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Review

Need of Integrated Regional Planning Approach for the Decentralisation and Optimisation of Renewable Energy Based Electric Vehicle Infrastructure: A Comprehensive Visualisation

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Abstract: The existing research narrates avenues in the regional and thematic area preconditions set via the framework and institutional mechanism towards energy decentralisation (ED). Moreover, with the entrant stakeholders and inclusive energy policy, the researchers find potential in local resources and capacity towards the decarbonisation of the economy. Consequently, governments around the globe emphasise multi-level sectoral economic support packages to buffer the immediate to medium-term gap and subsequently investigate their implementation in infrastructure and technology. The present review attempts to focus on the conditions of energy transformation in enabling a policy and regulatory framework. As such an integrated regional spatial framework focuses to identify support packages across urban and rural planning, transportation, renewable energy, infrastructure, environment and climate change and sustainability. Moreover, the present review revolves its thematic focus around the transport sector to strategize the energy decentralisation of the local potential in the ongoing electric vehicle (EV) transportation. The presented review toils on EV users' struggle to orient to the need of the hour in the inadequacies of refill/charging infrastructure. Thus, it is imperative to review parameters such as availability and access to charge, depending on the source of energy in the charging infrastructure, facilities and services at the regional level. The presented review investigates under categoric and key search across conceptual regional settlement hierarchy to strategize the development of the Renewable Energy based Electric Vehicle Infrastructure (REEVI) package under system, support and services (SSS). Conclusively, the review study brings out a tentative regional settlement hierarchical integrated methodology for REEVI-SSS in the missing linkages and gaps of spatial planning to ease medium and long trip EV transportation challenges faced at the inter-city–rural, i.e., regional level.

Keywords: decentralisation; EV transportation; charging infrastructure; integrated regional planning

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1. Introduction

The current development trend links to the increase in travel pattern demand in many countries with varying spatial morphology [1]. Research concern on unmet future energy demand from current sources of non-renewable energy, i.e., fossil fuels, etc. due to their sooner resource depletion [2]. Studies on the environment and climate change show that the transportation sector alone produces about 14% of the global greenhouse gas emission [3,4] due to unclean sources of energy. For example, the City of Calgary has a very high carbon footprint per population as Canada's oil and gas capital [5]. Similarly, the United States [6], Malaysia [7], Korea [8], etc. have a high carbon footprint. In view of such environmental and climate change repercussions, the source of energy is being transitioned from non-renewable energy to renewable energy (RE) across the globe.

The literature on global energy transformation investigates the technical and economic nature of an augmented energy transition by 2050 [9,10]. The analysis highlights that the core elements of the energy transition are based on energy efficiency and RE technologies and their integration. Conducive economy, optimisation of resources, scalable technology, and critical socioeconomic advantages reinforce such a transformation. It is evident now that about two-thirds of the earth's energy demand can be supplied by renewable energy [11–13]. It can lead to the bulk reduction of the greenhouse gas emissions as required between now and 2050 to limit the average earth's surface temperature increase below 2 °C [14,15]. Thus, an adjustment in enabling policy and regulatory frameworks will be required to mobilise the six-times acceleration of renewables growth with the highest progression projected for wind, solar photovoltaic (PV) technologies, etc., accompanied by a high level of energy efficiency. However, new technology and innovation will be required to ensure the ultimate removal of carbon dioxide emissions, especially in the transport and manufacturing sectors.

Findings from the special issues in Renewable and Sustainable Energy Reviews, stress upon the policy and incentives, scope, stakeholders and types of decentralisations cannot be generalised but remains country-, as well as region-specific. Moreover, it adds that energy decentralisation (ED) witnessed in the unbundling and liberalisation of the energy market has further emphasised the clean technology transition for decarbonisation. The engagement of new actors such as civil society mobilisation is going on in the wake of climate change with its provision at the international and national agendas. ICT, sensors, demand response, distributed storage and electric vehicles endure unbundling upcoming occasions for the participation of new actors, unsettling old business and institutional models of electricity generation, distribution and trade. The United Nation General Assembly has launched a Global Action Plan for Decentralised Renewable Energy (DRE), setting ED crucial to the achievement of Sustainable Development Goals numbers 7, i.e., energy access to all [16]. However, the RE decentralisation lies in its inclusivity of the stakeholders at the local [17] scale through conducive implementation mechanisms and incentives. For instance, studying the solar home systems implication, Khan [18] proved that these effects are influenced due to absence of financing structures and technical backing. It conditions the broad organisational base for numerous remote energy access assignments in developing nations [16]. As such, to support local potential and remote access, the earlier five-year plans of India deliberated upon regional studies to implement decentralisation through integrated spatial planning towards equitable distribution of public goods and services, facilities, infrastructure, etc. [19].

To enrich the ongoing research on energy decentralisation and local inclusion around regional and thematic areas, the presented paper focuses on the enabling policy and regulatory frameworks as the preconditions of energy transformation to identify the regional spatial economic support packages. Based on these accords, this review research brings a multi-level–sectoral regional spatial integration of urban and rural planning, transportation, local RE, infrastructure [17], environment and climate change and sustainability. The transport sector, as the significant contributor to deal with global energy demand and sustainable development, remains the thematic focus of the present review research [16].

Examining the ongoing attempts, electric vehicles (EV/s) are introduced in many cities and countries for use of green and clean energy aligning to renewable sources in the transportation sector to meet future energy demands, curb pollution and global warming. EV launched in various countries will cut down the repercussions due to consumption by combustion vehicle's energy or fuel system. Nevertheless, the implementation and use of EV seems to face stiff challenges in developing countries such as India. However, India has also introduced the electric vehicle charging infrastructure (EVCI) handbook to implement public electric vehicle charging stations (EVCSs) [20].

