asked whether electrification could support clean cooking, and Mutual Support explored how the two could reinforce each other, the present challenge is more fundamental:

What would energy systems look like if they were designed from the outset to meet cooking demand?

Answering this question requires moving beyond incremental adjustments to existing models and toward a more integrated approach in which cooking is treated as a central, not peripheral, component of energy demand.

Until this shift occurs, there is a risk that energy systems will continue to be planned in ways that underestimate both the scale of demand and the opportunities associated with meeting it.

#### 4.2. Loop1:- The Investment Feedback Loop: From Demand to System Expansion

Building on the dynamics outlined in Sections 2–4, electric cooking can be understood not only as a new source of demand, but as a mechanism that can strengthen and expand energy systems over time. [6] [7] This occurs through a reinforcing investment loop in which increased utilisation improves financial performance, enabling further investment, which in turn supports deeper and more reliable use.

At its simplest, the loop begins with the adoption of electric cooking across household, commercial, and institutional segments. As shown in Section 2, these forms of demand are not only substantial but structurally valuable: they are regular, often predictable, and—when considered together—extend and diversify the load profile. [3] The immediate effect is an increase in electricity consumption per customer, often shifting users from low-consumption access levels to more economically meaningful usage.

This increase in consumption translates into higher and more stable revenue streams for utilities and mini-grid operators. In systems where low demand has historically constrained viability, even modest increases in average consumption can have a disproportionate effect on financial performance. Revenues become less dependent on connection growth alone and more grounded in depth of use, improving indicators such as average revenue per user and overall system utilisation. [10].

It is at this point that the loop begins to reinforce itself. Improved revenue and utilisation strengthen the operator's ability to cover operating costs, service debt, and build confidence in future cash flows. This, in turn, creates space—both financially and institutionally—for incremental investment. These investments may take multiple forms: expansion of generation capacity, reinforcement of distribution networks, integration of battery storage, or improvements in system management and maintenance.

Crucially, these investments directly address one of the primary constraints on electric cooking: reliability. Cooking is a time-bound activity, and users are unlikely to depend on electricity where supply is inconsistent. As reliability improves—through both physical upgrades and better system operation—households, businesses, and institutions become more willing to shift a greater share of their cooking practices to electricity. This deepening of use further increases demand, reinforcing the revenue base and sustaining the cycle. [8]

The resulting dynamic can be expressed as a reinforcing loop:

increased eCooking adoption → higher electricity consumption → improved revenue and load factor → greater investment capacity → improved reliability and service → further adoption

While conceptually straightforward, this loop represents a significant departure from earlier models of electrification. In many traditional approaches, electrification is treated as a one-off capital intervention, with limited attention to how systems evolve financially after connections are made. Here, by contrast, ongoing consumption becomes the driver of system growth, linking user behaviour directly to infrastructure development.

An important feature of this loop, highlighted in Section 2, is the role of diversified cooking demand. Household cooking contributes scale and regularity, but is often concentrated in evening periods. Commercial cooking introduces daytime, income-generating demand, while institutional cooking provides scheduled, high-volume loads at predictable times. Together, these segments create a more balanced demand profile, improving the alignment between generation and consumption and enhancing the economic efficiency of the system. [7] [13] This diversity strengthens the loop by ensuring that increased demand translates not only into higher revenues, but into more effective utilisation of assets across the day.

However, the investment loop is not automatic, nor is it universally observed. Its operation depends on the alignment of several enabling conditions. [6] [8] [10] Tariff structures must allow operators to capture the value of increased consumption without discouraging use. Appliance efficiency must be sufficient to prevent excessive strain on system capacity. Access to appliances—through markets, finance, or programme support—must enable households and institutions to adopt electric cooking in the first place. Where these conditions are not met, the loop may stall: increased demand may not translate into improved financial performance, or improved systems may not lead to greater adoption.

There is also an important question of scale and timing. In many contexts, the loop may begin with small, localised changes—such as a cluster of commercial users adopting electric cooking, or a school shifting its kitchen operations. These initial changes may not transform system economics

immediately, but they can provide early signals of demand growth, helping to justify incremental investment. Over time, as adoption spreads and system improvements accumulate, the loop can become more pronounced.

The implication is that electric cooking should not be viewed solely as an outcome of successful electrification, but as a driver of its maturation. [14] By converting latent energy demand into sustained electricity consumption, it creates the conditions under which energy systems can move beyond basic access toward financially viable, service-oriented infrastructure.

