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DOI
10.1016/j.erss.2020.101763

Publication date
2020

Document Version
Final published version

Published in
Energy Research and Social Science

Energy Research & Social Science 70 (2020) 101763

Contents lists available at ScienceDirect

Energy Research & Social Science

journal homepage: www.elsevier.com/locate/erss

Can industries be parties in collective action? Community energy in an Iranian industrial zone

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ARTICLE INFO

Keywords:
Collective action
Industrial collaboration
Common pool resources
Community energy systems
Renewable energy transition
Institutional analysis and development framework

ABSTRACT

The industrial sector plays a huge role in creating economic growth. While energy is vital for industries to thrive, various factors are undermining the availability of energy including phasing out of fossil fuels, CO2 emission caps and, the large gap between the fast developments of industrial clusters and the energy supply, especially in developing countries.

Recently, enabled by renewable energy technologies, a transition process is taking place towards decentralized settings for energy provision where households in neighbourhoods initiate renewable electricity cooperatives. The question addressed in this research is if or to what extent the model of collective action deployed by citizen cooperatives is applicable to collaborations between industries in an industrial cluster.

We identified the conditions for the establishment of Industrial Community Energy Systems (InCES) from a collective action perspective by using Ostrom's Institutional Analysis and Development Framework. The case study selected is the industrial city of Arak, one of the largest and most diversified industrial clusters in Iran. Besides desk research, data was also collected by conducting semi-structured interviews and by holding stakeholder workshops.

The results of this study highlight the importance of community spirit and trust for the establishment of InCES, unlike citizen cooperatives where finance and environmental attitude are essential. A transparent legal framework to resolve conflicts that might emerge in industrial partnerships is another crucial element given the many differences among industries such as differences in energy demand and in usage patterns.

1. Introduction

The industrial sector plays a leading role in driving economic growth. A crucial condition for industry to thrive is the provision of reliable and affordable energy services [1]. As such, security of electricity supply and price stability are important concerns for energy policy making, which is increasingly challenging for two reasons. First, climate policy ambitions necessitate governments to phase out fossil fuels from the power generation mix and increase the share of renewable energy sources (RES)[1]. As wind and solar energy are replacing fossil fuels in the generation mix, electricity production is becoming more variable (weather dependent) and electricity prices more volatile. Second, as industry itself is also forced to phase out fossil fuels, many high temperature processes which are currently driven by fossil fuel combustion, especially in the chemical and metal industry, will in the future be replaced by electrochemical conversion routes [2,3]. The industrial electricity demand is thus expected to increase substantially in the future [4].

Aforementioned developments are important reasons for many industrial corporations to rethink the provision of electricity. In many developing countries, however, the challenge is of a more urgent nature, as industrial development there may be thwarted by lagging investment in generation and infrastructure capacity, resulting in more or less frequent brown-outs of electricity supply [5]. To tackle these challenges, one possible solution for industries is to self-generate the electricity required. For this strategy to be sustainable, only renewable

Abbreviations: RES, Renewable energy sources; IAD, Institutional analysis and development; InCES, Industrial community energy system; CES, Community energy system; MOE, Ministry of energy; REC, Regional electricity company; PGMC, Power generation management company; DISCO, Distribution company; GENCO, Generation company; IGMC, Iran grid management company; IEMRB, Iran electricity market regulatory board; FIT, Feed-in-tariff; CPR, Common pool resource; CEO, Chief executive officer; kWh, Kilowatt hour; kWp, Kilowatt peak; MWh, Megawatt hour; PV, Photovoltaic; MW, Megawatt; CSP, Concentrated solar power; ISIPO, Iran's small industries and industrial parks organization; IRR, Iranian Rial

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https://doi.org/10.1016/j.erss.2020.101763
Received 6 November 2019; Received in revised form 1 July 2020; Accepted 26 August 2020

energy resources apply. Besides the high initial investment, it is most often the limited availability of space that poses an unsurmountable hurdle for industrial plants to become self-sufficient [6].

Another approach, given the fact that industries are often located in industrial clusters, is to collectively produce electricity from renewable energy sources and collectively manage electricity demand. Instances of collective power generation and consumption are commonly referred to as "community energy systems" (CES) [7]. CESs are becoming increasingly popular among households in various neighbourhoods around the world. CESs are valuable in terms of self-sufficiency and sustainability [8]. Moreover, they contribute to decreasing the amount of power loss through the transmission and distribution grid. Therefore, a great deal of research is being directed towards their development [7,9-19] and one line of research in particular focuses on their bottom-up, self-organizing nature by viewing their management as a collective action problem [18,20-26].

Although CESs may also hold great potential for communities of industrial partners, to-date, energy management in industries has never been studied as a collective action problem. Given the great potential of community-driven energy management, and the challenges industries currently face, our goal in this research is to study whether industrial clusters can be considered as communities to collectively produce electricity and manage their demand.

In order to identify the conditions that lead to collective action for establishing an industrial community energy system, we use the Institutional Analysis and Development (IAD) framework [27] of the Noble Laureate, Elinor Ostrom. This framework has been proven effective in studying collective action problems [27] and has been successfully used to study CESs [20-26].

In this research, the IAD framework is applied to analyse the industrial cluster of Arak in Iran as a case study. This industrial cluster consists of seven distinct industrial zones with diverse types of industries and a large number of active industrial companies which are working with different working shift schemes and with different demands for electricity. Our goal is to study whether collective action is possible among industries in this case study, and to identify opportunities, challenges and barriers for such collective action. More specifically and given the factors raised by the IAD framework, we will be looking into the physical (both bio and technological), the social (i.e., community) and the institutional opportunities and barriers of establishing an industrial community energy system, which we will refer to as InCES in this paper.

The structure of this paper is as follows. In Section 2, the challenges for collective management of electricity in an industrial cluster are explained. In Section 3, we will discuss how a collective action lens can benefit this research. Section 4 presents the case study, electricity management in Arak, the role of the government in promoting renewable energy in the industrial sector and the data collection process. Section 5, delineates the systematic analysis of our case study using the IAD framework. In Section 6, we reflect on our findings. Finally, Section 7 provides the conclusion.