1.1. Contributions of the Paper

The presented review paper dives deeper into the ongoing policy attempts across existing global research to deal with the agitation of EV users making medium and long trips. On the other hand, the policy intervention needs a holistic preview and understanding from the users' end to ease the trips to promote EV ownership and transportation and supporting charging infrastructure, as well as RE transition. Therefore, this review investigates the provision of supporting public charging infrastructure and services to facilitate medium and long trips for EV transportation at the regional level.

The presented paper strategizes the RE decentralisation potential in ongoing EV transportation promotion in India. In addition, this paper strategizes the demand and supply of RE for EV users struggling to orient the need of the hour. Such inadequacies of refill infrastructures have been strategized in this paper to complement the transportation needs of medium and long trips of EVs. As such, it makes it imperative to study the parameters, for example, availability and access to the charge and source of energy in the refill infrastructure, facilities and services at the regional scale. Considering such evidence, this paper carries the review of articles under categoric and key search as fits into the regional settlement hierarchy to sort Renewable Energy Based Electric Vehicle Infrastructure (REEVI) package under system, support and services (SSS). The study brings out a tentative integrated regional settlement hierarchical methodology for the REEVI package (SSS) in the missing linkages and gaps of spatial planning to ease EV transportation challenges faced at inter-city–rural patterns for the regional level.

Most of the existing research was found on the EVCSs during the literature review on the electric vehicle infrastructure (EVI). However, the existing body of research dealt with the location and optimisation of EVCSs in specific domains in a piecemeal attempt. In contrast, studies also use the method of traffic pattern for EVCS locations, and optimisation is done, which also facilitates the intra-city movement of EV circulation. Additionally, the location of the EVCSs is suggested along transport corridors and highways of regional significance, as evident in the body of knowledge. Recently, the concept of a source of energy in EVCS optimisation has been much talked about. Furthermore, the existing research fraternity dwells on transition of energy from non-renewable to renewable energy sources. The evidence of EVI seems to have disintegrated attempts in missing spatial hierarchical understanding and approach.

The presented review tries to integrate the existing ED and local inclusivity as valuable efforts under the package [16] of REEVI-SSS in a regional spatial planning hierarchy approach. Therefore, the articles were segregated under the REEVI package of SSS. Further, the REEVI package of SSS was classified under the Regional Spatial Planning three-tier Hierarchy, i.e., Local Area Level, City Level, and the Regional Level. Finally, spatial planning gaps and missing linkages are visualised. Thus, an attempt to integrate the existing piece-meal efforts through regional RE decentralisation with local inclusive spatial planning approach brings novelty to the presented review article.

1.2. Organisation of the Paper

The paper has been structured as Section 7, Section 1 discusses the introduction and background on EV transportation and energy demand of the transport sector with the context of carbon emission. Additionally, its emphasis on energy transition and the targeted need for renewable energy to boost regional EVI. Moreover, it discusses the novelty in comparison to the existing methodology contribution of the body of knowledge. Thus, the Section 2 brings out the classification of system, support and services under REEVI packages in the approach to integrated regional spatial planning. Further, the Section 3 discusses the development of methodology through key search on EVI, whereas the cumulative literature distribution over last two decades to demonstrate the missing linkages as a comprehensive strategic visualisation to implement RE towards Sustainable Development Goals (SDG) are described in Section 4. A hierarchical methodology has been proposed in Section 5 to fill the missing linkages in spatial planning for REEVI and regional settlement planning. Furthermore, discussion is put forth in the Section 6 that states the gap of an earlier state-of-the-art and need of policies and framework reformation to achieve holistic sustainable development for city planning duly considering ED and REEVI. This section also points to the scope and limitations of the presented article. Therefore, it sets the way for further work and outcomes beyond this review paper. Finally, a conclusion is drawn in the Section 7 to sum up the presented paper for advancement and application to the research fraternity and stakeholders.

2. Classification of System, Support and Services for REEVI Package and Spatial Planning

2.1. System

It is observed that the existing research concludes on drawing the source of energy to EVCSs optimisation lie in renewable energy [18] available locally [17]. The presented paper views devices, hardware, technology, utilities, etc. of energy decentralisation [16] efforts as a 'system' for the purpose of urban and regional planning and the optimisation of EVI. Thus, RE-dedicated devices, hardware, technology and utility, for instance, EVCS is denoted by 'system' for the purpose of reviewing the approach of spatial study in urban and regional planning. Rightly, calling it as renewable energy-based electric vehicle charging stations (REEVCSs) in Figure 1. Further, setting the REEVCS identifies the REEVI system (Figure 1) as literature findings, covered in Table 1. Thus, the REEVI system of Devices/Hardware/Utility that fits in the final REEVI package (SSS) setting. Furthermore, the systems as [16] public hotspot [21] activities prevalent in existing research fits at the local [17] level in the urban and regional spatial planning hierarchy.