This represents a further step in the progression from Two Birds, where electrification was positioned as an enabler of clean cooking, and from Mutual Support, where the relationship between cooking and energy systems was understood as mutually reinforcing. The emerging evidence suggests a more specific and operational insight: electric cooking can catalyse a self-reinforcing cycle of demand, revenue, and investment that underpins the long-term viability of energy systems.

#### 4.3. Loop 2:- Carbon Finance and the Second Reinforcing Loop

Alongside the electricity-based investment dynamics described in Section 5, a second and increasingly important reinforcing mechanism is emerging through carbon finance. [30] While conceptually distinct from utility and mini-grid revenue flows, this mechanism interacts closely with them, creating a parallel pathway through which electric cooking can improve the economics of transition for households, suppliers, and energy systems.

At its core, the carbon finance opportunity arises from the displacement of biomass and other fossil-based cooking fuels. In many contexts, traditional cooking relies on wood, charcoal, or LPG, all of which are associated with greenhouse gas emissions—either directly, or through upstream processes. [31] The shift to electric cooking, particularly when powered by increasingly low-carbon electricity systems, can therefore generate quantifiable emissions reductions, which may be monetised through carbon markets. [32]

##### 4.3.1. From Avoided Fuel to Monetised Value

The basic logic of carbon finance in cooking transitions is well established: emissions reductions are estimated relative to a baseline scenario—typically continued use of biomass or fossil fuels—and credits are issued based on the difference between baseline and project emissions. Historically, however, this approach has faced significant challenges, particularly in relation to baseline assumptions, most notably the fraction of non-renewable biomass (fNRB). [32]

Estimates of fNRB vary widely across contexts and methodologies, and small changes in assumptions can lead to large differences in credited emissions reductions. This has contributed to ongoing debates around the integrity and credibility of carbon credits generated from improved cookstove and fuel-switching projects. [31] In some cases, these concerns have translated into price discounts or buyer hesitancy within voluntary carbon markets.

Electric cooking introduces an important shift in this landscape. Rather than relying primarily on modelled estimates of fuel savings, eCooking interventions—particularly those involving modern appliances—enable the possibility of direct measurement of energy use. [32] Through embedded sensors, smart meters, and increasingly low-cost connectivity, it is now feasible to track actual electricity consumption associated with cooking activities at the device or household level.

##### 4.3.2. Metered Methodologies and the Question of Integrity

This capability underpins a new generation of metered and measured methodologies, in which emissions reductions are calculated based on observed energy use, rather than inferred fuel displacement. By linking electricity consumption data with established emissions factors, these approaches can provide a more transparent and verifiable basis for carbon accounting.

The implications for carbon market integrity are significant. Metered approaches reduce reliance on uncertain parameters such as fNRB, minimise the scope for overestimation, and align more closely

with broader trends in carbon markets toward data-driven, high-integrity credits. [33] In doing so, they position electric cooking as one of the few areas within household energy transitions where measurement can approach the granularity and reliability seen in industrial or energy-sector projects.

This has begun to be reflected in market perceptions. While prices in voluntary carbon markets remain variable, credits associated with higher levels of measurement and verification are increasingly differentiated. Indicative ranges suggest values of approximately USD 10–15 per tonne in voluntary markets for higher-quality credits, with potential for higher values—USD 20 per tonne and above—in compliance or results-based finance contexts where integrity requirements are more stringent. [31]

#### 4.3.3. From Project Revenue to Household Economics

A further distinguishing feature of some eCooking carbon models is the way in which carbon revenue is distributed along the value chain. In many traditional carbon projects, revenues accrue primarily to project developers or intermediaries, with limited direct impact on end-users beyond the initial provision of technology. [34]

In contrast, emerging models in electric cooking are beginning to channel carbon revenues directly to households, effectively reducing the cost of access to modern cooking services. [35] Pay-as-you-cook or energy service models, for example, can incorporate anticipated carbon revenues into their pricing structures, lowering the effective cost of cooking for users. In some cases, carbon income is used to subsidise appliance costs, reduce tariffs, or provide rebates linked to verified usage. [36]

This creates a second reinforcing dynamic at the household level:

adoption of eCooking → measured emissions reductions → carbon revenue → reduced effective cost of cooking → increased adoption and sustained use

This loop complements the utility-focused investment loop described in Section 5. While the first operates through system-level revenues and investments, the second operates through household-level affordability and incentives.