2. Challenges for collective management of electricity in an industrial cluster

2.1. Existing collaborations among industries

Collective action is defined as: " the action taken by a group (either directly or on its behalf through an organization) in pursuit of members' perceived shared interests" [28]. Collective action or collaboration between industrial companies is not new. There is an extensive body of literature on industrial symbiosis (IS) which is a well-known model of cooperation in which industrial companies exchange resources and by-products [29]. This sharing of resources results in the improvement in eco-efficiency of industrial clusters by reducing the use of virgin raw materials and industrial waste. Although the final goal of IS is to have a more sustainable and efficient industrial process in terms of both energy and raw materials, it principally has tight strings with "cyclical industrial activities" and the focus of this approach is on optimization of resource consumption as a result of collaboration between various industries [30]. Collaborative electricity generation in an industrial cluster as proposed here, is different from IS, in the sense that the main focus is entirely on electricity generation from shared RE sources and the challenges are primarily related to social collaboration among the industrial community members rather than optimization of production processes as in IS.

2.2. Key collective management challenges for industries

There is a comprehensive body of literature on the formation of CES for the case of private households [9,10,16,31–33] which is however not directly applicable to industrial communities. One of the main differences is related to the decision-making process. Decision making within and between private households is typically not structured by strategic and rational procedures [34,35] comparable to those of large industrial companies [36,37]. However, in the latter case, these are required for reaching consensus between different decision makers with different interests and viewpoints (referred to as political decision making) [38-43].

In addition to the decision-making process, InCESs face many technological, socio-economic, environmental and institutional challenges different from those of communities of households [44]. Industrial firms have higher demands for electricity with more stringent requirements on the availability and quality of electricity service provision. There are also much more pronounced differences in electricity consumption patterns between firms compared to households in a 'conventional' community energy system. Therefore, reaching consensus between industrial participants of an energy community may be much more challenging than in a household setting where the members have similar demands [45].

The diversity of energy demand in industry largely stems from the different needs of industrial production processes. For example, while in process industries, production processes are often continuous or semi-continuous, manufacturing industries (producing specific product parts or assembling products) are intermittent and therefore, differ in energy needs and flexibility [46]. Such differences create challenges for a community of industries who aim to generate electricity collectively to satisfy the collective and yet diversified demand. Further complications arise from the variable (weather dependent) nature of both solar and wind power, which may require additional investment in energy storage capacity so as to satisfy the large baseload of the industrial community at all times [47]. Another hurdle for industrial community energy systems aiming for renewables is the land requirement. Most industrial zones are characterized by a high density of industrial buildings and installations, and hence do not have sufficient space for renewable power generation facilities. The industrial community is, therefore, likely to rely on generation capacity to be built outside the industrial zone [48].

Our goal in this paper is to look at these challenges through a collective action lens, and to use existing theories to explore the feasibility of this type of collective action.

3. Energy management in industries from a collective action perspective

3.1. The collective action problem of InCES

Collective action problems traditionally deal with shared resources and services [49-51]. These resources and services can be common pool resources (CPR) such as forests, or common infrastructures such as irrigation systems. In collective action problems, individuals may act in their own self-interest and pursue a course of action that will not result in the ideal collective outcome. This may happen because of different levels of trust [17,52] or autonomy among individuals [53], or in order to circumvent the imposed risks and expenses by the collective action. This phenomenon is known as the "prisoner's dilemma" in game theory literature [54] which can be a serious barrier for collective action projects [55-57]. Furthermore, the so-called free-riders[1] problem [58], which can result in the tragedy of the commons[2] [59–61] has always been a part of collective action problems.

For illustrative purposes and to explain how building an InCES can be seen as a collective action problem, we postulate that we are dealing with shared infrastructures, investments and power generated which can all be seen as CPRs [62]. Electricity generation and consumption, as well as investments in infrastructure and generation capacity, may be allocated unevenly among participants in an InCES given the differences among the participating industries as discussed in Section 2. Furthermore, if we consider the produced electricity and also the shared infrastructure as CPRs, free-riding can happen if members of the community do not pay their monthly or yearly fees which may lead to inadequacy of the power plant and eventually lead the whole system to supply shortages. Furthermore, different trust and autonomy levels among industrial participants can be crucial factors impacting the dynamics of collective action. To prevent problematic situations, institutional arrangements are required to help industries coordinate their collective investment decisions and the management of the shared resources (i.e., electricity and infrastructure).

The IAD framework addresses collective action problems such as the ones described above. The IAD framework provides a systematic approach to analyse a social system through an institutional lens. It helps analysts to understand complex social situations and to break these situations down into manageable sets of practical activities [63]. The framework can also help in organizing knowledge from empirical studies [64].

The core of the IAD framework is the 'action situation'; a conceptual unit that can be utilized to describe, analyse, predict and explain behaviour within institutional arrangements (see Fig. 1) [27]. Contextual factors (left in Fig. 1) affect action situations which are the social spaces where individuals interact and exchange goods. The actions taking place in the action arena lead to patterns of interaction that explain the outcomes of the system. Using a set of evaluative criteria, the patterns of interaction and outcomes can be analysed. This analysis may lead to changes in the contextual factors including the institutions, and even the technological components of the system which in our case is the energy infrastructure.

Fig. 1. shows three categories of contextual factors affecting an action situation at a particular time [65]. Biophysical conditions include the physical and material conditions that influence action situations. Attributes of community describe the cultural context and the norms of behaviour. Rules-in-use are the institutions in the system that influence the actions, interactions and outcomes.

3.2. Using the IAD framework to analyse InCES

We divided the IAD framework into three main sections as illustrated in Fig. 2. In this paper, we use the components in Box A which are the contextual factors for having a community energy system, to analyse the industrial cluster from a collective action perspective in order to find out whether an InCES is feasible in the context of our industrial cluster case. The challenges that were raised in Section 2 can be categorized into the IAD components in Box A. We use the "attributes of the community" component to look into the industrial cluster as a community, and to identify the social and economic challenges. We use the "rule-in-use" component to look into the formal rules (i.e., government regulations and incentives) that provide constraints or support for establishing an InCES project. We also look into the informal rules within the community that also play a great role in shaping an InCES. Finally, we use the "bio-physical conditions" to identify the environmental conditions for different energy sources. Technological aspects, however, do not entirely fit into the bio-physical conditions of the IAD framework, which is why we have included a fourth component in Fig. 2 called "technical aspects of the power plant". This is because applications of the IAD framework so far mainly focus on socio-ecological systems, and the technological aspects such as the power plant and the grid have a different nature in terms of financial feasibility and availability. Therefore, we propose to analyse these aspects separately, as will be shown in the coming section.

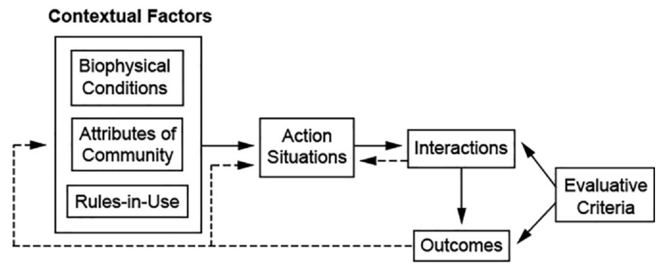

Fig. 1. IAD Framework [27]

Using the aforementioned components of the IAD framework, we will analyse our industrial cluster to explore the full potential of having an InCES. We will explore the feasibility of such collective action by highlighting the barriers and opportunities.