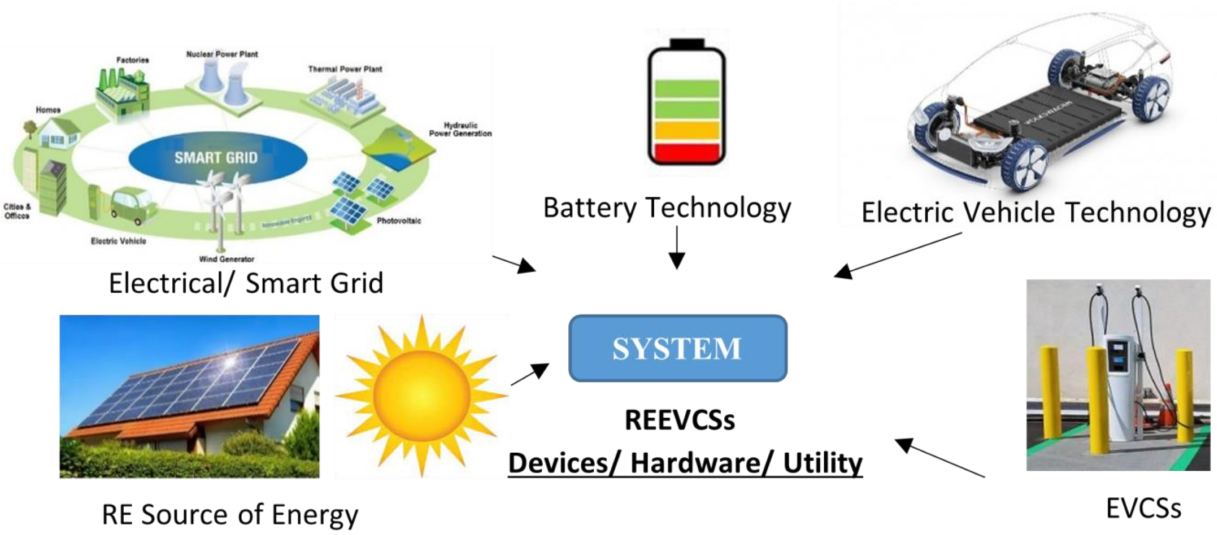

Figure 1. Setting REEVCSs for the REEVI system.

Table 1. Research on REEVI system Identification.

S. No.	Reference	Type of Research	Findings
1	[22,23]	Battery Technology in EV	• Battery remains the prime focus of most of the research.
2	[24–29]	Electrical Grid for EVCSs	• Research confined to electrical source of charging infrastructure.
3	[30–48]	EVI Source of Energy	• Technology advancement explored for Hybrid Vehicles and its infrastructure. • Renewable energy-based charging infrastructure system.
4	[21,49–65]	Smart Grid for EVCSs	• Integration of smart system for renewable energy. • Quality based research appeared for user satisfaction understanding. • Decentralisation of renewable energy sources.

Table 1. *Cont.*

S. No.	Reference	Type of Research	Findings
5	[8,21,49–52,66–75]	EVCSs location	• Infrastructure needs addressed on mobility pattern. • Optimal location of EVCSs dedicated to EV transportation system
6	[76]	Electric Vehicle User Experience	• Some indication of system learning based on users of EV.
7	[77,78]	RE Policy	• Few research oriented to understand the energy transition and policy scope for EV systems

2.2. Support

Existing studies for EVCSs are dedicated on roadside amenities and utilities (such as shopping mall, parking, etc.) as the strategic identification of public hotspots [21] to facilitate city-level EVIs for EV trips. These public hotspots are parking lots, hotels, shopping complexes, office buildings, etc. [21]. Understanding drawn from the current body of knowledge, the review studies of REEVI support were set (Table 2) in order to facilitate user experience of end-to-end user-friendly services (Figure 2). Various land use and transportation models such as work–home relations provided much ease to commuters' experiences in transport planning studies. To ease the medium and long trips of EVs, the roadside amenities and land use are called the 'Support' [16] for the purpose of presented review study.. Further a REEVI Support of public hotpot area fits in land use activities at the intra-area level that, in turn, fits in the services of settlement and hierarchical facility planning.

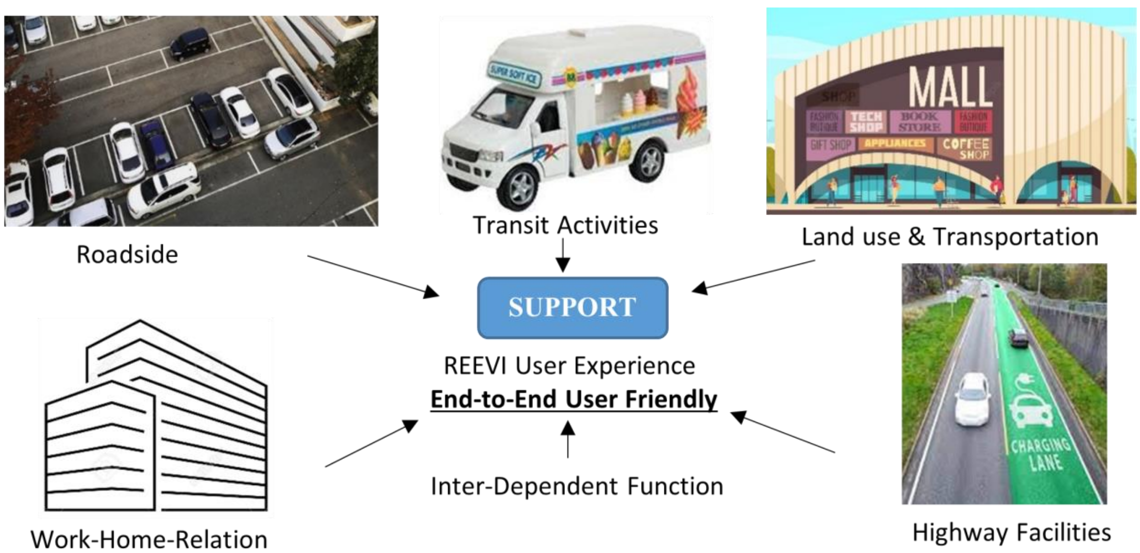

Figure 2. Setting for REEVI Support.