#### 4.3.4. Interactions Between the Two Loops

The interaction between these two reinforcing mechanisms is particularly important. Carbon finance can help address one of the key barriers identified in earlier sections: the upfront cost of appliances and the perceived risk of switching. By lowering entry costs or ongoing expenses, carbon revenues can accelerate adoption, thereby increasing electricity demand and strengthening the revenue base for utilities and mini-grids. [10]

Conversely, improvements in system reliability and service quality—driven by the electricity revenue loop—are essential for sustaining the usage patterns that underpin carbon credit generation. Without reliable electricity, households are unlikely to rely on electric cooking, limiting both emissions reductions and the associated carbon revenue. [8]

In this sense, the two loops are mutually reinforcing:

- the electricity revenue loop strengthens supply and system viability;
- the carbon finance loop strengthens demand and affordability.

Together, they create a more robust economic foundation for the transition to electric cooking than either mechanism could provide in isolation.

#### 4.3.5. Remaining Challenges and Uncertainties

Despite these advances, several challenges remain.

First, while metered methodologies improve integrity, they introduce new requirements around data collection, connectivity, and verification, which can increase transaction costs and complexity. Ensuring that these systems remain cost-effective at scale is an ongoing area of development. [31]

Second, although metered approaches reduce reliance on fNRB assumptions, they do not eliminate all uncertainties. Questions remain around baseline scenarios, including the extent to which

electric cooking displaces existing fuels in practice, particularly in contexts where fuel stacking persists. [19]

Third, carbon markets themselves remain volatile and evolving, with ongoing debates around standards, governance, and the future role of voluntary versus compliance mechanisms. Price signals, while improving for high-integrity credits, are not yet stable or universally predictable. [32]

Notwithstanding these challenges, the role of carbon finance in electric cooking transitions appears to be evolving from a supplementary funding source to a more structural component of the overall value proposition.

In earlier approaches to clean cooking, carbon finance was often treated as an additional revenue stream that could improve project viability. In the context of eCooking – particularly when combined with metered methodologies and consumer-facing models – it is increasingly becoming part of the core economic architecture, influencing pricing, adoption, and system dynamics.

This represents a further step in the progression from Two Birds through Mutual Support to the present analysis. Where earlier work focused on aligning cooking with energy systems, and subsequent work demonstrated mutual reinforcement, the emerging picture suggests a more complex and potentially powerful configuration:

*electric cooking transitions are supported by two interacting reinforcing loops – one driven by electricity revenues and system investment, and the other by carbon finance and household economics.*

Understanding how these loops operate, and how they can be strengthened and aligned, is central to assessing the future trajectory of modern energy cooking.

Example - Mission 300 Compacts: Positioning eCooking within National Energy Transitions

Mission 300 represents one of the most significant current efforts to accelerate electricity access, with a focus on enabling 300 million additional connections across Africa through country-led compacts. These compacts are designed to align policy reform, investment, and implementation around national electrification priorities.

Within many of these compacts, clean cooking is referenced, but often as a parallel objective – linked to health, environment, or gender outcomes – rather than as a core component of the electricity system itself. The analysis in this paper suggests that this positioning may understate the strategic role that electric cooking can play in achieving Mission 300's broader objectives.

From “add-on” to “core demand”. If cooking demand is treated as external to electricity planning, compacts risk:

- underestimating future electricity demand,
- undersizing infrastructure,
- and missing opportunities to improve system viability.

By contrast, integrating eCooking into compact design reframes cooking as:

- a major source of latent demand, already financed by households through expenditure on fuels;
- a driver of utilisation, increasing revenue per connection;
- and a mechanism for strengthening the financial sustainability of utilities and mini-grids.

Implications for compact design. In practical terms, this suggests several shifts in how compacts are structured:

- Demand forecasting: Incorporate cooking scenarios into load projections, rather than relying on low-consumption baselines.
- Investment planning: Recognise that higher demand from cooking can improve the case for grid extension, densification, and generation investment.
- Financing strategies: Integrate appliance finance (including on-bill and PAYGO models) into electrification programmes, rather than treating appliances as a separate market issue.
- Tariff and regulatory design: Ensure that tariff structures enable utilities to benefit from increased consumption while maintaining affordability.

Leveraging reinforcing loops. Mission 300 compacts are well positioned to activate the two reinforcing loops described in this paper:

- the electricity revenue loop, through increased demand and improved utility economics;
- the carbon finance loop, by linking electrification with high-integrity emissions reductions.

By explicitly incorporating eCooking into compact frameworks, countries can align these loops with national electrification strategies, potentially accelerating both access and utilisation.

