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The Paradox of Compensatory Policies: A Systems Analysis of Iran's Electricity Deficit Focusing on Feedback Loops and the Water-Energy-Food Nexus

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A B S T R A C T

The electricity deficit in Iran, predominantly managed through interventionist measures such as demand-side management and planned outages, has become a structural challenge for the national economy. Adopting a systems analysis approach, this study investigates how these short-term interventions fail to address the root causes and, instead, exacerbate the crisis in the long run by creating and reinforcing vicious feedback loops. Using a qualitative system dynamics modelling methodology validated by an expert panel, this research identifies and analyzes several detrimental feedback mechanisms. Findings indicate that power outages in the industrial sector lead to production stagnation, diminishing the investment capacity for energy efficiency and eroding social capital. In the agricultural sector, these imbalances threaten food security and inadvertently reignite urban electricity demand by intensifying the "Urban Heat Island" effect. Furthermore, the Water-Energy (WE) Nexus analysis reveals how sectoral policies—such as promoting evaporative coolers in water-scarce regions—can aggravate the energy crisis when viewed through an integrated lens. The results suggest that current strategies exemplify the "Fixes that Fail" archetype, wherein short-term solutions undermine the system's fundamental capacity to solve the problem. Ultimately, this paper emphasizes the need to shift from reactive crisis management to systemic, integrated planning focused on the Water-Energy-Food Nexus to achieve long-term sustainability.

Keywords

Electricity Deficit, System Dynamics, Fixes that Fail Archetype, Feedback Loops, Water-Energy-Food Nexus, Energy Policy.

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1. Introduction

Iran's electricity deficit faces a managerial paradox: the very solutions designed to address the crisis in the short term may, in the long term, become drivers of its exacerbation. To prevent grid collapse, policymakers have increasingly resorted to short-term compensatory measures, such as planned power outages across industrial, agricultural, and residential sectors. While these measures offer a temporary reprieve, they reflect a deeper, fundamental challenge in the country's energy management structure. Since these measures merely delay the problem rather than address its roots, the system not only faces recurrent shortages in the future but also confronts unintended consequences arising from mechanisms triggered by the outages themselves.

This situation confirms that the electricity deficit is not merely a technical shortage but the outcome of complex interactions among numerous factors within a dynamic system characterized by self-reinforcing feedback loops (Taiebnia and Barkhordari, 2022, Solaymani, 2021). Consequently, the core challenge is not limited to electricity generation shortfalls but extends to how management policies might inadvertently trap the system in an unsustainable trajectory of recurring crises.

To elucidate this paradox, this research utilizes systems analysis as a robust theoretical framework enabling the comprehension of the problem's underlying structure and the identification of a leverage point (Gavrilova and Salov, 2019) .Specifically, it focuses on the "Fixes that Fail" archetype. We argue that the policy of "load management" via planned / unscheduled power outages creates a precise instance of this archetype. As an immediate solution, it diverts attention from fundamental remedies (e.g., infrastructure investment, price reform, and consumption optimization) and, through unintended consequences, erodes the system's capacity to resolve the issue over time.

Therefore, the contribution of this research is threefold: First, it applies the "Fixes that Fail" archetype to model compensatory policies as endogenous, crisis-generating variables. Second, it focuses on socio-economic feedback loops (such as reduced industrial productivity and social capital erosion) often absent in prior systemic models. Third, it analyses one of the most destructive loops through the Water-Energy-Food Nexus framework, demonstrating how agricultural outages threaten food security and recursively pressure energy resources. Finally, by mapping these complex dynamics, this paper underscores the urgent need to transition from reactive crisis management to systemic, integrated policymaking for long-term sustainability.

2. Theoretical background and literature review

2.1. Electricity deficit

In power systems, consumption and generation must be balanced instantaneously to maintain frequency stability (Eicke et al., 2021). An electricity deficit in a system (be it a country, region, or economic sector) occurs when energy demand exceeds supply (generation and/or imports) for various reasons, leading to operational disruptions, restricted access, unintended economic and social costs, and threats to energy security. For instance, in South Africa, structural issues at Eskom, insufficient generation capacity, and high reliance on coal have caused shortages and planned outages (Viljoen and Dube, 2023, Ateba and Prinsloo, 2018). In Ghana, reduced rainfall affecting dams like Akosombo, coupled with gas import issues, has intensified deficits (Baafra Abeberese, 2020). Ecuador faces shortages due to drought and insufficient investment (Zhiña et al., 2025), while Pakistan struggles with rising demand against dwindling resources (Valasai et al., 2017). Jordan faces disruptions due to reliance on imported gas (Saadeh et al., 2023) and Yemen and Egypt, despite hydrocarbon exports, face domestic supply challenges (El-Katiri, 2014).

In Iran, the gap between electricity generation and consumption has grown significantly, transforming from a constraint in the late 2000s to a serious challenge for both the electricity industry and macro-management in recent years. Figure 1 illustrates the comparison between peak electricity demand and peak electricity consumption (MW) over the last three decades.

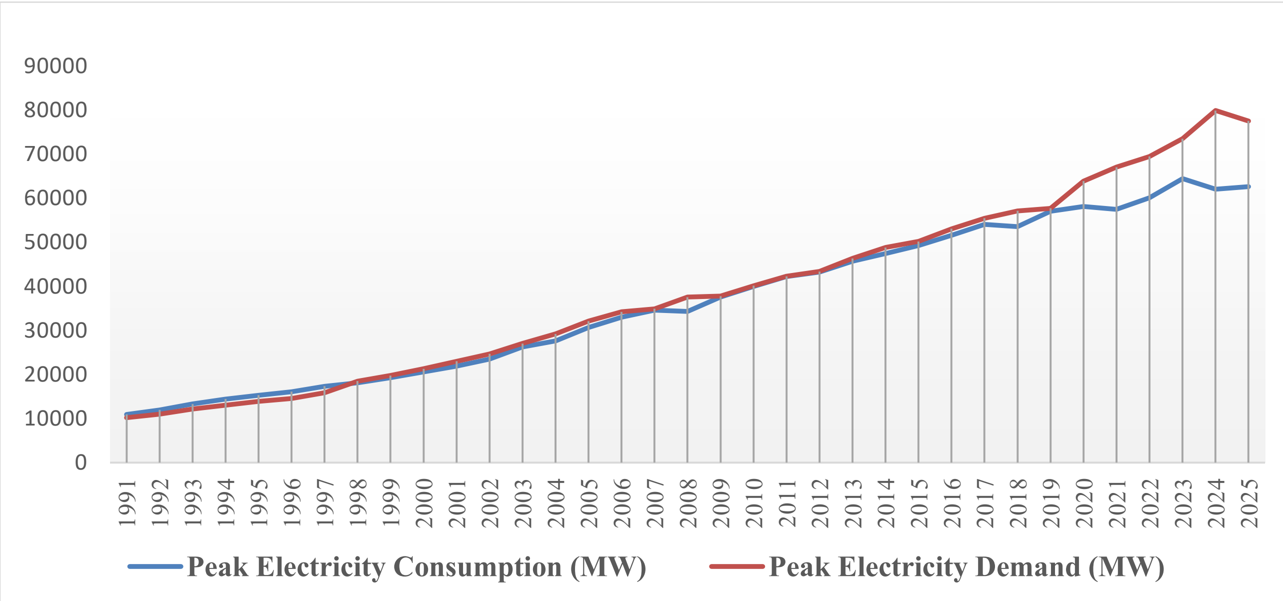

Figure 1. Comparison of peak electricity demand and peak electricity consumption (MW)