Given our extensive analysis, our main focus will be on box A. The action arena (Box B) will be used to propose action situations in a potential InCES which is the next step in our research. Box C will be used to project the potential outcomes of such a collective action scenario which we partly address in our concluding section.

4. Material and method

In order to study the feasibility of collective energy management in InCES, we take a case study approach which will be thoroughly analysed from a collective action perspective using the IAD framework.

4.1. Case study: Arak industrial cluster

For the feasibility study of InCES formation we selected Arak industrial cluster in Iran. Industry in Arak, and wider Iran, struggles with power shortages on a regular basis, mainly as a result of infrastructure investments lagging behind the increase of electricity demand in Iran's industrial sector. Moreover, recent long drought periods necessitate several weekly brown-outs due to lack of cooling water resources for the conventional fossil-fired power plants. Considering the urgent need for expansion of power generation capacity, renewable energy resources come into play. However, due to heavy subsidies on electricity price, power generation from renewable sources is currently financially infeasible. Given the mission of Iran's power ministry to gradually privatize the electricity sector and liberalize the electricity market, the business case for investment in renewables is bound to improve in the near future. In addition, this liberalized electricity price in the future can increase the production costs and be considered as a threat for the industrial companies. Moreover, the Iranian government has recently introduced financial incentives to stimulate the utilization of renewable energy resources. Hence, renewable power generation is promising for

[1] In economics the free-rider problem happens if those who benefit from resources, goods, or services do not pay for them [78].

[2] The tragedy of the commons is an economic theory of a situation within a shared-resource system where individual users act independently according to their own self-interest, eventually resulting in the depletion or destruction of the resource.

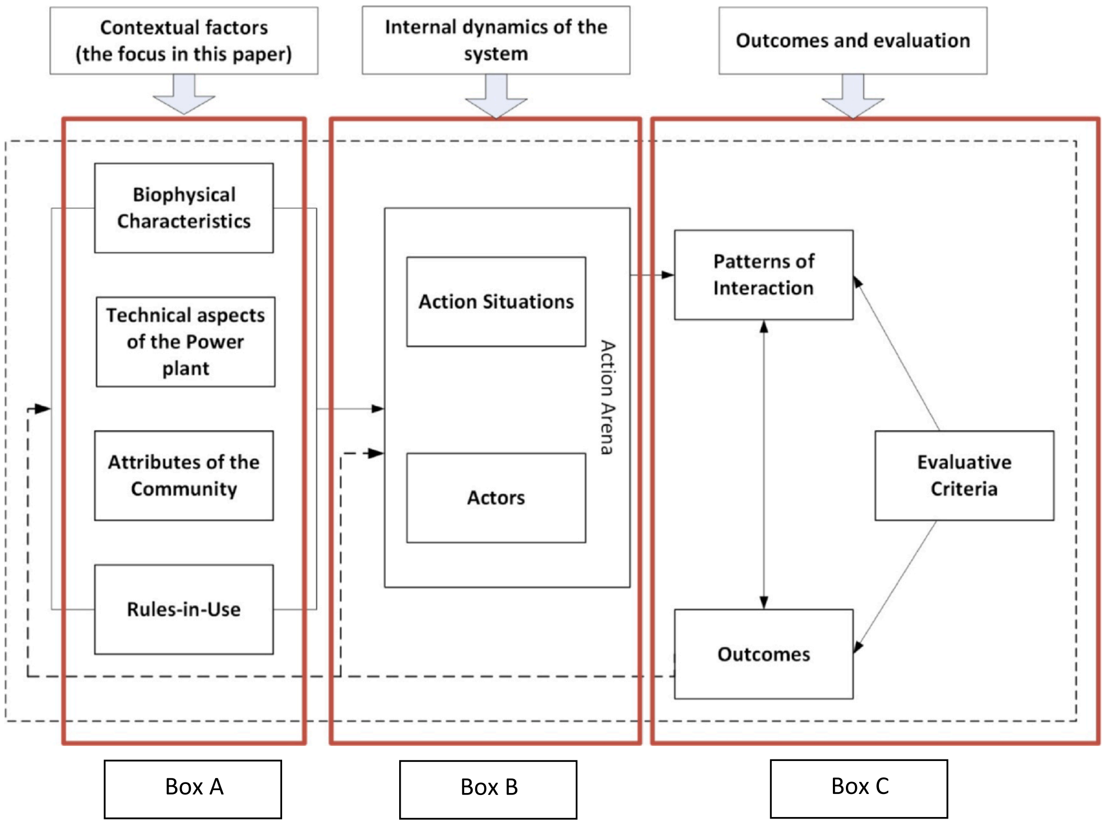

Fig. 2. Conceptualization of the IAD framework in this paper.

industries in Iran. We selected Arak as a case study, as it is a mature industrial city with a large number of active companies and a large variety in types of industries. Arak is spatially distributed over seven industrial zones/clusters, with the smallest and largest cluster consisting of 30 and 400 companies, respectively.

4.1.1. Electricity management in Arak

Ministry of Energy (MOE) is the chief player in Iranian electricity sector in general and in Arak in particular. Iran Power Transmission, Generation and Distribution Company (Tavanir), a state-owned company working under the supervision of MOE is responsible for generation and transmission capacity and electricity wholesale all over the country [66].

Accordingly, in Arak, the regional electricity company as a regional subordinate of Iran's MOE is the only player in charge of electricity provision. Similar to other regions in Iran, the price of electricity in Arak is determined by the MOE, based on the consumption patterns of the consumers in different sectors. So, the key element in the price of the electricity bill for industrial companies in Arak is the amount of electricity that they use during different hours of a day.

4.1.2. Role of government in promoting renewable energy in the industrial sector

From 2010, Iran's government issued a series of incentives to promote renewable energy in Iran. Following this goal, the Iranian government announced plans to build 2,000 MW of renewable energy capacity between 2010 and 2015. Iran is also working to make renewable energy commercially viable and the MOE is required to buy privately produced renewable energy at world market prices. Also, the MOE introduced feed-in-tariff (FIT) mechanisms in payment terms of contracts between renewable energy producers and the government as an incentive.

In 2012, Iran allocated €500 million from the National Development Fund to renewable energy projects, partly in support of the renewable (solar) industry in Iran. The state-sponsored Renewable Energy Organization of Iran (SUNA), with an annual budget of around €55 million, is associated with the MOE.