A system-level opportunity. The implication is not simply that Mission 300 should “include cooking”, but that it should treat cooking as a central element of energy system design. Doing so would align electrification efforts with one of the largest sources of household energy demand, while also strengthening the financial and environmental case for investment.

In this sense, eCooking offers Mission 300 an opportunity to move beyond connection targets toward a model of high-utilisation, financially viable, and development-oriented energy systems.

#### 4.4. An Enabling Layer: System Integration, Finance, Control, and the Orchestration of Demand

A third, enabling layer of system integration (finance + control) underpins both loops. The preceding sections have described two reinforcing economic loops: one driven by electricity revenues and system investment, and a second enabled by carbon finance and household affordability. For these loops to operate effectively at scale, a further layer of system integration is required — one that connects finance, technology, and system operation more directly.

This section examines two emerging dimensions of that integration: embedded finance and appliance-level control, both of which are increasingly enabled by digitalisation and connected devices.

One of the most persistent barriers to electric cooking adoption, identified across both Two Birds and Mutual Support, is the upfront cost of appliances. While lifetime economics are often favourable — particularly where cooking displaces purchased fuels — the initial investment remains a significant hurdle for many households and institutions.

A range of financing mechanisms has emerged to address this challenge, including retail credit, microfinance, savings groups, and supplier-led instalment models. Increasingly, however, a more integrated approach is gaining traction: embedding appliance finance within the energy system itself.

In particular, on-bill financing offers a distinctive and potentially powerful mechanism. Under this model, the cost of the appliance is recovered through the electricity bill over time, aligning repayment with usage. For utilities and mini-grid operators, this approach has several advantages:

- it links appliance adoption directly to increased electricity consumption, reinforcing the revenue loop described in Section 5;
- it leverages existing billing relationships, reducing transaction costs and improving repayment rates;
- and it allows operators to capture part of the value created by increased demand, rather than relying solely on tariffs.

From the user perspective, on-bill financing reduces the need for upfront capital and aligns payments with realised benefits. Where combined with carbon revenue streams (Section 6), this can further reduce effective costs, making electric cooking accessible to a broader range of households.

Related models extend this logic through pay-as-you-go (PAYGO) systems, in which appliances are equipped with embedded controls that enable usage-based payment. These systems, widely used in solar home systems, are now being adapted to cooking appliances, allowing for flexible payment structures that match household cash flows.

Taken together, these approaches represent a shift from treating appliance acquisition as a separate financial decision to integrating it within the ongoing provision of energy services.

The same digital capabilities that enable PAYGO and on-bill financing also introduce a second, less explored dimension: the appliance as a point of interaction between the user and the energy system.

Modern electric cooking devices, particularly those equipped with sensors, connectivity, and control systems, are capable not only of measuring energy use (as discussed in Section 6), but also of

responding to external signals. This creates the potential for a form of distributed demand management embedded directly within appliances.

In practical terms, this could allow system operators to manage aggregate demand without disrupting user experience. For example, in a scenario where multiple appliances are operating simultaneously and approaching system limits, it may be possible to briefly modulate or stagger power delivery across devices—reducing peak load without noticeably affecting cooking outcomes. Given the thermal inertia of many cooking processes, short interruptions or adjustments in power can often be absorbed without impacting performance.

While still at an early stage, this approach suggests a model in which electric cooking appliances function not only as loads, but as active participants in system operation. This has several implications:

- it reduces the risk that cooking demand will overwhelm system capacity;
- it enables more efficient use of existing infrastructure;
- and it creates new opportunities for aligning demand with variable generation, particularly in solar-based systems.

In this sense, the appliance becomes part of a broader “smart demand layer”, complementing traditional supply-side control mechanisms.

The combination of embedded finance and appliance-level control points toward a more integrated model of system operation, in which financial and technical functions are increasingly intertwined.

For example, PAYGO-enabled appliances can simultaneously:

- manage payment flows,
- monitor usage for carbon accounting,
- and provide data that supports demand forecasting and system planning.

Similarly, on-bill financing models can be linked to usage patterns, allowing for more sophisticated approaches to risk management and customer segmentation. Users with consistent cooking-related consumption may represent lower credit risk, while also contributing more significantly to system revenues.

These integrations suggest that electric cooking is not simply adding demand to energy systems, but is contributing to the development of new system architectures, in which devices, users, and operators are more closely connected.

While these developments open new possibilities, they also introduce additional layers of complexity.