Table 2. Research on REEVI Support Identification.

S. No.	Reference	Type of Research	Findings
1	[79–91]	Mobility Resources Electric Vehicle Use	• Research witness to achieve breakthrough technology on battery charging, battery power/range, battery charging, duration of charging, access to charging can provide ease to Electric Vehicles (EVs) users.
2	[37,92–98]	EV Infrastructure (EVI)	• Economic and Environmental Prospects for Battery Electric- and Fuel Cell Vehicles also remains a challenge for EV

Table 2. *Cont.*

S. No.	Reference	Type of Research	Findings
3	[84,86,88,94,99–110]	Electric Vehicle User Experience	• Most of the research were found about the lack of public Electric Vehicle Charging Stations (EVCSs) and emphasised to study on locational prospects of EVCSs.
4	[31,106,110]	EVI Source of Energy	• Transport and corridor studies suggests on installation of EVCSs along highways. • Traffic density studies have been carried for access to charging identifying EVCSs pattern at City Level.
5	[111–115]	EVCSs location and optimisation	• Ranking of preferred EVCSs location identifies public hotspots, e.g., hotels, apartment buildings, workplaces, fuel stations, universities, shopping malls, supermarkets, restaurants, hospitals, airports, amusement parks, movie theatres, train stations, libraries, zoos and stadiums

2.3. Services

The existing literature dwells upon energy decentralisation and inclusivity for RE dedicated network of charging infrastructure and government investments for new Electric Vehicle Charging Projects (EVCPs) [31]. Additionally, research Canada brings the understanding of legislative codes and standards applicable to EVI deployment. Similarly, India introduced the EVI handbook and guidelines [20], where the increase in the EV industry across the world is basically driven by the demands of consumers [31] as a location of EVCSs. In India, it is evident that the factors affecting the location of charging infrastructure highlights the need of regional policy and standards to access EVI [116] dedicated to renewable energy in the local potential [117]. Finally, the set of policies, standards, norms and guidelines, etc. complies to set the 'services' for review investigation of the present research (Figure 3) for the REEVI hierarchy of services. Therefore, the REEVI services were spotted from the research in the ongoing effort (Table 3) to fit in services such as hierarchy, settlement pattern and transportation, networking and clustering. Thus, the REEVI package of services suits the settlement (urban and rural) and services planning in Figure 4 as well as spatial planning hierarchy of Figure 5.

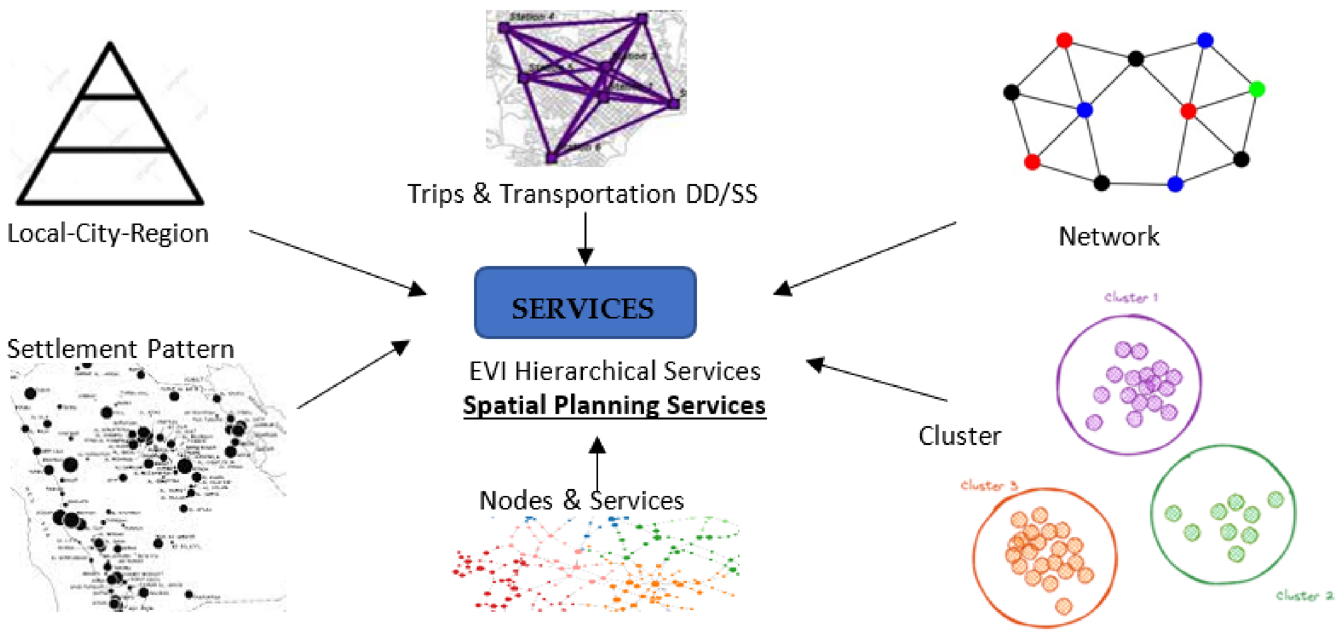

Figure 3. Setting REEVI Services.

Table 3. Research on REEVI Services Identification.