4.2. Data collection

According to the IAD framework, to study the feasibility of InCESs in Arak, we need information regarding the technical feasibility of various renewable energy sources, the existing governmental incentives and regulations regarding local power generation from renewable sources, the attributes of various industries such as their size and electricity consumption patterns, the perception of industries about community electricity production and their willingness to contribute to such initiatives. To collect this data, we used various means:

- Workshops

We held two 3-hour workshops in Arak's industrial cluster. In the first workshop, the participants were the CEOs of 36 industrial companies in the region. We discussed existing challenges which industrial companies are facing with regard to their electricity demand and also discussed possible solutions for that. The second workshop included the CEOs of 22 industrial companies in the region and some authorities from the regional power company in Arak in order to discuss the feasibility of establishing an InCES in this industrial cluster and the effectiveness of existing government incentives for encouraging renewable power generation.

- Semi-structured interviews

We used the IAD framework to design semi-structured interviews. We conducted 9 interviews with CEOs of industrial companies in Arak and asked questions regarding their difficulties in meeting the electricity demand in their companies, their mindset about joining partnerships in general and collective power generation specifically. Also, we solicited their opinion about the establishment of an InCES and the required institutional arrangements that need to be in place. For selecting these interviewees, we considered the size of the industrial companies (small, medium and big) as an indicator of their electricity consumption.

Additionally, we conducted a semi-structured interview with the Director General of the Power Generation and Supervision Bureau of Iran's Ministry of Energy as one of the key authorities in order to gain insight regarding the current rules, incentives, payback periods and existing challenges of renewable power generation in Iran. Moreover, we conducted three more semi-structured interviews with consultants in the field of renewable energy regarding their analysis of the cost and benefits of a renewable power plant in Arak.

- Study of legal documents

We conducted an extensive desk research on the existing rules and regulations regarding the power sector in Iran, including the limitations, incentives, and the goals towards meeting their environmental targets which might affect the feasibility of establishing an industrial renewable cooperative. Moreover, we studied the different versions of contracts signed between the MOE and renewable power generation companies to assess their effectiveness in encouraging clean electricity production.

5. Systematic analysis of Arak industrial cluster

5.1. Biophysical characteristics of Arak industrial city

The biophysical conditions of Arak determine which renewable energy resources are feasible in the region. A thorough exploration of the potential for various renewable energy resources in the region of Arak, show that both solar and wind energy can be utilized. The photovoltaic power potential factor of Iran is shown on the map in Fig. 3. The border of Markazi province in which Arak is located has been highlighted in red on the map. According to *globalsolaratlas.info*, the photovoltaic power potential in this region is between 1680 and 1826 kWh/kWp. Moreover, on average, Arak has about 300 sunny days per year with a peak sun hour of 4.5–5.5 kWh/m^2 per day [67] which makes this region an attractive area for solar power generation.

In addition, according to *globalwindatlas.info*, The wind blow intensity in Arak which is about 250 W/m2 is shown in Fig. 4. The average wind speed in this region is about 4.2 m/s. Within this region and based on these data, a recent model of a 2.5 MW wind mill would be able to produce about 3 MWh electricity per year[3].

5.1.1. Biophysical challenges for Arak

This information illustrates that both wind and solar technologies can be utilized in this region for power generation. Nevertheless, selection of a specific technology would not affect the results of this research considerably since the focus is on the socio-economic challenges of forming an InCES, regardless of the type of the technology involved.

Another issue worth discussing in this section is the *location* of the power plant in relation to the industrial cluster. In solar power generation, land usage differs substantially based on the production method. For instance, for small and large photovoltaic (PV) power plants, the area needed ranges from 2.2 to 12.2 acres per megawatt (MW), with a capacity-weighted average of 6.9 acres per MW, while concentrated solar power plants (CSP) require land between 2.0 and 13.9 acres per MW with a capacity-weighted average of 7.7 acres per MW [48,68]. Unlike solar energy, the projection of wind energy land-usage is more complex due to the type of selected wind mill and its wake effect accordingly [69]. However, it is noteworthy that both wind and solar technologies have seen substantial developments during recent years which consequently decreases the land usage of these technologies [69].

Considering the industrial demand for electricity in our case study and regardless of the type of solar and wind technology which might be utilized, it can be concluded that *land-usage* is a crucial aspect which should be taken into account. Given the geographical dispersion of Arak industrial city, which is in fact composed of seven industrial clusters, the distance between the power plant and the industrial community members which are making the investment is a significant factor. In fact, acquiring a suitable piece of land which is large enough in terms of solar power generating capacity and close enough to the industrial community might be a hurdle for an Arak InCES to be brought into being.

5.2. Technical aspects of Arak industrial city

The technical aspects for this case are mainly concerned with the choice of generation technology, the existing electricity infrastructure and whether or not investment in transmission and distribution infrastructure is needed. Independence from the national grid makes a substantial difference in terms of capital and technological requirements, as compared to being connected to the grid. Off-grid design of the power plant necessitates the InCES to implement energy storage capacity, such as high capacity batteries (or other energy storage technologies), so that the collective electricity demand can be satisfied at all times. Without storage capacity, for instance if we use solar energy, night shifts cannot be operated and even during daylight hours, electricity shortages can occur due to the variability of solar irradiation intensity. Energy storage capacity, however, requires a substantial additional investment. Being connected to the national electricity grid prevents the need for investment in energy storage capacity. This option also creates the opportunity for the InCES to sell its electricity surplus to the utility owner which in the case of Arak is the government of Iran.

Furthermore, all industries in Arak industrial cluster are connected to the national grid. Most of the companies represented by the interviewees had never experienced power blackouts or had only experienced it once a week. So, until recently, the current electricity system has been providing adequate reliability of service. This relatively stable electricity supply situation has changed, however, due to the more frequent occurrence of prolonged drought periods in Iran, resulting in cooling water shortages for the thermal power plants which dominate the national power generation mix. As a consequence of the droughts, the electricity system has been facing series of brown-outs during the hot seasons. For the future, many companies in Arak industrial city indicate serious concerns about the inability of the regional power company to satisfy their increasing electricity demand. The lack of investment in both new generation capacity and expansion of transmission capacity implies that the industries in Arak cannot fully utilize their production capacity. This is a strong motivation for industrial companies to consider collective power generation in order to satisfy their electricity demand.