- Institutional capacity: Utilities and mini-grid operators may not yet have the systems or regulatory frameworks needed to implement on-bill financing or manage appliance-level control.
- User acceptance: While short-duration load management may be technically feasible, its acceptability depends on transparency and trust.
- Data governance: The collection and use of detailed usage data raise questions around privacy, ownership, and security.
- Interoperability: Ensuring that appliances, financing systems, and grid management tools can operate together requires standards and coordination.

These considerations highlight that the integration of finance and control is not purely a technical issue, but one that spans regulation, business models, and user engagement.

The developments described in this section point toward a broader shift in how energy systems are conceived. Rather than a one-directional flow from generation to consumption, systems are becoming increasingly interactive and orchestrated, with feedback loops operating across multiple layers.

Electric cooking sits at the centre of this shift. Through its combination of substantial demand, measurable usage, finance integration, and controllable load, it represents one of the most promising

entry points for developing more responsive and financially viable energy systems in low- and middle-income contexts.

If the earlier sections of this paper describe the emergence of reinforcing economic loops, this section suggests how those loops can be actively managed and strengthened through system design. The implication is that the future of modern energy cooking will depend not only on adoption and economics, but on the extent to which these emerging capabilities are harnessed to create coordinated, adaptive energy systems.

#### 4.4. Barriers, Tensions, and Limits to Scale

The preceding sections have set out a progressively stronger case for electric cooking as a system-strengthening force, supported by reinforcing loops in electricity revenue, carbon finance, and emerging forms of system integration. However, the transition from promising dynamics to widespread, sustained scale is neither automatic nor assured. A number of structural barriers and tensions continue to shape the pace and direction of adoption, and in some cases may limit the extent to which the identified loops can fully materialise.

This section does not revisit earlier arguments, but rather draws together the principal constraints that emerge when electric cooking moves from pilots and early adoption into system-wide deployment.

Despite improvements in lifetime affordability, the upfront cost of appliances remains one of the most persistent constraints. As discussed in Section 7, a range of financing mechanisms—on-bill financing, PAYGO, microcredit, and supplier-led models—are beginning to address this barrier. However, these mechanisms do not eliminate the underlying issue; rather, they redistribute risk across actors.

For households, the decision to adopt electric cooking involves uncertainty around:

- future electricity prices,
- reliability of supply,
- and actual savings relative to existing fuels.

For financiers—whether utilities, lenders, or suppliers—the risk lies in:

- repayment performance,
- appliance utilisation,
- and the durability of demand.

The transition therefore depends not only on the availability of finance, but on who is willing and able to carry these risks, and under what conditions. In many contexts, this remains unresolved, limiting the scale at which financing models can be deployed.

Electric cooking is uniquely sensitive to service reliability. Unlike lighting or phone charging, cooking is both time-bound and central to daily routines. Even relatively short or infrequent outages can undermine confidence in electricity as a primary cooking fuel, reinforcing continued reliance on biomass or LPG.

This creates a threshold effect: below a certain level of reliability, adoption remains partial and characterised by fuel stacking; above that threshold, more complete transitions become possible. The challenge is that reaching this threshold often requires investment ahead of demand, while the investment loop described in Section 5 depends on demand growth to justify such investment.

This tension—between the need for reliability to drive adoption, and the need for adoption to justify investment—can slow the transition, particularly in weaker systems.

Related to reliability is the widespread practice of fuel stacking, in which households and institutions use multiple fuels and technologies in parallel. Even where electric cooking is adopted, it is often used selectively—for specific dishes, times of day, or when electricity is available.

From a system perspective, this creates ambiguity:

- electricity demand increases, but not necessarily to the level required to fully activate the reinforcing loops;

- emissions reductions are partial, complicating carbon accounting;
- and planning becomes more difficult, as demand is context-dependent and variable.

Fuel stacking is not simply a transitional phase; in many contexts, it reflects rational decision-making under uncertainty. However, its persistence limits the extent to which electric cooking can displace existing fuels and fully realise its system-level benefits.

Tariff design plays a critical role in shaping both adoption and system outcomes. In some cases, tariff structures—particularly those with steeply rising block tariffs—can penalise higher levels of consumption, making electric cooking less attractive as usage increases. Conversely, tariffs that are too low may undermine the financial viability of utilities and mini-grid operators, weakening the investment loop.

This creates a delicate balance:

- tariffs must be affordable enough to encourage adoption and sustained use;
- but also cost-reflective enough to support system viability and expansion.

In practice, achieving this balance is complicated by political, regulatory, and institutional factors. Subsidies—particularly for competing fuels such as LPG—can further distort incentives, reducing the relative attractiveness of electric cooking even where it is economically efficient.