S. No.	Reference	Type of Research	Findings
1	[7,9–11,13–16,18,52, 54,58,114,118–124]	RE Policy	• Preconditions such as source of energy for location of EVCSs holds future in Renewable Energy (RE)
2	[31,111–116,125]	EVCSs location and optimisation	• Various RE works seems underway via energy, economic and environmental GIS–based analysis of shallow geothermal potential in urban areas
3	[4,50,125,126]	RES integration	• National policy emphasises on renewable energy transformation based EVCSs.
4	[125,127]	Electric Vehicle User Experience	• Review of energy pattern have been carried in the transport sector • Energy transition is happening across the globe.
5	[4,31,51,61,63,92,93, 97]	EVI Source of Energy	• City mobility and EVCSs pattern to access charging caters to short-run trips. • Optimal operation and simultaneous analysis of the electric transport systems and distributed energy resources are carried in the smart city.

2.4. Renewable Energy Based Electric Vehicle Infrastructure (REEVI) Package

The review in Table 4 visualises the research done across the three components of the package of REEVI-SSS. Table 4, presents the segregation of articles across system, support and services, where "✓" symbol shows the consideration and "X" shows the omission relevant to SSS. This review lays the base to understand urban and regional (spatial) planning in the evidence of above set components of 'system, support and services' (SSS) for RE dedicated EVI. The optimise and spatially integrate location of EVI services is knowns as REEVI package (Figure 4) in the knowledge of energy decentralisation and local inclusivity [16]. The presented review dwells upon system, support and services (SSS) collectively calling the 'REEVI package' [16] to set the hierarchy, level, and scale for review assessment of integrated regional spatial planning (Figure 4) approach towards energy decentralisation [128]. Figure 4 presents the devices, hardware, and utilities encompass as a 'system', which is located at activities carried out by population fits in the spatial planning and land use which were referred as public hotspots in earlier research. In turn, the 'support' could be arranged or optimised under order of 'services' via hierarchy, networking, nodes and cluster in the interest of urban and regional planning and "REEVI package' optimisation associated with the integrated spatial hierarchy (Figure 5).

Table 4. Literature Identification across the REEVI Package of System, Support and Services (SSS).

S. No.	References	System	Support	Services	Studies on REEVI Package
1	[3,8,12,18–26,30–32,34–39,43–45,47,49,50,52–54,56,57,59,61–68,70–72,85,97]	✓	X	X	X
2	[6,76–84,86–88,90–93,95,96,98–102,105,106]	X	✓	X	X
3	[1,2,4,5,7,114,119,120,122–126,129–134]	X	X	✓	X
4	[33,40–42,73–75,85,97,103,104]	✓	✓	X	X
5	[9–11,13–17,46,48,51,52,55,58,60,115–118]	✓	X	✓	X
6	[31,89,94,107–112,128,135]	X	✓	✓	X
7	[27,29,69,113,121,127]	✓	✓	✓	✓