5.3. Attributes of the community

The industrial cluster of Arak which can be considered as our "community" in Ostrom's terms is very diverse in terms of the type of industry. The type of industry influences the electricity demand and consumption pattern. According to Iran's Small Industries and Industrial Parks Organization (ISIPO), Arak industrial city has 646 active industrial companies in different sectors as shown in Fig. 5. [70]:

Currently 98% of the companies in this area are privately owned

[3] The calculation of the power output is done based on:Hub height of the wind mill: 85 m, rotor diameter: 104 m, wind speed: 4 m/s, Weibull parameter (β): 2.7,air density (ρ): 1.035 kg/m^3

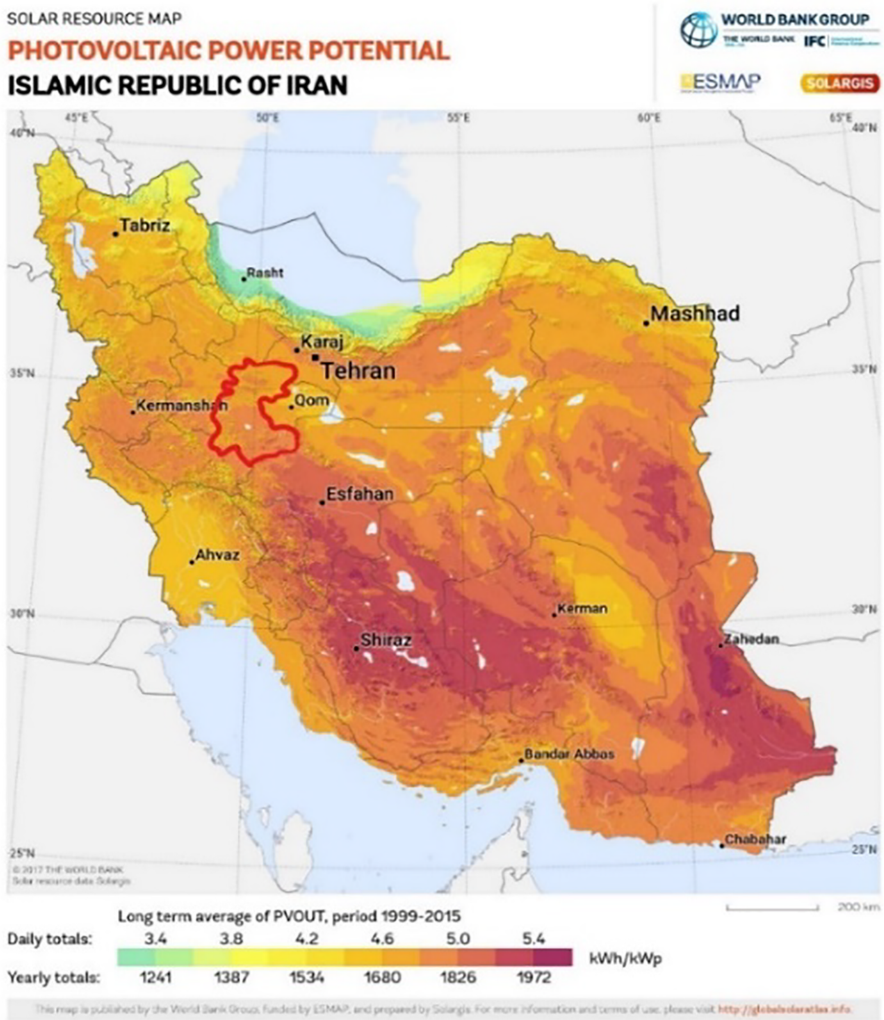

Fig. 3. Solar radiation intensity of Iran. Map obtained from obtained from the "Global Solar Atlas 2.0, a free, web-based application is developed and operated by the company Solargis s.r.o. on behalf of the World Bank Group, utilizing Solargis data, with funding provided by the Energy Sector Management Assistance Program (ESMAP). For additional information: https://globalsolaratlas.info.

and the rest are public companies, with their stocks being traded in the public stock market.

The diversity in type and size of industries in Arak indicates large differences between individual companies in how dependent they are on electricity provision and especially how flexible they are in dealing with service interruptions of short and longer duration. Depending on their sensitivity to service interruptions and on their plans for production capacity expansion in the future, different companies are not equally motivated to join an InCES. Evidently, not every company will be willing to invest, and not every company which does invest will be prepared to make the same investment contribution. To some extent, such differences in willingness to invest are also at play in the formation of household CES. In a community of households, however, the differences in electricity demand and consumption patterns are far less pronounced than in the case of an InCES as we are exploring for Arak industrial city.

A promising aspect about Arak, however, is that companies are already engaged in other forms of collective action and already see themselves as a community. The clearest example of collective action in Arak is a community banking system that has been successfully running for almost four years. The initiative of establishing a community bank stemmed from the inadequacy of the Iranian banking system to meet industry needs. In order to become independent from the Iranian banks in financially disconsolate periods, a collective of industries in Arak industrial city decided to form a community bank, providing loans with no interest rate. In this collective fund system, rules were collectively defined in order to ensure its reliability for all members. The initiators first created a list of prominent industrial company owners eligible to join the 'club' as core members. The main mission of the founders of this collective fund system was to ensure the reliability of the members and to guarantee that the money will circulate safely among the members. The institutional arrangements included both "entrance rules" and "sanctioning rules" (as a tool for punishing the members who abused trust within this community).

Since shared practical understandings can influence humans' daily routines and can influence their attitude towards changes to new situations [71,72], the existing collective fund system with about 36 industrials members has already made the industries in Arak familiar with the collective action approach. In our interviews, we were eager to find out if the positive experience with the collective fund system may contribute to the industries' willingness to also pursue collective action in solving their energy problems. Yet, our interviews revealed that many industries which had not participated in the collective fund system are not also particularly eager to partner with other industries for collective power generation. Many of mentioned CEOs interviewed preferred not to share electricity infrastructure with other industrial companies since they considered electricity as a highly strategic issue. They did not want to be bothered with partnership challenges such as