The transition to electric cooking sits at the intersection of multiple sectors: energy, health, environment, finance, and social protection. As a result, responsibility is often fragmented across institutions, each with its own mandates, priorities, and funding streams.

This fragmentation can lead to:

- misaligned policies (e.g., electrification strategies that do not consider cooking demand),
- duplicated or uncoordinated interventions,
- and gaps in critical areas such as appliance standards, financing mechanisms, or consumer engagement.

The system-level dynamics described in earlier sections—particularly the interaction of revenue and carbon loops—require a degree of coordination that is not yet typical in many contexts.

While the rise of metered methodologies and connected appliances is improving the evidence base, significant data gaps and uncertainties remain.

- Empirical data on long-term usage patterns, particularly at scale, is still limited;
- the performance of financing models across different contexts is not yet well established;
- and the interaction between cooking demand and system performance—especially in mini-grids—requires further validation.

These gaps do not invalidate the emerging insights, but they do suggest that current conclusions should be treated as provisional and context-dependent. Continued data collection and analysis will be essential to refine understanding and guide decision-making.

As discussed in Section 6, carbon finance represents a significant opportunity, but also introduces its own set of uncertainties.

- Ongoing debates around baseline assumptions, particularly in relation to biomass use and displacement;
- variability in carbon prices and demand across voluntary and compliance markets;
- and evolving standards around integrity and verification.

While metered approaches address some of these concerns, they also introduce new challenges related to cost and complexity. The long-term role of carbon finance in supporting electric cooking remains promising, but not yet fully settled.

Taken together, these barriers point toward a broader risk: that electric cooking may achieve partial but not transformative scale. In such a scenario:

- adoption increases, but remains uneven;
- system benefits are realised in some contexts, but not others;
- and the reinforcing loops identified in this paper operate only weakly or intermittently.

This outcome would represent progress relative to past approaches, but would fall short of the more systemic transformation implied by the “Two Birds” framing.

Importantly, the barriers outlined here should not be understood solely as obstacles, but as design challenges. Each reflects a point at which system elements—finance, technology, policy, behaviour—must be better aligned.

- Upfront cost becomes a question of financing design and risk allocation;
- reliability becomes a question of investment sequencing and system planning;
- fuel stacking becomes a question of user experience and service quality;
- tariffs become a question of incentive alignment;
- and institutional fragmentation becomes a question of coordination and governance.

Addressing these challenges is not simply a matter of scaling existing approaches, but of refining the architecture of the transition itself.

In this light, the limits to scale are not fixed boundaries, but evolving frontiers. Understanding where and why the system stalls is essential to determining how the reinforcing dynamics described in earlier sections can be strengthened and extended.

Generative artificial intelligence (GenAI) has been used to generate graphics, and for superficial text editing.

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## 5. Conclusions

The analysis presented in this paper suggests that electric cooking is no longer best understood as a niche intervention within the clean cooking sector, but as a system-level opportunity that sits at the intersection of energy planning, infrastructure investment, and household welfare. The progression from Two Birds through Mutual Support to the present framing points toward a clear implication: realising this opportunity depends less on proving viability, and more on aligning policy, planning, and market structures to enable scale.

This section sets out the key areas in which policy and system design will determine whether the reinforcing dynamics described in earlier sections can be translated into sustained, large-scale transitions.

### 5.1. Integrating Cooking into Energy Planning

A first and foundational step is the explicit inclusion of cooking demand within energy planning frameworks. As discussed in Section 4, current models often underestimate demand by excluding or minimising cooking loads. This leads to conservative system design and underinvestment.

Policy frameworks should therefore:

- require the inclusion of cooking scenarios in national electrification plans and least-cost models;
- incorporate cooking demand into load forecasting and infrastructure planning;
- and recognise cooking as a core component of energy access, rather than an external objective.

This shift moves planning from a focus on connections toward a focus on service provision, aligning system design with actual energy needs.

### 5.2. Designing Tariffs for Depth of Use

Tariff structures play a central role in shaping both adoption and system viability. If electric cooking is to function as a revenue engine, tariffs must be designed to encourage sustained and meaningful levels of consumption, while maintaining affordability.

This implies a move toward:

- tariff structures that avoid penalising moderate increases in consumption associated with cooking;

- mechanisms that allow utilities and mini-grid operators to capture the value of increased demand;
  - and, where appropriate, targeted support to ensure affordability for lower-income households.
- The objective is not simply low tariffs, but well-aligned tariffs that support both user adoption and system sustainability.