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2.2. Consequences of electricity deficit

Electricity serves as a critical commodity in modern society (Salashenko et al., 2023), upon which contemporary communities rely heavily to secure essential needs such as food and habitable living environments (Hachem-Vermette and Yadav, 2023). Furthermore, this form of energy underpins a diverse range of activities, including telecommunications and transportation systems (Kent et al., 2023). Power outages can inflict significant disruption upon daily operations and services, spanning basic necessities, transportation networks, banking and financial systems, healthcare services, and communications (Abi Ghanem, 2018, Hasselqvist et al., 2022). Moreover, electricity interruptions may lead to various medical complications, the exacerbation of existing health conditions, disruption of livelihoods, and psychological health detriments (Ezzati et al., 2025). The following section details specific consequences of electricity deficits for citizens:

During power outages, the fulfilment of certain human functions and needs may become severely constrained. For instance, communication channels can be severely disrupted (Wethal, 2023), including critical lines to police and fire services, thereby jeopardizing public safety (Zimmerman and Restrepo, 2009). Additionally, power cuts restrict accessibility to high-rise residential buildings, particularly disadvantaging vulnerable individuals (Meireles et al., 2022).

Basic thermal comfort, achievable through adequate heating and cooling, may become unattainable, especially during extreme weather events (such as heatwaves or severe cold spells) (Erba and Barbieri, 2022). This deprivation can significantly impact resident well-being and, in certain instances, necessitate evacuations of buildings. The domestic hot water supply may also be compromised if dependent on electric heating. Furthermore, outages affect food preservation in refrigerators and disrupt water supply and sanitization systems, potentially leading to the outbreak of gastrointestinal diseases (Liddiard et al., 2017, Gehringer et al., 2018).

For vulnerable individuals reliant on electricity-dependent medical devices for survival (such as cardiac or respiratory support equipment), even short-term outages can result in life-threatening situations (Mango et al., 2021, Flores et al., 2023). Consistent access to electricity is essential for the elderly and children, those dependent on electro-medical equipment (e.g., oxygen concentrators), and individuals requiring assistance for daily living activities (Molinari et al., 2017), those with thermal sensitivity, and patients with underlying conditions (respiratory, cardiovascular, and renal) that may be exacerbated by triggering events associated with power loss (Klinger et al., 2014, Bean et al., 2020).

Additionally, medical facilities and pharmaceutical supply chains may remain vulnerable to operational disruptions, even with emergency backup power generation. It is also noted that reliance on gasoline generators as a backup poses risks of carbon monoxide (CO) poisoning (Casey et al., 2020).

Finally, power outages can precipitate anxiety, stress, and diminished individual well-being by fostering uncertainty regarding access to climate control (heating/cooling), food, water, and healthcare services (Moreno and Shaw, 2019, Amadi, 2015).

2.3. The "Fixes that fail" archetype

A pivotal and recurring structure within the analysis of complex systems is the "Fixes that Fail" archetype. This archetype delineates a dynamic mechanism wherein an intervention intended to resolve a specific problem generates unintended consequences following a temporal delay, which not only leaves the initial problem unresolved but also exacerbates it **(**Biella et al., 2024**).**

The structural configuration of this archetype comprises two feedback loops:

- The Balancing Loop (B): This loop represents the symptomatic, immediate intervention. Upon identifying a problem symptom, an expedient measure is implemented that appears to alleviate the issue in the short term.
- The Reinforcing Loop ®: This loop illustrates the unintended, long-term consequences of the immediate fix. The implementation of the symptomatic solution, after a significant time delay, impacts a secondary variable. This variable, in turn, amplifies the original problem symptom, rendering the situation more critical than it was initially.

In this study, the policy of load management via power outages across industrial, agricultural, and residential sectors serves as a quintessential example of the "Fixes that Fail" archetype. As an immediate remedy, this policy effectively curbs electricity demand in the short term. However, its long-term consequences manifest as increased financial strain on producers due to production losses. This financial pressure diminishes their capacity to invest in energy-efficient equipment and the optimization of production processes. The long-term implication of this reduced productivity is the persistence of high energy consumption demand in these sectors, which will consequently deepen the electricity deficit crisis in the future.

2.4. The water-energy-food (WEF) nexus

The Water-Energy-Food Nexus framework serves as a systemic approach for analyzing the complex interdependencies and reciprocal relationships among water resources, energy systems, and food production (Li et al., 2025). This framework is predicated on the principle that decision-making within a single sector (e.g., energy) inevitably generates cascading effects across allied sectors (i.e., water and food). In the specific context of electricity deficits, power outages targeted at the agricultural sector restrict access to irrigation water, thereby reducing cultivated acreage and, consequently, threatening food security. This contraction in domestic agricultural output compels the government to increase food imports, thereby imposing fiscal strain on the public budget; this, in turn, diminishes the state's fiscal capacity for essential capital investment in energy infrastructure. Furthermore, inefficient energy subsidies in Iran have historically incentivized excessive groundwater extraction for agricultural purposes, contributing to severe environmental impacts such as land subsidence. For instance, in the Central Iranian Plateau, the over-exploitation of groundwater aquifers for traditional farming practices has not only depleted water reserves but also jeopardized soil stability. Ultimately, the WEF Nexus framework facilitates the identification of leverage points for integrated policymaking—such as promoting low-water-intensive cropping patterns, adopting modern irrigation technologies, and deploying renewable energy sources—to mitigate the compounded pressure on water and energy resources.

2.5. Literature review

To accurately delineate the position of this research, the extant literature is examined across three distinct layers: first, the global application of systems approaches in analyzing complex crises to demonstrate the robustness of the theoretical framework; second, an analysis of the dominant stream of studies regarding Iran's energy crisis, which predominantly adopt a linear and sectoral approach; and third, a review of emerging systemic studies in Iran to precisely identify the gap this research aims to bridge.