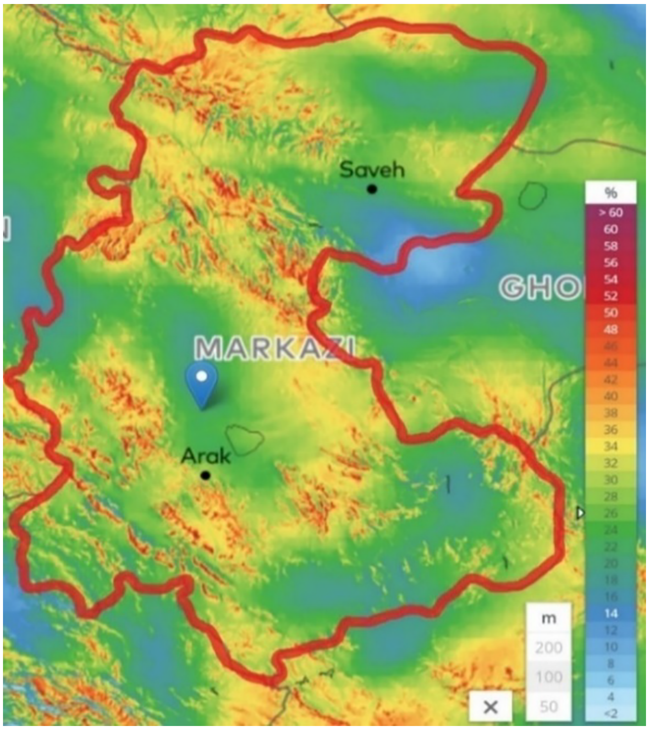

Fig. 4. Wind blow intensity in Arak. Map obtained from “Global Wind Atlas 3.0, a free, web-based application developed, owned and operated by the Technical University of Denmark (DTU). The Global Wind Atlas 3.0 is released in partnership with the World Bank Group, utilizing data provided by Vortex, using funding provided by the Energy Sector Management Assistance Program (ESMAP). For additional information: https://globalwindatlas.info”

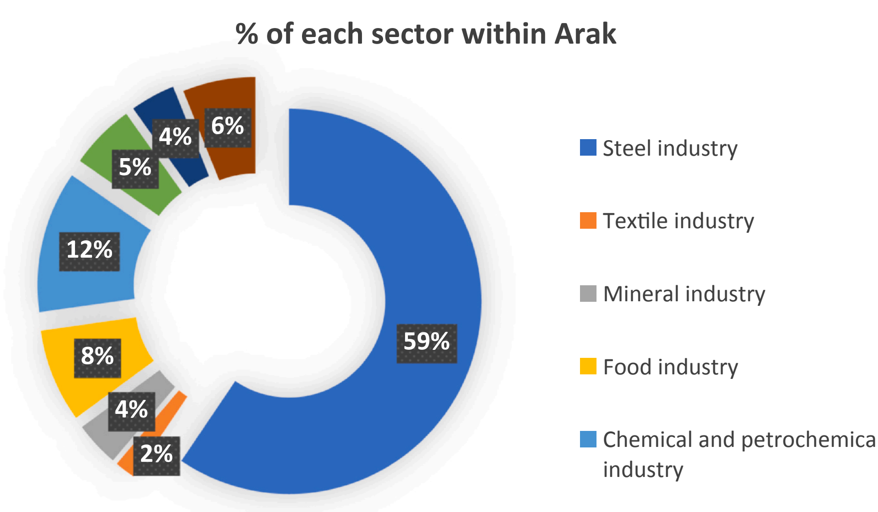

Fig. 5. Percentage of each sector within Arak industrial city [70].

not having enough trust in partners, and not having full autonomy over their electricity supply and consumption. This is mostly because these CEOs see the lack of a clear and agile legal structure in Iran as a critical factor that may put the whole partnership on hold in case of a serious conflict which can only be resolved in court. However, some of the CEOs did indicate interest in collective power generation as a potentially reliable solution to meet their companies' electricity demand. These CEOs believe that the partnership challenges can be overcome with effective institutional arrangements to manage conflicts that might arise due to different levels of trust, autonomy, etc. Last but not least, almost all of the interviewees mentioned that due to the poor condition of Iran's economy (worsened by the current boycott and global trade conflicts) they are unwilling to invest in a long-term strategic plan.

During our interviews, it became apparent that most industries in Arak had no or very limited information about renewable energy. Almost none of these companies were aware of the requirements of renewable power generation, its costs and the incentives introduced by the government to encourage such projects. As a result, they were inclined to see industrial scale renewable power generation as a mission impossible. Given the lack of knowledge, it seems that collective action towards an InCES cannot evolve spontaneously from the Arak industrial community itself. This issue was also experienced by cooperatives in Europe, like the case of formation of the REScoops[4] [73]. It seems that a third party may be needed to inform the industrial companies on the potential of renewable energy and to define a feasible project, which specifies the costs and benefits for all industrial partners involved.

5.4. Rules in-use

In this section, we explain the institutional setting that can affect the emergence of an InCES in Arak Industrial Cluster. We extracted formal rules (in-use and in-form) through legal documents and interviews and identified the informal rules in our interviews and workshops.

5.4.1. Current institutional setting for electricity management in Arak

As it was mentioned in Section 4, the only electricity provider in Arak is the regional power company as a subset of Ministry of Energy. This company provides a centralized system in which most of the electricity comes from a thermal power plant with a capacity of 1300 MW. In this system, each of the customers are billed for their electricity consumption at the beginning of the month and have a three weeks deadline for paying the electricity bill. Legally speaking, those customers who refuse to pay their bills after two official notices, will be detached from the electricity grid and in addition to paying the electricity bill with a surcharge, they will also be charged for getting reconnected to the grid.

Although Arak industrial cluster has been benefiting from relatively stable electricity provision over past decades, due to recent drastic

[4] REScoop.eu is the European federation of renewable energy cooperatives. It's a growing network of 1,500 European energy cooperatives and their 1,000,000 citizens who are active in the energy transition[74].

drought periods in Iran, the industrial sector faces frequent black-outs during hot seasons. To deal with this issue, the regional power company organizes scheduled black-outs (brown-out) during hot seasons to prevent sudden power outages. Although, this seems to be an acceptable solution, it would eventually result in insufficient production capacity for industrial companies.

In addition to the power outages during hot seasons, electricity posts located in Arak work with their full capacity indicating that there has not been sufficient investment for increasing the capacity to meet industrial developments in the region. Correspondingly, companies with expansion plans will be incapable of satisfying their additional electricity requirement. Asking for additional capacity is possible but is a long and bureaucratic process.

5.4.2. Institutions influencing establishment of InCES

The formal rules can be categorized into the following types:

- Rules regarding the establishment of a local private electricity market
- Incentives introduced by the government for producing renewable electricity
- Rules regarding transformation and transmission of electricity through the national grid
- Rules regarding the ownership of a grid that is developed by a private company in Iran

In this section, we will describe the rules and the institutional arrangements which have an impact on the establishment of an InCES.