### 5.3. Enabling Appliance Access Through Integrated Finance

Addressing the upfront cost barrier requires policy support for integrated financing models, particularly those that align with energy system dynamics.

This includes:

- enabling and regulating on-bill financing mechanisms, allowing utilities and mini-grid operators to recover appliance costs through electricity bills;
- supporting PAYGO and other usage-linked financing models, including through standards and consumer protection frameworks;
- and leveraging public or concessional finance to de-risk early-stage markets.

Importantly, these approaches should be viewed not as standalone financial interventions, but as part of a broader strategy to convert energy demand into sustained system revenue.

### 5.4. Leveraging Carbon Finance with Integrity

Carbon finance has the potential to play a significant role in accelerating electric cooking adoption, but its effectiveness depends on both integrity and integration.

Policy and programme design should therefore:

- support the development and adoption of metered and measured methodologies, enhancing transparency and credibility;
- align carbon finance with consumer-facing models, ensuring that benefits are reflected in reduced costs or improved access;
- and engage with emerging compliance and results-based finance mechanisms to secure higher-value, high-integrity funding streams.

At the same time, policymakers must remain attentive to the evolving nature of carbon markets, ensuring that reliance on carbon finance does not introduce undue risk.

### 5.5. Supporting System Design for Cooking Demand

The integration of cooking into energy systems requires attention not only to demand, but to system architecture.

Policies should encourage:

- system design that anticipates cooking loads, including generation sizing and storage integration;
- the adoption of efficient appliances, through standards, labelling, and market support;
- and the development of tools and guidelines for planning and operating systems with cooking demand in mind.

In mini-grid contexts, this may include revisiting design norms to reflect higher and more diversified demand profiles.

### 5.6. Enabling Digitalisation and Smart Demand

The emergence of connected appliances and embedded control systems creates new opportunities for demand-side management and system optimisation. However, realising these opportunities requires supportive policy environments.

Key actions include:

- establishing frameworks for data governance, including privacy, ownership, and security;
- supporting interoperability standards to ensure that appliances and system operators can interact effectively;
- and enabling the use of appliance-level control as part of broader demand management strategies.

These measures can help ensure that electric cooking contributes not only to increased demand, but to more flexible and responsive energy systems.

#### 5.7. Coordinating Across Sectors and Institutions

The transition to electric cooking cuts across multiple policy domains. Effective implementation therefore depends on coordination across sectors, including energy, health, environment, and finance.

This may involve:

- establishing cross-sectoral platforms or task forces to align strategies and interventions;
- integrating cooking into broader initiatives, such as electrification programmes, climate strategies, and social protection schemes;
- and ensuring that institutional mandates and incentives are aligned with system-level objectives.

Without such coordination, there is a risk that interventions remain fragmented, limiting their overall impact.

#### 5.8. From Pilots to Programmes

A final implication concerns the shift from pilot projects to programmatic approaches. Much of the evidence base for electric cooking has been built through pilots and targeted interventions. While these have been essential in demonstrating feasibility, scaling requires a transition to systematic, policy-supported programmes.

This involves:

- embedding electric cooking within national strategies and investment plans;
- mobilising public and private finance at scale;
- and establishing the institutional and regulatory frameworks needed to support sustained implementation.

#### 5.9. A Shift in Perspective

Taken together, these implications point toward a broader shift in how electric cooking is understood within policy frameworks. Rather than being treated as a discrete sectoral issue, it should be seen as a lever for strengthening energy systems, improving household welfare, and advancing climate objectives simultaneously.

This perspective echoes the original insight of Two Birds, but extends it. The opportunity is no longer simply to achieve multiple objectives through a single intervention, but to align multiple systems—energy, finance, and carbon—around a common transition pathway.

Realising this opportunity will require deliberate policy choices, institutional alignment, and sustained commitment. The evidence presented in this paper suggests that the foundations are now in place; the challenge is to build upon them at scale..

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## Appendix A

### *Appendix A.1 Limitations and Tensions*

This paper adopts a narrative, literature-informed synthesis approach, drawing on a combination of peer-reviewed studies, programme evidence, and emerging grey literature. As such, several limitations should be acknowledged in interpreting the findings and the conceptual framework proposed.

**Evidence base and generalizability.** First, the empirical evidence underpinning electric cooking transitions remains heterogeneous and context-specific. Much of the available data is derived from pilot programmes, targeted interventions, and relatively small samples—particularly in mini-grid and weak-grid contexts. While these studies provide valuable insights into technical feasibility, user behaviour, and system interactions, they do not yet constitute a statistically representative or globally generalisable evidence base.