2.5.1. Global evidence on failed policies

The complexity of modern crises, ranging from energy and the environment to food security, has challenged linear cause-and-effect paradigms. Globally, systems thinking, particularly its archetypes, has become a powerful tool for understanding why well-intentioned solutions often fail. Among these, the "Fixes that Fail" archetype holds a prominent position. This archetype elucidates how a quick, symptomatic solution designed to address a problem symptom eventually exacerbates the situation in the long run through unintended consequences and the activation of vicious feedback loops.

For instance, Laimon et al. (2022), in their analysis of the Australian energy sector, demonstrated that short-term policies aimed at increasing fossil fuel supply exemplify this archetype, leading to long-term energy dependence and insecurity (Laimon et al., 2022). Similarly, Awah et al. (2024), in analyzing flood management in Cameroon, and Benninger et al. (2021), in examining food inequity in the United States, arrived at convergent conclusions: reactive and piecemeal measures (such as river dredging or the demolition of illegal structures), while providing temporary relief, ignore root causes and entrap the system in a cycle of recurring crises (Awah et al., 2024, Benninger et al., 2021). These studies emphasize that escaping these vicious cycles requires identifying and breaking unintended feedback loops and focusing on fundamental solutions.

2.5.2. Energy crisis in Iran: from linear solutions to systemic insights

The literature pertaining to Iran's electricity imbalance can be categorized into two primary streams:

Stream 1: The Dominant Technical-Economic Paradigm. A substantial portion of existing studies analyzes the crisis through a linear lens, seeking solutions in two main domains: technical (increasing generation capacity, grid optimization) and economic (price reform and subsidy rationalization). For instance, Solaymani (2021), while providing a comprehensive review of energy policies, focuses on challenges such as reliance on fossil fuels and the inefficiency of subsidies, advocating for a transition to renewables (Solaymani, 2021). Taiebnia and Barkhordari (2022) demonstrate how political and social pressures render price reforms ineffective (Taiebnia and Barkhordari, 2022). The shared limitation of this category of studies is the oversight of complex feedback structures that often cause these seemingly rational solutions to fail in practice or yield suboptimal results.

Stream 2: The Emergence of Systemic Approaches. In recent years, a new wave of research has emerged utilizing System Dynamics modeling to gain a deeper understanding of this crisis. Dehghan et al. (2021), by modeling the feedback loops between price, consumption, and investment, highlighted the necessity of long-term pricing policies (Dehghan et al., 2021). Doroodi et al. (2024), employing an integrated system dynamics model, demonstrated that short-term electricity trade regulation policies—whether in the form of exports or imports—can lead to long-term dependency and structural instability by undermining investment and pressuring generation capacity (Doroodi et al., 2024). Other studies have similarly applied this approach to analyze the impacts of sanctions (Balali et al., 2025), the potential of residential photovoltaics (Pazuki et al., 2025), and long-term supply and demand scenarios (Asadi et al.,

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2023, Faryadras et al., 2025). These studies represent significant strides in moving beyond linear analyses.

2.5.3. Identifying the Gap: Beyond Technical-Economic Models

Despite the advancements achieved in the second stream, a significant analytical gap persists. Existing systemic studies in Iran have predominantly focused on modeling technical-economic variables (supply, demand, price, carbon emissions, investment). However, the electricity deficit is not merely a techno-economic crisis; it is fundamentally a managerial crisis, in which short-term compensatory policy interventions (such as planned outages) have evolved into dynamic, crisis-generating variables.

The existing literature has failed to address the following critical questions: What are the unintended consequences and feedback loops stemming from the load management policies? How do power outages in the industrial sector erode the sector's long-term capacity to invest in energy efficiency? How do power outages in the agricultural sector, through the Water-Energy-Food Nexus, threaten food security and subsequently exert renewed pressure on energy resources? And most crucially, how do these policies impact social variables, such as social capital and public trust, thereby reducing the willingness to cooperate in resolving the crisis?

This research is designed to bridge this specific gap. As summarized in Table 1, the innovation of this study lies in explicitly placing the "paradox of compensatory policies" at the center of the model. By relying on the "Fixes that Fail" archetype, it models and analyzes the socio-economic and environmental feedback loops (within the Water-Energy-Food Nexus) that originate from these policies, thereby offering a deeper understanding of the reasons behind the chronic nature of this crisis.

Table 1. Conceptual framework and literature positioning.

Key concept	Main references	Literature gap concerning iran's electricity crisis	Research contribution to bridging the gap
"Fixes that Fail" Archetype	(Laimon et al., 2022) ; (Awah et al., 2024); (Benninger et al., 2021)	While this archetype is widely applied in global crisis analysis, short-term compensatory policy interventions in Iran's electricity crisis (such as planned outages) have rarely been explicitly modeled and analyzed within this framework.	This study explicitly models load management policies in Iran as a classic instance of the "Fixes that Fail" archetype, unveiling their unintended long-term consequences.
Water-Energy-Food Nexus	(Li et al., 2025); (Barati et al., 2023)	In Iranian studies, the WEF nexus has been primarily examined from the perspective of the water crisis. The direct impacts of electricity management policies (e.g., agricultural power outages) on nexus dynamics, as well as the feedback loops that subsequently re-intensify the electricity crisis have received limited attention.	This research demonstrates how agricultural power outages activate a vicious feedback loop through the WEF Nexus, ultimately threatening food security, increasing pressure on resources, and exacerbating the energy deficit.

Key concept	Main references	Literature gap concerning iran's electricity crisis	Research contribution to bridging the gap
System Dynamics Modeling in Iran's Energy Sector	(Dehghan et al., 2021); (Doroodi et al., 2024) ؛ (Asadi et al., 2023) (Balali et al., 2025) (Pazuki et al., 2025, (Faryadras et al., 2025)	Existing literature predominantly focuses on techno-economic variables (price, supply, demand, investment, and CO2 emissions). Socio-economic feedback loops resulting from compensatory policies (such as reduced industrial productivity and social capital erosion) are largely absent in these models.	By employing qualitative modeling, this study integrates socio-economic feedback loops into existing systemic analyses, illustrating how these loops can render techno-economic solutions ineffective in the long run.