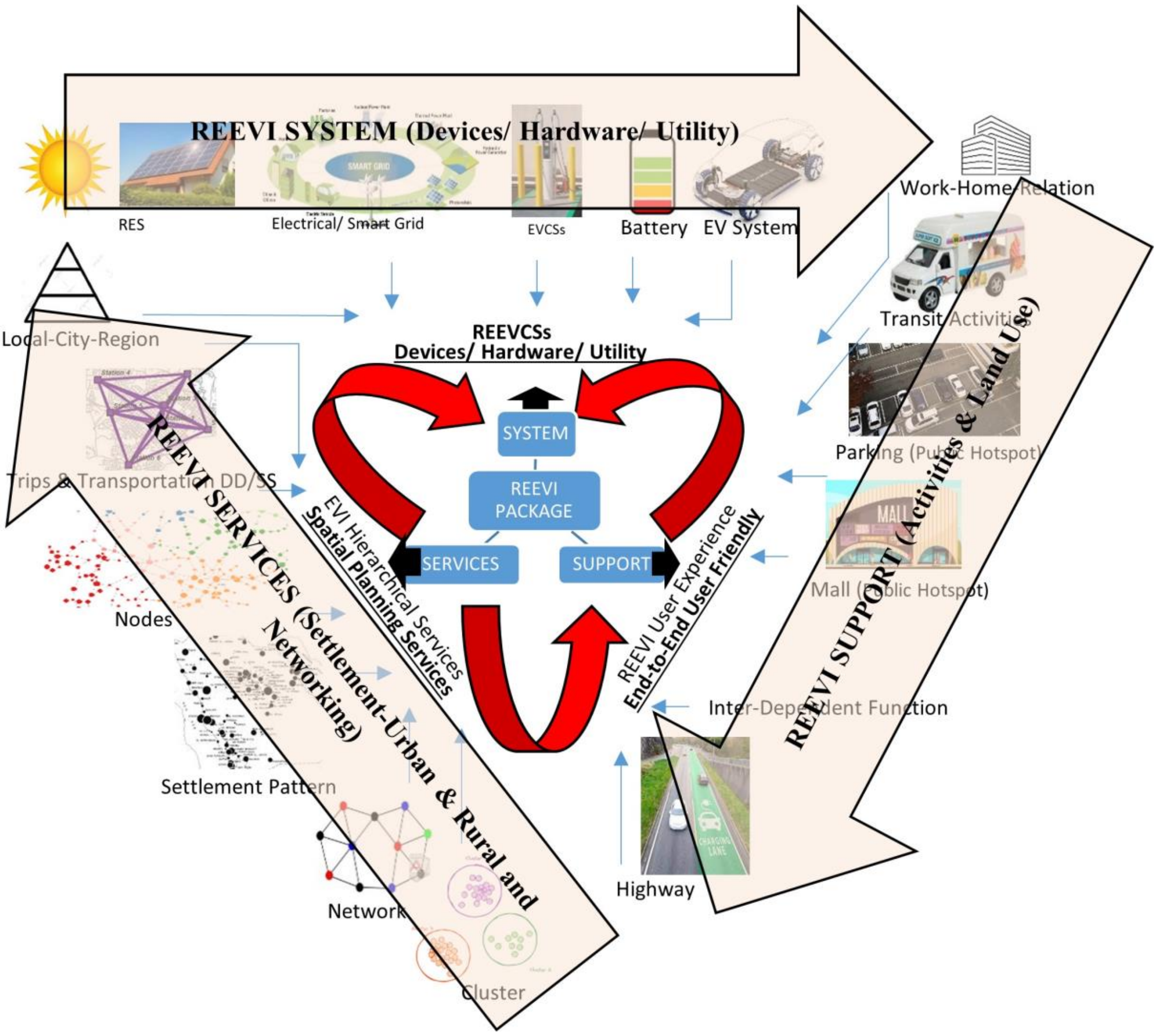

Figure 4. Urban and Regional (Spatial) Planning REEVI Package Setting, Source: Authors.

2.5. Hierarchy and Scale in Integrated Regional Spatial Planning

Inclination towards EVs suffer the issue of EVCSs optimisation and technology, etc. The present integrated regional spatial planning EVI optimisation review categorises the point locations (of system), as 'unit level' understanding within the confinements of the 'local area level' to cater short trips of EVs fits at the base of the three tier-hierarchy of integrated spatial planning approach (Figure 5). As such the SSS seems to be currently available at the local level to facilitate the short trips of EVs. Thus, the setting of REEVI package in Figures 4 and 5 intends to maximum the 'local level' potential to enhance the medium and long-distance transportation of EVs. To facilitate medium-range trips, the second hierarchy, i.e., the 'city level' fits right above the 'local area level'. Additionally, the studies on highway corridor [7,47,63] approaches towards location optimisation of EVCSs show some understanding on regional trips as found to underline the need of integrated spatial planning review to optimise EVI. Therefore, to manifest the long-distance trips of EVs needs a third and final hierarchy of 'regional level' lies at the top of 'city level'. Additionally, the existing disintegrated knowledge of the REEVI package is distributed across the integrated regional spatial levels through cluster, nodes, network and hierarchy. Interestingly, the presented review paper impacts the overarching need of energy decentralisation in local RE inclusivity from grassroot level to regional level distribution of EVI for transportation EVs integrating the existing knowledge. However, the technology advancement of EVCSs and EV would also implicate the integrated regional REEVI is outside the scope of the review.

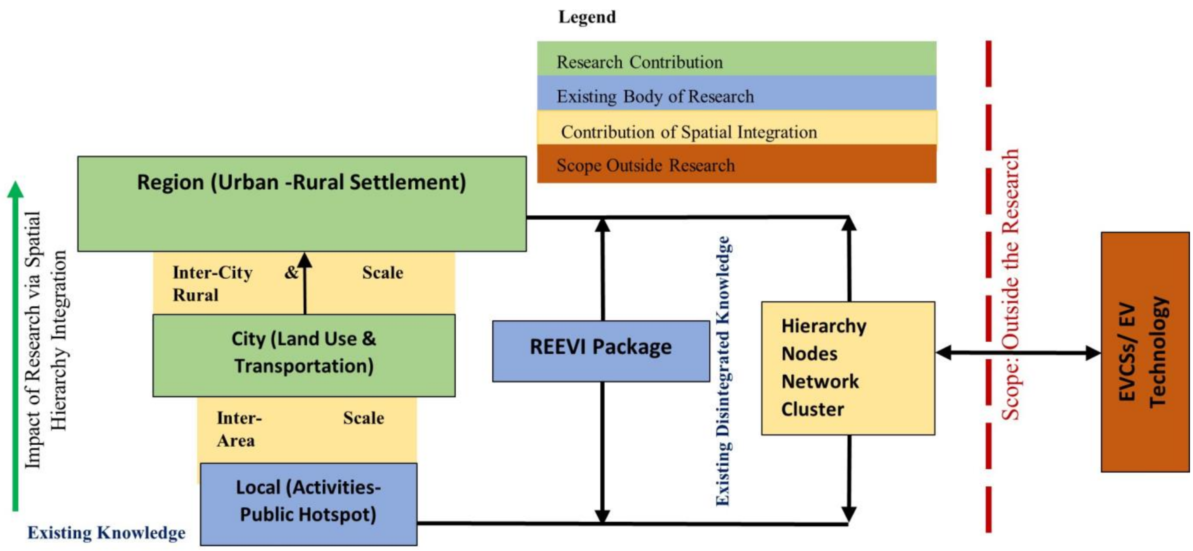

Figure 5. Hierarchy and Scale in Spatial Planning. Source: Authors.

3. Methodology to Identify Spatial Planning Gaps

The presented review article gives increased attention to spatial planning gap and missing links to integrate electric vehicle infrastructure (EVI) policy for regional EV transportation demand and supply based on renewable energy. Therefore, in an approach to regional spatial planning integration review, this research carries search on existing research articles on specific key arguments, i.e., energy and economy, optimisation of resources, scalable technology, and socioeconomic condition. Although, the key search gave further challenge to modify and refine them to existing research efforts due their domain specific studies. This points that the importance of missing spatial and integrated regional studies are required to integrate and network the package of REEVIs across scale and hierarchy to decentralise the energy network system [128].

Finally, the presented review identifies that the electric vehicle (EV) users' struggle towards their regional trips due to the inadequacies of public refill infrastructure in case of medium and long trips. In turn such inadequacies were found to exist due to the unavailability and in access to charge for medium and long trips across regional spatial planning hierarchy. Moreover, this is closely associated with the problem of source of renewable energy to refill and facility to support inter-city and regional demand and supply for EV energy and transportation in its EVI [7,11,13,135].