Rules regarding the establishment of a local private electricity market

Currently, the price of each kilowatt hour electricity in Iran's industrial sector, based on the latest directive by the Ministry of Energy, is calculated as table 1:

It is allowed by law to generate and sell renewable electricity privately. As the price of electricity which is being offered by the government is highly subsidized, the chance of establishing a local private market with a higher price than offered by the government is low therefore currently there is no private electricity market for renewable electricity. However, at times of insufficient electricity supply from the government, the industrial consumer might be interested to buy electricity from a private supplier, if there is one. It could also be the case that at the location of the consumer there is no electricity grid and therefore, the private electricity market may be the only option. In this case, they only need to develop a grid between their company and the local power plant which, in some cases, would be relatively more financially feasible than establishing a grid between their company and the national grid.

Incentives introduced by Iran's government for producing electricity from renewable sources

- **Land allocation:** In some places, based on the availability, the government has committed itself to allocate land for power generation from renewable energy sources. The land would be rented to the producer almost free of charge for long periods.
- **Feed-in-tariff (FIT) incentives:** the government will buy the generated renewable electricity based on a FIT system. The FIT system's budget is financed by allocating 8% of each electricity bill which the government collects from all the electricity consumers per year. The price of generated electricity varies based on the scale of production and is calculated as depicted in Table 2:

Table 1
Price of Electricity for Industries in Iran [74].

Consumption time	Price (IRR per kWh)
Peak time	1,270 (0.01 €)[1]
Mid-peak	639 (0.005 €)
Off-peak	320 (0.0025 €)

[1] At the time of conducting this research, the exchange ratio between Iranian Rial and Euro was: 1 € = 126,000 IRR.

Table 2
Price of renewable electricity to be purchased by the government [75].

Amount of RE production	Price (IRR per kWh)
Capacity less than 20 kW	8,000 (0.063 €)
Capacity between 20 and 100 kW	7,000 (0.055 €)
Capacity between 100 kW and 10 MW	4,900 (0.038 €)
Capacity between 10 MW and 30 MW	4,000 (0.031 €)
Capacity more than 30 MW	3,200 (0.025 €)

Based on the FIT contracts and according to the production scale, the above prices would be fixed and guaranteed for a 15 years period. In addition, the average inflation rate would be added to the annual payments by the government.

- **Financial aids:** The government supports renewable electricity producers to invest in renewable energy technologies in the form of bank loans to cover up to 80% of the required investment with a 5 years grace period. It must be noted though that the interest rate for these loans is relatively high (currently 18%).

Rules regarding transformation and transmission of electricity through the national grid

In case the power plant is connected to the national grid, it is allowed by the government to export the power to the grid and import it somewhere else almost free of charge. This can be an effective incentive for those producers who are harvesting renewable electricity in the central parts of Iran (where solar irradiation intensity is highest). They may choose to export the power generated to neighbouring regions or countries. An InCES in Arak could also decide to harvest solar power in central Iran and use the national grid for free storage and transmission to the location where the power is consumed.

Rules regarding the ownership of the grid that is developed by a private company in Iran

Development and ownership of a private electricity grid is possible but must be done under the supervision of the regional power company. If the private grid is to be connected to the national grid, the design of the private grid should be approved by the regional power company. Also, if the private grid is connected to the national grid, the access of the regional power company to this grid cannot be excluded.

5.4.3. Informal institutional setting

By interviewing various industrial CEOs and holding workshops, we aimed to identify the informal rules and norms that apply within the current community of industries. Generally speaking, the CEOs of the industrial companies in Arak are confident that they are able to gain support from the local government, as the government is dependent on the local industrial sector to curb the unemployment rate in the region. The CEOs tend to trust the local government, as they see the interests of the local government to a large extent aligned with the interests of their own companies. Regarding the mutual trust among the industrial companies, we see large differences. From the responses of the interviewees, we already concluded that many industrial companies in Arak are not eager to partner with other companies, for lack of trust in the reliability of a partnership. The mutual fund system, however, illustrates that there is a community of industries in Arak which trust each other enough to help one another in financially or technically difficult times by lending money or giving free technical consultancy. Overall, this implies that we are dealing with a fragmented community regarding mutual trust in Arak industrial zone.

Furthermore, the interviewees response to the questions regarding the electricity price and availability reflected that most of the CEOs see their companies as entitled to abundant supplies of cheap electricity. This attitude is the traditional norm for oil-rich countries which however, is rapidly changing [76]. It creates a negative atmosphere towards generating electricity from renewable resources which would require a large upfront investment.

Another social norm in the industrial community of our case study which was mentioned by the managers of two industrial clusters in Arak during the interviews and is worth highlighting here is that the companies of an industrial cluster normally look up to the bigger and more powerful companies in that cluster. This means that the level of persuasiveness among the companies are not the same. Therefore, leadership for such collective projects may be largely dominated by bigger companies.

In our interviews with the CEOs, we specifically probed the members of the “community bank system” to get a better understanding of the agreements and rules that they collectively defined to manage the system and to ensure its robustness.

We categorized the existing in-use community rules which may also be functional in the case of InCES, using Ostrom’s eight design principles [28].

i) Clearly defined boundaries

In this regard, the founders of the community bank system defined a set of strict entrance rules in order to build a trustworthy environment for the potential members. Any candidate requesting to join the community, will be subjected to a background check on the basis of which he can be accepted or rejected.

ii) Congruence between appropriation and provision rules and local conditions

The amount which the system can provide in loans to the members is equal to the cumulative amount which was invested by the members when they joined this system. There is a minimum investment contribution for each member joining the community.

iii) Collective-choice arrangements allowing for the participation of most of the appropriators in the decision-making process

In this system, institutional arrangements (rules by which the community bank is supposed to run) were being defined through a democratic process in which all the members had the right to vote.

iv) Effective monitoring by monitors who are part of or accountable to the appropriators

For monitoring the status quo of the system, an accountant was hired. The role of this inspector position is to monitor if the loans to members are being paid back on time or not. The accountant provides a monthly report on the financial situation of the bank.

v) Graduated sanctions for appropriators who do not respect community rules

Founders of this system deeply believe that trust-killing actions by the members should be strictly sanctioned. Accordingly, there is a consensus among members that if any member’s action is damaging trust, that member will be sanctioned, which implies that he/she will not be allowed to join any other collective initiative in the industrial cluster (which is counted as an intense punishment). Trust eliminating actions are normally related to delays in payback.

vi) Conflict-resolution mechanisms which are cheap and easy to access

Although the founders of this system tried rigorously to avoid any type of conflict by setting strict entrance rules, they defined a mechanism as the guarantee for the loaned money in case there is a conflict between the system and a member. In this sense, if a member is borrowing money from the bank, he/she should deliver a check with the same amount to the inspector as the guarantee.

vii) Minimal recognition of rights to organize (e.g., by the government)

There is a board of directors who are elected by the members and these directors have discretionary rights to decide about some issues such as extending the period of a loan, prioritizing requests when there is a high number of requests for borrowing money, etc.