3. Methodology

Anchored in the pragmatist paradigm, this study employs a qualitative mixed-methods approach. The primary analytical tool utilized is Qualitative System Modeling based on Causal Loop Diagrams (CLDs). This approach facilitates the identification and visualization of the complex feedback structure governing Iran's electricity imbalance and the unintended consequences of compensatory policies. The process of model construction and validation was conducted in three main phases as follows:

3.1. Problem definition and system boundary determination

In the initial phase, the system's analytical boundaries were delineated. The studied system encompasses electricity supply and demand at the national level. On the demand side, it focuses on three key sectors—residential, industrial, and agricultural—as the system's internal boundaries. The analytical time horizon was selected as long-term, spanning a two-decade period, to enable the observation of dynamic behaviors and the inherent time delays within feedback loops. The ultimate objective of this phase was to transcend linear, short-term analyses and focus instead on identifying the underlying "behavior-generating structure" of the crisis.

3.2. Drafting the preliminary model

In the second phase, the initial draft of the Causal Loop Diagram was developed utilizing two complementary techniques:

A) Systematic Literature Review: A structured search was conducted in reputable domestic and international scientific databases using keywords such as "Iran's electricity crisis," "energy imbalance," "energy policy," and "energy subsidies." Following the application of inclusion and exclusion criteria (focusing on systems analysis, specific time frames, and direct relevance to policy-making), 42 articles were selected for in-depth analysis. Key variables and cause-and-effect relationships extracted from these sources formed the initial framework of the model.

B) Analysis of Upstream Documents: Official reports from the Ministry of Energy, the Parliament Research Center, Cabinet resolutions regarding electricity consumption management, and annual reports of Tavanir Company were examined using content analysis. This analysis aided in precisely identifying official policies and uncovering the mental models that govern policymakers' decisions.

Ultimately, the outputs from these two sections were synthesized in Vensim into an initial Causal Loop Diagram that visualizes the research hypotheses regarding defective feedback loops.

3.3. Model validation via expert panel

In the third and final phase, to enhance the validity and robustness of the qualitative model, an expert panel method utilizing a modified Delphi approach was employed. A panel comprising 22 specialists was selected through purposive sampling. The composition of this panel was designed to include representatives from key institutions involved in the issue (including the Ministry of Energy, Tavanir Company, Regional Water Company, Electricity Distribution Companies, Agriculture Organization, and the Chamber of Commerce, Industries, mines and Agriculture), as well as prominent academic professors in the fields of energy, water, and economics.

The model validation process was conducted across three 2-hour focus group sessions, employing structured brainstorming techniques. In each session, the draft model was presented to the experts, who were asked to critique, refine, and complete the variables, the polarity of causal relationships (positive/negative), and the identified feedback loops. This iterative process continued until the third session, where no new key variables or feedback loops were added to the model, and the panel reached "theoretical saturation" and general consensus regarding the final structure of the model. Table 2 illustrates the demographic characteristics of the expert panel.

Table 2. Demographic characteristics of the expert panel

Expert ID	Organizational position / Affiliation	Education	Field of study / Area of expertise	Work experience (Years)
P1–3	Deputies / Managers of the Electricity Sector	Ph.D. / M.Sc.	Energy / Resource Management	28–30
P4–5	Deputies of the Water Sector	Ph.D.	Water Resources Management	27 and 29
P6–7	Agricultural Research Center	Ph.D.	Sustainable Agriculture and Food Security	23 and 28
P8	Head of Agriculture Dept., Chamber of Commerce	Ph.D.	Agriculture	22

Expert ID	Organizational position / Affiliation	Education	Field of study / Area of expertise	Work experience (Years)
P9	University Professor (Energy Domain)	Ph.D.	System Dynamics and Modeling	> 30
P10–11	University Researcher (Water Domain)	Ph.D.	Water Resources and Climate Change	19 and 26
P12	Economic Analyst	M.Sc.	Energy Policy	20
P13–15	University Professors and Mid-level Managers	Ph.D. / M.Sc.	Interdisciplinary (Economics, Energy, Agriculture)	15–30
P16–20	Government Experts	B.Sc. / M.Sc.	Resource Management and Policymaking	> 20
P21–22	Academic Researchers	Ph.D.	Systems Analysis and WEF Nexus	> 15

4. Analysis of findings

The systemic analysis of the electricity deficit crisis in Iran, as illustrated in the Causal Loop Diagram (Figure 2), reveals that conventional management policies often fail to solve the problem. Instead, by establishing and reinforcing vicious cycles, these interventions tend to exacerbate the crisis over the long term.