As a result, the system dynamics described in this paper—particularly the reinforcing electricity revenue and carbon finance loops—should be understood as indicative patterns rather than universally observed outcomes. Their applicability will vary depending on local conditions, including electricity tariffs, reliability, appliance availability, cultural practices, and institutional capacity.

**Partial transitions and fuel stacking.** A second limitation relates to the persistence of fuel stacking. The analysis in this paper is, in part, structured around the displacement of biomass, charcoal, or LPG by electricity. However, extensive evidence from clean cooking transitions indicates that households and institutions rarely shift entirely from one fuel to another. Instead, multiple fuels are used in parallel, with choices shaped by cost, availability, reliability, and cooking practices.

This creates a tension between appliance adoption and actual energy displacement. Increased electricity consumption associated with cooking does not necessarily translate into proportional reductions in traditional fuel use, particularly in the early stages of transition. For carbon accounting, this complicates baseline assumptions and the estimation of emissions reductions. For system planning, it introduces uncertainty into demand projections and load profiles.

**Reliability and sequencing constraints.** The analysis highlights the importance of electricity reliability as a precondition for sustained electric cooking. However, this introduces a structural tension in system development. On the one hand, improved reliability is necessary to drive adoption of electric cooking. On the other hand, the investment required to improve reliability is often justified by expectations of increased demand and revenue.

This creates a sequencing challenge: systems may need to invest ahead of demand to reach a reliability threshold that enables cooking adoption, while the reinforcing investment loop described in this paper depends on demand growth to unlock such investment. The extent to which this tension can be resolved will vary across contexts and institutional arrangements.

**Tariff design and competing incentives.** Tariff structures represent another area of tension. Electric cooking requires moderate to high levels of electricity consumption, which may be discouraged by rising block tariffs or high marginal prices. At the same time, tariffs that are set too

low—whether for political or social reasons—may undermine the financial viability of utilities and mini-grid operators.

In addition, the relative competitiveness of electric cooking is influenced by subsidies or pricing structures applied to alternative fuels, particularly LPG. In contexts where LPG is heavily subsidised, electric cooking may struggle to compete on short-term cost, even where it is efficient or system-beneficial. This highlights the importance of considering cooking transitions within a broader energy pricing and subsidy landscape, rather than in isolation.

**Carbon finance uncertainty.** While the paper identifies carbon finance as a potentially important reinforcing mechanism, this remains an evolving and uncertain domain. Recent scrutiny of cookstove carbon credits has highlighted concerns around baseline assumptions, over-crediting, and the integrity of methodologies—particularly those relying on estimates of the fraction of non-renewable biomass (fNRB).

Metered approaches associated with electric cooking offer a pathway toward improved accuracy and transparency, but they introduce new requirements related to data collection, verification, and cost. Moreover, carbon markets themselves are subject to price volatility, evolving standards, and regulatory uncertainty, including the development of Article 6 mechanisms under the Paris Agreement.

As such, carbon finance should be viewed as a potentially valuable but uncertain component of the economic architecture of electric cooking transitions, rather than a guaranteed or stable revenue stream.

**Emerging system integration and data constraints.** The paper also explores emerging models of system integration, including on-bill financing, PAYGO-enabled appliances, and appliance-level demand control. While these developments are promising, they remain at an early stage of deployment, with limited large-scale evidence on performance, user acceptance, and institutional feasibility.

In particular, the integration of digital monitoring, payment systems, and demand management raises questions around data governance, privacy, interoperability, and regulatory oversight. The extent to which these systems can be implemented at scale—especially in low-resource or fragmented institutional contexts—remains uncertain.

**Conceptual synthesis and attribution.** Finally, the two reinforcing loops presented in this paper—the electricity revenue loop and the carbon finance loop—represent a conceptual synthesis of multiple strands of evidence, rather than directly observed, fully quantified system dynamics. While each component of the loops is supported by empirical or theoretical literature, the interaction between them is inferred rather than empirically demonstrated at scale.

This approach is appropriate for a hypothesis-generating, system-oriented analysis, but it also implies that the proposed framework should be treated as provisional and subject to further empirical validation.

These limitations do not undermine the central argument of the paper, but they do suggest that the transition to electric cooking should be understood as an evolving system transformation, in which outcomes depend on the alignment of multiple technical, economic, and institutional factors.

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