6. Result: Can community energy be a solution for Arak?

In this research, our goal was to see whether a community energy system, like the ones established between households in a neighbourhood, can emerge in a cluster of industries. In other words, we aimed to study whether industrial actors can also perform collective action to pursue shared goals. We used the IAD framework to analyse an industrial cluster in Arak, Iran and conducted multiple interviews and organized workshops to grasp the technological, institutional and community attributes of the system.

Our analysis shows that collective action can be a possibility for energy management among industries in Arak and potentially other places as we explain below.

In terms of technological and biophysical feasibility, it is possible to have a renewable power plant that can meet the electricity demand of the industries that would like to join the collective action project. Yet, other requirements need to be addressed in this regard including grid connection and storage. Given the rules in place for the use of the national grid, it is economically more attractive for industries in the collective project to stay connected to the national grid than to develop an off-grid project which would require substantial additional investment in energy storage capacity. The grid connection also caters for the widely different consumption patterns of the various industrial companies in Arak, so that coordination mechanisms for the use of power generated in the collective project are not needed.

Yet, there are many other social and institutional challenges, that are critical for the success or failure of an InCES in Arak. Starting from the institutional barriers, the uncertainties involved with government incentives make the system extremely vulnerable in terms of technological and financial independence. On the one hand, staying connected to the national grid is financially, technologically and security-wise the safe option. On the other hand, industries may not be wise to count on the feed-in-tariffs and payback arrangements recently introduced by the government, as the regulations may change again.

Regarding the community aspect of the system, the biggest challenge is that unlike households, industries do not have similar or comparable electricity consumption in terms of volume and pattern. While some industries are large and have high demand with limited working shifts, others may be small but with 24-hour working shifts. Therefore, their requirements and their investment possibilities and interests vary to a great extent. As such, collaboration, and reaching an agreement is more difficult than in traditional community energy projects among households.

Nonetheless, given the results of our analysis, it seems that even with all the vulnerabilities coming from the government side, a collective investment in electricity production from renewables is still an attractive solution for the industries in Arak as it actually makes them more energy independent than any other solution. Connecting the renewable power plant to the national grid is a crucial condition for the feasibility of the project, as a grid connection obviates the need for investment in energy storage capacity. In fact, it appears that even if the project cannot rely on government payback with regard to electricity feed-in, it is still economically feasible.

6.1. Proposed institutional design principles for collective action in InCES

In addition to the existing principles that hold for typical collective action problems including community energy systems among households, to establish an InCES the following principles for institutional arrangements hold:

1- Management of diversity: given the immense heterogeneity among members in multiple aspects, it is important to come up with rules that specifically address how members with such different profiles can 1) invest in a shared resource system and 2) use it. Computer aided support may in fact be helpful in this respect (see for example GENIUS [77] for electronic negotiation).

2- Trust building: as mentioned previously, electricity is one of the most crucial requirements for any industrial company. This is why many industrial companies are deciding about joining the InCES rigorously and seriously. Any successful experience which can enhance the industrial companies' mutual trust is greatly helpful in encouraging industrial companies to invest in an InCES.

3- Long-term vision: satisfying industrial electricity demand requires large and long-term financial investments. Therefore, the economic stability of the country in which the investment is taking place is a crucial factor.

Our final and key finding is the importance of community spirit among industries which we had not foreseen before this analysis. Regarding the social aspects of collaboration, although differences in the size and type of industries make collaboration very challenging, reaching consensus may still be feasible, at least in our case study. The community banking system established in Arak has demonstrated that the heterogeneity challenges in a community of industries can be tackled. It is very promising to see that a *community culture*, which is a main attribute of a community according to the IAD framework, already exists within the Arak industrial cluster and that there are strong social ties between the CEOs of the industrial companies. These existing ties are a strong cultural basis for further collaboration, in particular for a community energy system where the shared interest is strongly acknowledged by all members.

6.2. Lessons for InCES from a global perspective

This research focused on a specific case. Although the challenges for an InCES in Arak may seem very different from other industrial zones in the world, the challenges and opportunities of such a project are in many ways also similar. For example, although government related uncertainties may not exist or be as strong in other countries as in Iran, the fact that the world is moving toward a carbon–neutral footprint puts pressure on industries around the world to reduce their CO_2 emissions, hence providing similar incentives for industrial companies in other countries to join in collective action.

The three design principles: diversity management, trust building and long-term vision hold for every industrial zone. It is important to stress that the most important finding of our research that leads to successful design of these three principles is community spirit. In an industrial zone, community spirit plays a huge role in the success of such projects by reducing points of conflict. This aspect is especially important given the differences in size and type of industries which complicates negotiations and collaboration in general. The Arak industrial zone has the advantage of existing community collaboration. For other industrial zones in the world, if similar community spirit exists, the chances of successfully establishing an InCES are equally promising.

7. Conclusion

The goal of this research was to use a collective action perspective to study whether community energy projects which commonly take place among households are possible in industrial zones where the members of such projects are industrial companies. We used the IAD framework to analyse the system and to identify the opportunities and challenges for such form of a collaboration.

Focusing on Arak as our case study, we found that even with the many uncertainties industries face with regard to the incentive mechanisms provided by the government at different levels, an InCES is a promising approach to reach an acceptable level of independence for meeting electricity demand.

By looking into the key factors highlighted by the IAD framework, we were able to touch upon issues that would have otherwise not been in the spotlight to explore in this study. Most importantly, the "attributes of the community" part of the IAD framework was particularly insightful. The key factor that plays the most significant role in successfully establishing collaborative projects is the community spirit and the social bonding between the industrial partners in the cluster. This does not only hold for Arak, but any other zone in the world and the reason for that is the diversity of industries and the importance of trust. Since industries are different in terms of type and size, reaching consensus to initiate such projects and to resolve potential conflicts are extra challenging. The social bonding among industries can be a catalyser and a lubricant to smoothen such processes.

Although our key findings seem to hold for other industrial zones around the world, from a formal institutional perspective, given that there are no strict enforcement mechanisms to reduce CO_2 emissions, industries in Arak are only driven by financial incentives rather than environmental factors. This could be a point of difference between this cluster and other industrial clusters around the world.

Although the interviews provide many insights, the number of interviewees was limited to gain a full understanding of the opinions of the industries. Therefore, our next step is to conduct a survey among industries to better identify their characteristics and to propose pathways that can facilitate the formation of InCES in industrial areas. As a continuation of this research, we will continue to use the IAD framework and we will focus on the Action Situations to formulate the aforementioned pathways.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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