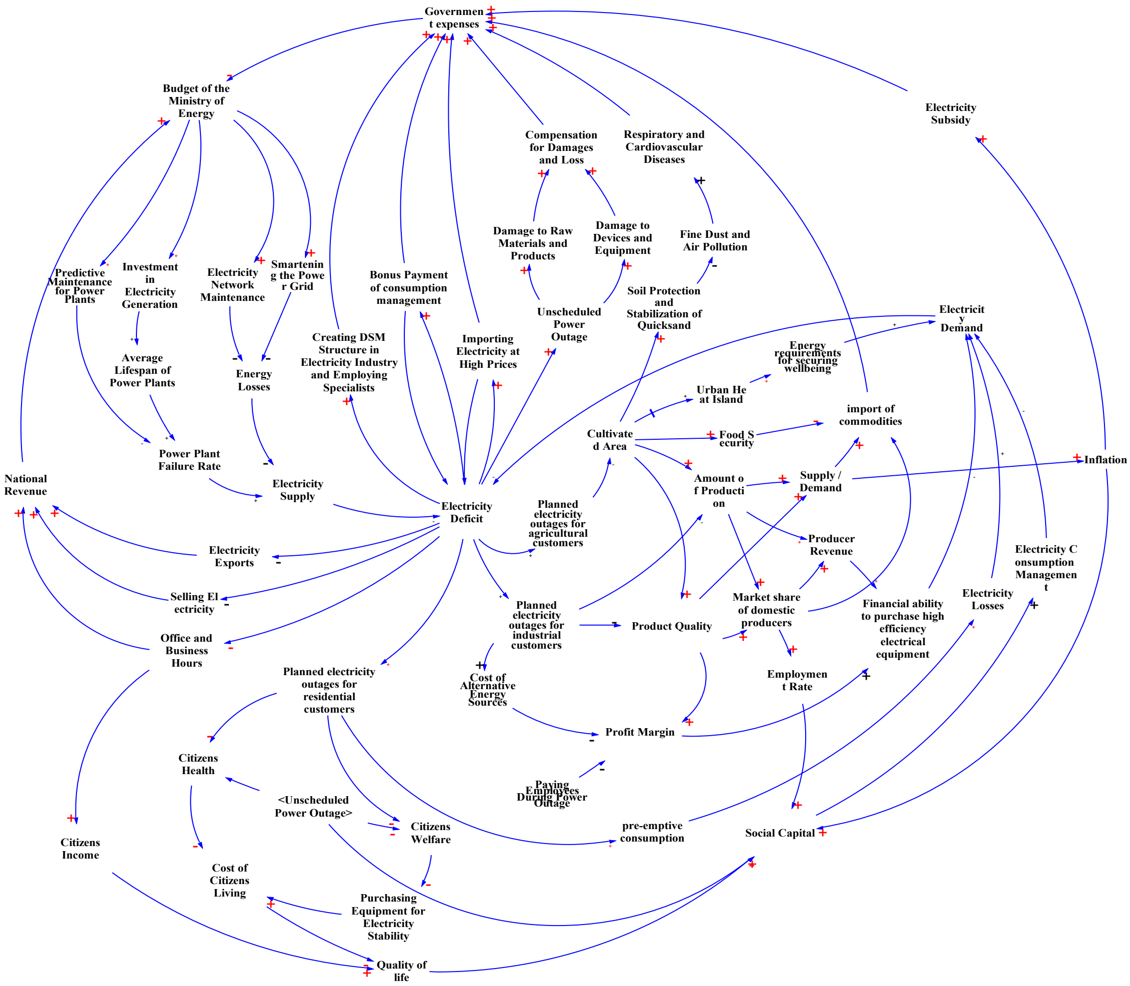

Figure 2. Causal loop diagram of electricity deficit and the consequences of compensatory policies

In the following sections, several key negative feedback loops across various economic and social sectors are analyzed.

4.1. The Pre-emptive consumption loop

This pattern describes a vicious cycle in which a policy intervention adopted to manage the energy crisis inadvertently intensifies it. In conditions of grid imbalance, electricity distribution companies typically implement planned power outages for residential subscribers, with prior notification, to mitigate damage and social dissatisfaction. However, this notification unintentionally triggers a reactive behavior known as "pre-emptive consumption" (Abi Ghanem et al., 2016). In this situation, citizens attempt to maximize their electricity usage before the announced outage time. Examples include excessive use of cooling appliances to store thermal energy ("precooling"), charging electronic devices, or running washing machines.

This sudden surge in electricity consumption not only imposes additional pressure on the grid but also reinforces inefficient consumption behaviors among subscribers. Essentially, to minimize the impact of the outage on their daily comfort, individuals seek to meet their electricity needs earlier than scheduled. This temporal shift in consumption does not resolve the issue; rather, it leads to greater grid instability (Brand et al., 2022). For instance, if individuals anticipate that they will be unable to use their cooling systems during the outage, they may aggressively cool their homes beforehand to avoid discomfort during the cut-off period—an action that, in practice, can result in a significant increase in consumption and energy waste. Figure 3 illustrates the Pre-emptive Consumption Loop.

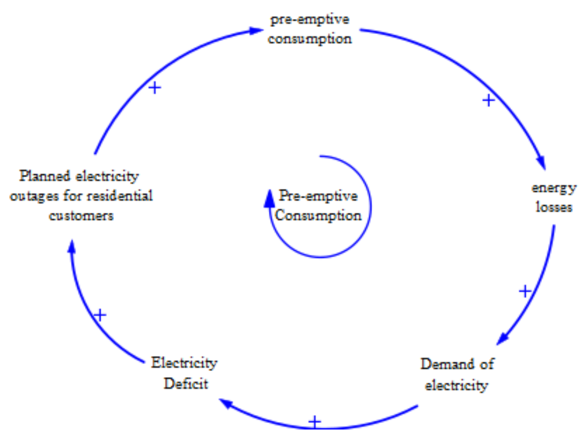

Figure 3. Pre-emptive consumption loop

Figure 4 presents a comparison of load on a purely residential feeder across two non-holiday days with similar temperatures in an affluent district of Mashhad, located in a hot, dry region.

As observed, the notification of the power outage triggered preemptive consumption to prevent a loss of welfare.

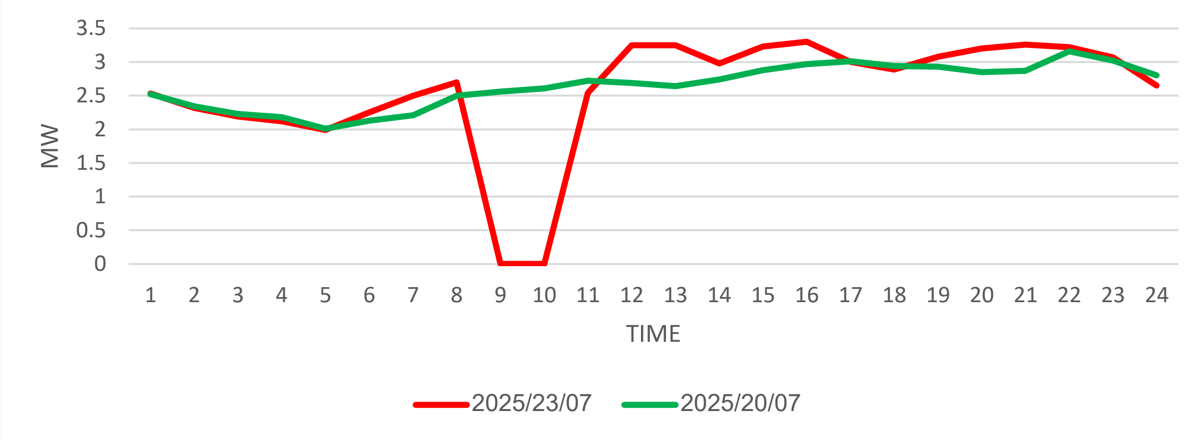

Figure 4. Comparison of load on a purely residential feeder on two non-holiday days with similar temperatures

4.2. The production stagnation (industrial and agricultural sectors) and social capital erosion loop

Figures 5 and 6 illustrate how power outages in the industrial and agricultural sectors can engender a vicious socio-economic cycle that undermines the foundations of social trust and complicates the resolution of the energy crisis. With the disconnection of power to industrial and agricultural subscribers, the production sector faces a halt or severe reduction in output (Bhorat and Köhler, 2025). A study titled “How Do Electricity Shortages Affect Industry? Evidence from India,” demonstrated that power shortages reduce the revenue and producer surplus of industrial firms by an average of 5–10% (Allcott et al., 2016). Similarly, in Iran, according to a report by the Iran Chamber of Commerce, energy instability has led to a 20% increase in production costs in the industrial sector, making international competition difficult for companies (Taleghani and Sola, 2025).