The presented paper adopts the method of integrated spatial (regional/settlement) planning hierarchy. Thus, the methodology in Figure 6 carries key search on energy and economy, optimisation of resources, scalable technology and socioeconomic condition as found in recent article of year 2022 and 2023 on EVI. However, research on battery, EVCSs, RE, solar and charging technology became more evident during the key search. Thus, it was observed that many literatures did not directly relate to spatial planning due to existing domain specific investigations. Thus, a more fine-tuned keyword search carried on EVCSs, EVCSs location, EVCSs optimisation, EVI and EVCSs, RE, solar and wind potential, charging technology, etc. gave an understanding of components to set the REEVI package Integrated Regional Spatial Planning hierarchy approach.

Further, the REEVI made evident that the presented review holds a mix understanding of system, support and services (SSS) that needs systematic sorting and hierarchical arrangement in the integrated regional spatial planning approach to optimise REEVI (Figure 6) services [16]. The sorting and arrangement along a three-tier hierarchy, i.e., Local Area Level, City Level (Figure 6) and the Regional Level, appeared to have potential towards optimisation of REEVI to facilitate medium and long trips of EV for city and its regional scale renewable energy demand [33]. Finally, certain spatial planning gaps and missing linkages were identified after the REEVI sorting and spatial hierarchy set-up reviewed in the integrated regional spatial planning framework [121], hierarchy and model.

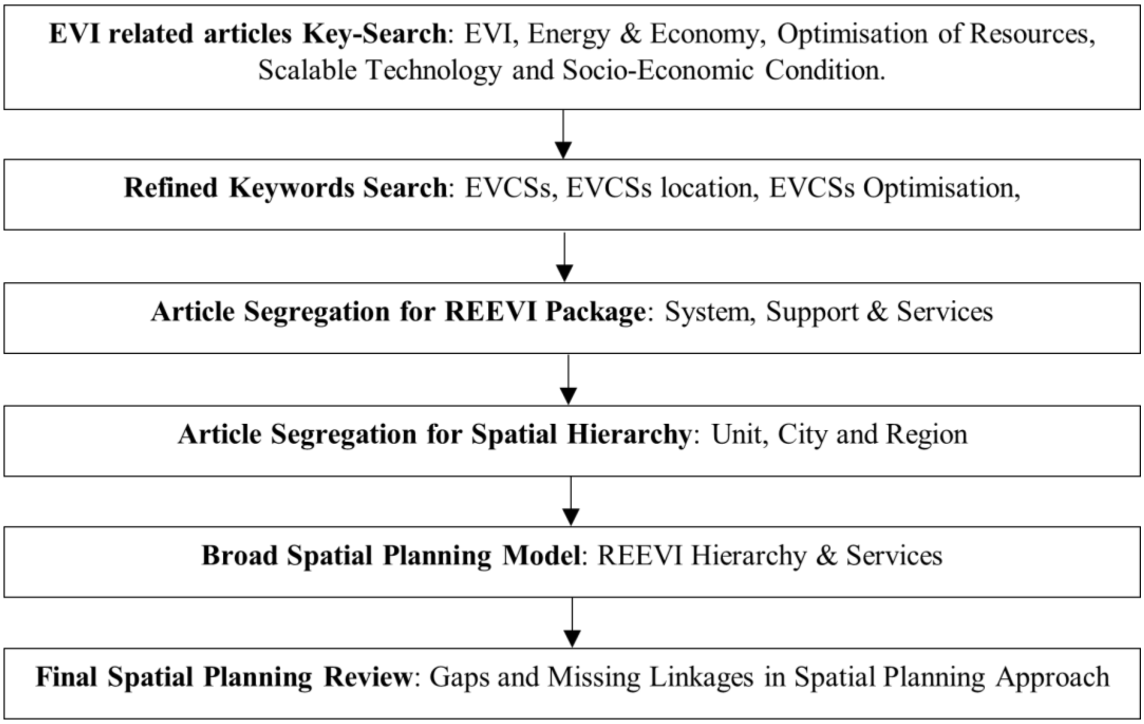

Figure 6. Sorting and arrangement process of articles along a three-tier hierarchy.

4. Distribution of Literature over the Last Two Decades and Missing Linkages

F. Ahmad et al. [29], F. Razi et al. [31], H.T. Nguyen et al. [54], and S. Jerome et al. [116]. emphasise EVI, energy and economy, optimisation of resources, scalable technology and socioeconomic condition to boost the market and acceptance of EV as perceived from their studies carried in the year 2022. Thus, the research work on components such as batteries, EVCSs, RE and solar and charging technology were more evident (Figure 7). Moreover, F Ahmad et al. [29] showed advancements in EVCS locational optimisation and its sustainable future in Renewable Energy System (RES) integration. Chronological spread of the research depicted in Figure 8 on REEVI seems to evolve from battery, charging technology, EVCSs location, adapter and charging devices of slow and fast EVCSs, wireless technology, source of renewable energy [31]. Subsequently, this review (Figure 9) shows that the REEVI evolved by 2022 (Figures 7 and 9). It was observed that much literature did not directly relate to spatial planning due to existing studies being domain specific. Thus, the review study on 138 articles highlighted key search relevant to spatial planning such as EVCSs, EVCSs location, EVCSs optimisation, EVI and EVCSs, RE, solar and wind potential, charging technology, etc. The spatial planning review on these advancements has tremendous potential to add to implementation, promotion and transition ease for EV renewable energy and EV transportation infrastructure [16,17,50,121].