This decline in production results in domestic producers failing to meet their obligations, thereby losing market share to imported goods or foreign competitors (Mabunda et al., 2023). To compensate for these losses and cut costs, many of these units are forced to downsize, fueling widespread unemployment (Bhorat and Köhler, 2025). The rise in unemployment and economic recession directly leads to the erosion of social trust; specifically, the public’s belief in the system’s efficiency and the government’s ability to solve problems diminishes. This distrust erodes the public’s willingness to manage consumption and cooperate in energy-saving programs (Caferra et al., 2021). Consequently, this lack of cooperation leads to higher, unmanaged electricity consumption, intensifying the electricity deficit, which, in turn, becomes a primary driver of future outages.

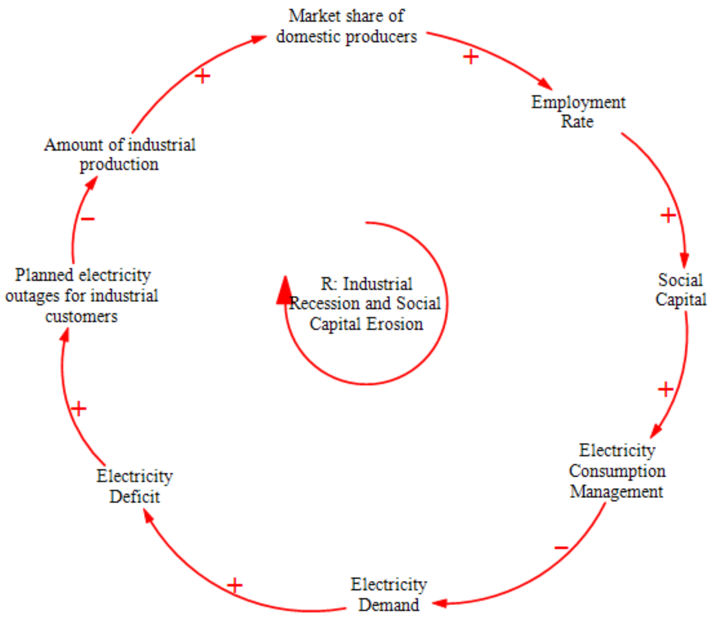

Figure 5. Industrial recession and social capital erosion cycle

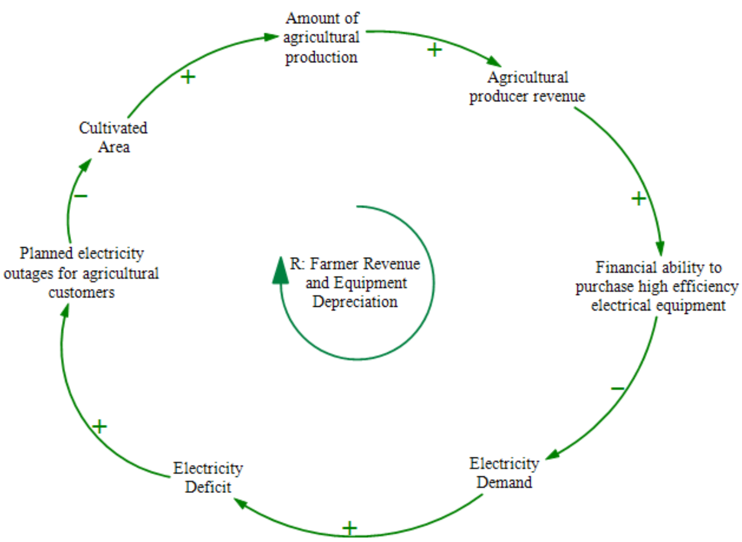

Figure 6. Farmer revenue and equipment depreciation

When the acceleration of problem deepening outpaces the pace of resolution, policymakers often prioritize short-term measures. Generally, these measures have little effect on addressing the crisis's root causes; instead, by temporarily delaying it, they gradually increase public dissatisfaction and contribute to the erosion of social capital. A prime example of this approach is shifting the start of administrative, educational, and banking activities from 7:00 AM to 6:00

AM during peak load periods. This measure was selected in lieu of changing the official country time (Daylight Saving Time)—which, according to reports by the Parliamentary Research Center, could have yielded over 1,000 MW in electricity savings by utilizing daylight more effectively—because the Islamic Consultative Assembly (Parliament) opposed the urgency of the relevant bill in May 2025. Opposing representatives emphasized that the government, under Article 87 of the Civil Service Management Law, could adjust working hours without altering the official time. Concerned about creating social confusion for citizens—including disruption of sleep patterns, increased road accidents, and pressure on family scheduling (especially for parents with school-aged children)—they prioritized maintaining stability in citizens' daily lives.

However, the implementation of the alternative policy resulted in disrupted sleep patterns for citizens, increased fatigue and stress (particularly for parents and shift workers), and reduced personnel efficiency. Public opinion polls indicate dissatisfaction among more than 70% of citizens, which has exacerbated distrust in government policies and reduced the willingness to cooperate in energy-saving programs. From a systems analysis perspective, this policy is part of the "Reinforcing Loop" of the "Fixes that Fail" archetype: short-term savings (150–1,800 MW during peak consumption) come at the cost of long-term consequences such as the erosion of social trust, which ultimately increases unmanaged consumption and deepens the electricity deficit.

4.3. The food security and grid depreciation loop

This loop depicts the consequences of agricultural power outages on a national scale. Similar to the loop in Figure 6, outages reduce cultivated areas, this time threatening the country's food security (Cloete et al., 2023). With the decline in domestic production, the government is compelled to import commodities (agricultural products) to meet societal needs, drastically increasing government expenditures. These increased costs (and the reduction in revenues from domestic production) negatively impact the government's and the Ministry of Energy's fiscal balance, diminishing their budgets and capacity to invest in modifying and optimizing the power grid. Consequently, the power grid remains dilapidated, and transmission losses increase. High losses reduce the effective supply of electricity to consumers, deepening the energy deficit and leading to further power outages. Figure 7 illustrates the cycle of Grid Depreciation and Food Security.

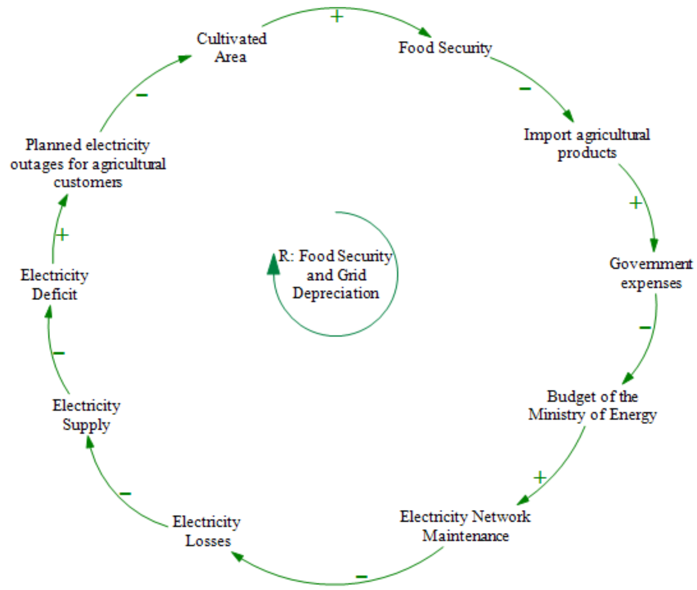

Figure 7. The food security and grid depreciation loop

4.4. The urban heat island loop

As illustrated in Figure 8, this loop represents a vicious environmental-social cycle wherein the reduction of agricultural cultivation and urban heating mutually reinforce one another. As the "Urban Heat Island" (UHI) phenomenon intensifies, city temperatures rise, increasing the electricity required to achieve a level of comfort (i.e., using cooling appliances) (Li et al., 2019).This requirement directly leads to higher electricity consumption, thereby creating or exacerbating the grid's electricity and energy deficit. To manage this deficit, the power company cuts electricity to agricultural subscribers in the suburbs to supply the urban sector. These power outages prevent farmers from irrigating their fields, reducing cultivated areas. Ultimately, the loss of this cooling green belt around the city intensifies the Urban Heat Island effect, making cities hotter than before (Rahaman et al., 2022). This, in turn, increases electricity demand in the subsequent cycle. This is a reinforcing loop in which the citizens' efforts to cool themselves come at the cost of destroying surrounding natural resources, worsening the heating problem in the long run.

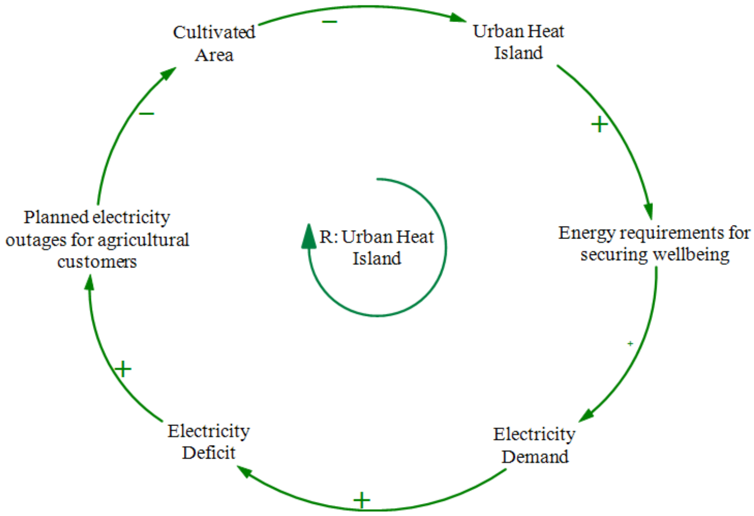

Figure 8. Urban heat island loop

This reinforcing loop reveals the hidden complexities of energy policymaking, demonstrating how a seemingly logical solution (Planned electricity outages for agricultural customers) can intensify the initial problem. This complexity deepens when examining technology choices at the end-consumer level, such as the choice between evaporative coolers and split air conditioners, through the lens of the Water-Energy Nexus. A common belief holds that evaporative coolers are a more optimal option due to lower direct electricity consumption. To the extent that, based on a resolution by the Supreme Energy Council, advertisements for split air conditioners have been banned in broadcasting and the press since 2023. However, an integrated analysis of water and energy, especially in regions facing both crises—such as the city of Mashhad—completely transforms this picture.

4.4.1. The paradox of evaporative coolers in the horizon of water supply from the sea of Oman

To accurately understand the trade-off between water and energy resources, the consumption of these two resources in evaporative coolers and split ACs in the city of Mashhad is compared under two scenarios. In this analysis, in addition to direct consumption, indirect consumption is also factored in: indirect water consumption (water used in power plants to generate electricity) and indirect electricity consumption (electricity used for pumping, treating, and transmitting water).

Scenario 1: Current status

Assuming the use of internal water resources, an evaporative cooler consumes an average of 4.8 kWh of direct electricity and 400 liters of direct water daily. Including indirect consumption, its total electricity consumption reaches 5.28 kWh, and total water consumption reaches 400.48 liters. In contrast, a split AC, with a consumption of 16 kWh of electricity and only 1.6 liters of water (indirect), is considered the more energy-intensive option in terms of electricity (Table 3).

Table 3. Water and Electricity Use: Evaporative coolers vs. split ACs (Current Scenario)

Cooler type	Total water consumption (Liters/Day)	Total electricity consumption (kWh/Day)
Evaporative cooler	400.48	5.28
Split AC	1.6	16

Scenario 2: Water supply from the sea of Oman

Given the water crisis and the implementation of water transfer projects from the Persian Gulf and the Sea of Oman to the Iranian central plateau, the energy footprint of this water must be included in calculations. For the desalination and pumping of each cubic meter of water from the Sea of Oman to Mashhad, approximately 53 kWh of electricity is required. In this scenario, the indirect electricity consumption of an evaporative cooler (to supply 400 liters of water) skyrockets to 21.2 kWh per day. Consequently, the total electricity consumption of an evaporative cooler reaches 26 kWh per day (Table 4).

Table 4. Water and Electricity Use: Evaporative coolers vs. split ACs (Oman Sea Supply)

Cooler type	Total Water consumption (Liters/Day)	Total Electricity consumption (kWh/Day)
Evaporative Cooler	400.48	26
Split AC	1.6	16

This comparison demonstrates that, when relying on unconventional water sources (such as desalinated water), the evaporative cooler, recognized as a low-consumption technology, actually consumes 62% more electricity than a split AC. This paradox stands as a prime example of the necessity for systems thinking and integrated analysis within the Water-Energy-Food Nexus framework. Sectoral policymaking that relies solely on direct electricity consumption as a criterion can drive the country toward technology choices that, in the long term, drastically exacerbate the energy crisis.

4.5. Turning the electricity deficit into an opportunity

The electricity deficit, if managed strategically, presents a unique window of opportunity to rectify inefficient mechanisms stemming from untargeted subsidies, encourage energy optimization, and accelerate the deployment of renewable energies. These reforms not only mitigate reliance on fossil fuels but also steer consumption patterns toward sustainability by establishing economic incentives for both consumers and producers. For instance, gradual increases in energy tariffs or the provision of incentives—such as exemptions from load-shedding programs for efficient industries—can drive the industrial sector to adopt more efficient technologies and encourage households to conserve energy. Ultimately, these measures lead to reduced greenhouse gas emissions and the preservation of natural resources.

Furthermore, managing the energy imbalance can curb excessive groundwater extraction and prevent land subsidence. In regions such as the central plains of Iran, where traditional agriculture is heavily dependent on groundwater, these policies restore ecological balance and prevent permanent soil degradation by promoting modern irrigation methods (e.g., drip irrigation) and reducing the energy consumed for water pumping. Ultimately, the energy deficit, by limiting access to water, facilitates the reform of cropping patterns and promotes the adoption of water productivity enhancement practices. Focusing on low-water-intensive crops and utilizing modern irrigation techniques not only strengthens food security but also breaks the vicious cycle of dependence on finite resources, aiding the long-term sustainable development of agriculture.

By fostering synergy among the energy, water, and agriculture sectors, this approach lays the groundwork for systemic sustainability within the Water-Energy-Food Nexus framework. The analysis presented regarding the “Evaporative Cooler Paradox” in the context of water supply from the Sea of Oman demonstrates how a seemingly optimal choice (the evaporative cooler) can become a destructive option when viewed systemically. This is precisely the juncture where the energy deficit can compel policymakers to re-evaluate such conventional wisdom.

4.6. Integrated analysis

Many conventional government countermeasures to the electricity deficit—such as high-cost electricity imports, payment of rewards for consumption management, or the creation of new administrative structures—often become part of a vicious cycle rather than providing a root-cause solution. The common denominator of all these policies is the imposition of heavy fiscal burdens on the government. These expenditures divert financial resources that should ideally be allocated to fundamental solutions, such as grid modernization and optimization, smart meter implementation, timely power plant maintenance, and investment in generation capacity.

Consequently, energy infrastructure weakens over the long term, leading to increased grid losses and power plant failure rates. This deterioration reduces the effective supply of electricity and exacerbates the initial deficit. In essence, these policies act as expensive palliatives that, by depleting infrastructure investment capacity, make the system's underlying pathology more chronic. Conversely, integrated, long-term policymaking centered on the WEF Nexus transforms the energy deficit from a crisis into an opportunity for consumption optimization, infrastructure reinforcement, and the realization of systemic sustainability.

5. Discussion and conclusion

A systematic analysis of the electricity crisis in Iran reveals that short-term compensatory policies represent a quintessential instance of the "Fixes that Fail" archetype in systems thinking. In this archetype, a symptomatic and immediate solution (power outages) diverts attention from fundamental, long-term solutions (infrastructure investment, price rationalization, consumption optimization, and renewable energy development). With the recurrence of this short-term fix, the system's capacity to fundamentally resolve the problem gradually erodes, while dependency on the quick fix increases.

The adverse feedback loops identified across the agricultural, industrial, and residential sectors clearly demonstrate that sectoral, isolated interventions lead to unintended and destructive macroeconomic consequences. Cutting power to the agricultural sector to secure urban electricity supply ultimately increases urban power consumption through the Urban Heat Island (UHI) effect. Similarly, shutting down industries to reduce load demand cripples their financial capacity to invest in energy efficiency, rendering them more energy-intensive in the long run.

To exit this state, energy policy-making must shift from a reactive approach to a comprehensive, integrated, and long-term framework. In other words, if managed correctly, energy imbalances can serve as a lever to correct inefficient energy and water consumption patterns and enhance systemic sustainability. The following policy recommendations are proposed with the aim of breaking these adverse feedback loops and establishing stability in the energy system:

1. Strategic and Smart Infrastructure Investment: Instead of focusing solely on constructing new power plants, the government must redirect investments toward optimizing and modernizing existing infrastructure and developing renewable energy. Reducing grid losses, identified in the analysis as a vicious cycle, is an urgent and critical measure achievable through

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smart grid technologies and the refurbishment of transmission and distribution infrastructure. Furthermore, expanding solar and wind generation capacity, given their rapid deployment potential and Iran's abundant resources, can help break the cycle of supply shortage.

2. Structural Reforms in Energy Economics and Price Rationalization: A root cause of the imbalance is inefficient subsidies that eliminate economic incentives for consumption optimization. The gradual, targeted rationalization of energy prices—while accounting for social dimensions and supporting vulnerable groups—can serve as a powerful policy lever to shift consumer and industry behavior. Consequently, reduced consumption would improve the financial health of energy companies, thereby enhancing their ability to invest further in infrastructure.

3. Promoting Efficient Technologies and Cultivating Responsible Consumption: To break the vicious cycle of "underinvestment due to deficits," the government must encourage industries and farmers to modernize equipment and adopt high-efficiency technologies through financial facilities and incentives. Additionally, raising public awareness and promoting a culture of responsible consumption in the residential sector can increase social capital and public cooperation in demand management, thereby weakening the loop of social capital erosion.

4. Integrated Planning Based on Quantitative System Modeling: The energy crisis is not merely a technical problem but a complex systemic challenge with tight interdependencies within the Water-Energy-Food Nexus. This research, by presenting a qualitative system model, establishes the fundamental and necessary step of identifying and validating the feedback structure generating the crisis. The Causal Loop Diagram presented in this paper is not merely a preliminary sketch but a robust conceptual framework that elucidates key variables, causal relationships, and self-reinforcing feedback loops. This framework serves as a valid roadmap paving the way for the logical next step: quantitative System Dynamics modeling. Based on this validated structure, a quantitative simulation model can be developed to test various policy scenarios and assess their long-term impacts on key variables, including industrial productivity, food security, and electricity imbalances. This two-stage approach—first understanding the structure, then simulating behavior—enables policymakers to avoid repeating failed solutions, based on a deep, evidence-based understanding, and to move toward sustainable and effective policy-making.

Finally, while this research has analyzed the structure of the crisis in the industrial, agricultural, and residential sectors using Causal Loop Diagrams, it faces certain limitations.

The qualitative nature of the model limits the precise quantification of relationship intensity and time delays. Furthermore, the focus on three main sectors has arguably underemphasized macro factors such as international sanctions, climate change, and public acceptance of policies. Additionally, the lack of statistical data and econometric analyses has confined the analysis to a conceptual level. For future research, it is recommended that the qualitative model be converted into a quantitative System Dynamics model to simulate and evaluate policies such as energy price rationalization or renewable energy development. Empirical validation of feedback loops using time-series data, expanding the model to encompass socio-political factors, and designing an integrated Water-Energy-Food Nexus model would significantly enrich the analysis. These approaches contribute to the formulation of sustainable policies. Ultimately, the electricity imbalance crisis can only be resolved through the intelligent management of feedback loops and the adoption of long-term strategies. These research avenues guide policymakers toward comprehensive and sustainable decision-making, moving away from sole reliance on temporary and costly solutions.

Disclosure statement

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