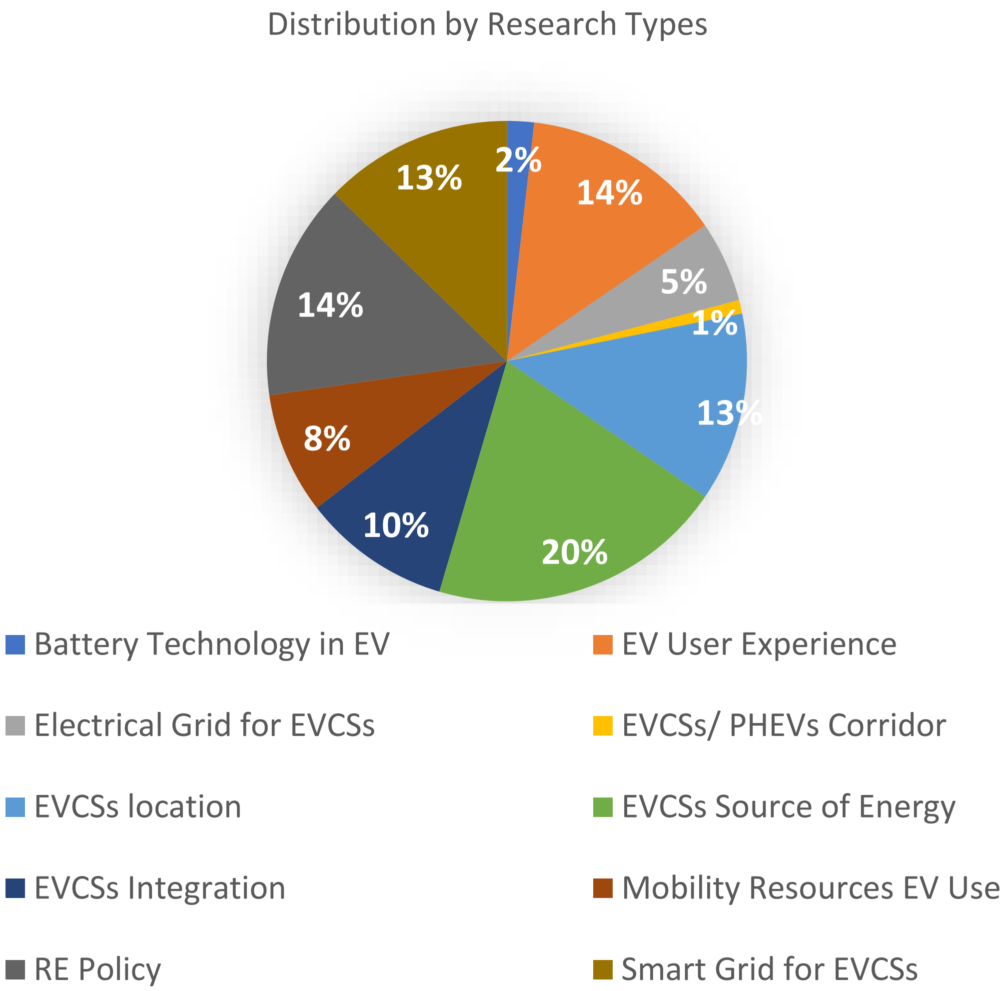

Figure 7. Distribution by Research Types.

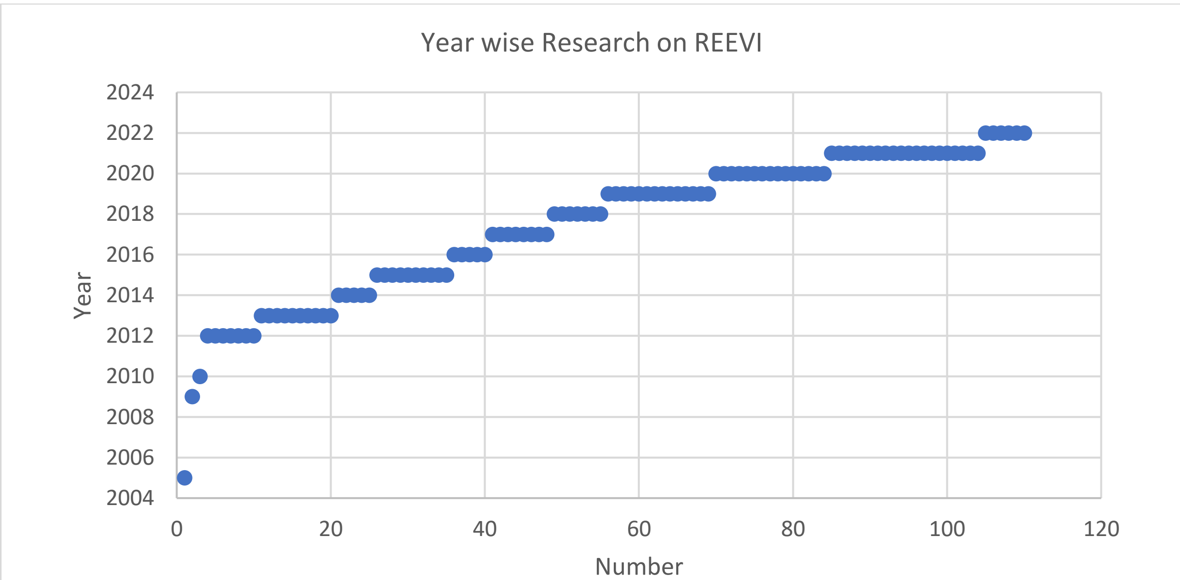

Figure 8. Research Distribution on EVI Optimisation for Spatial Planning.

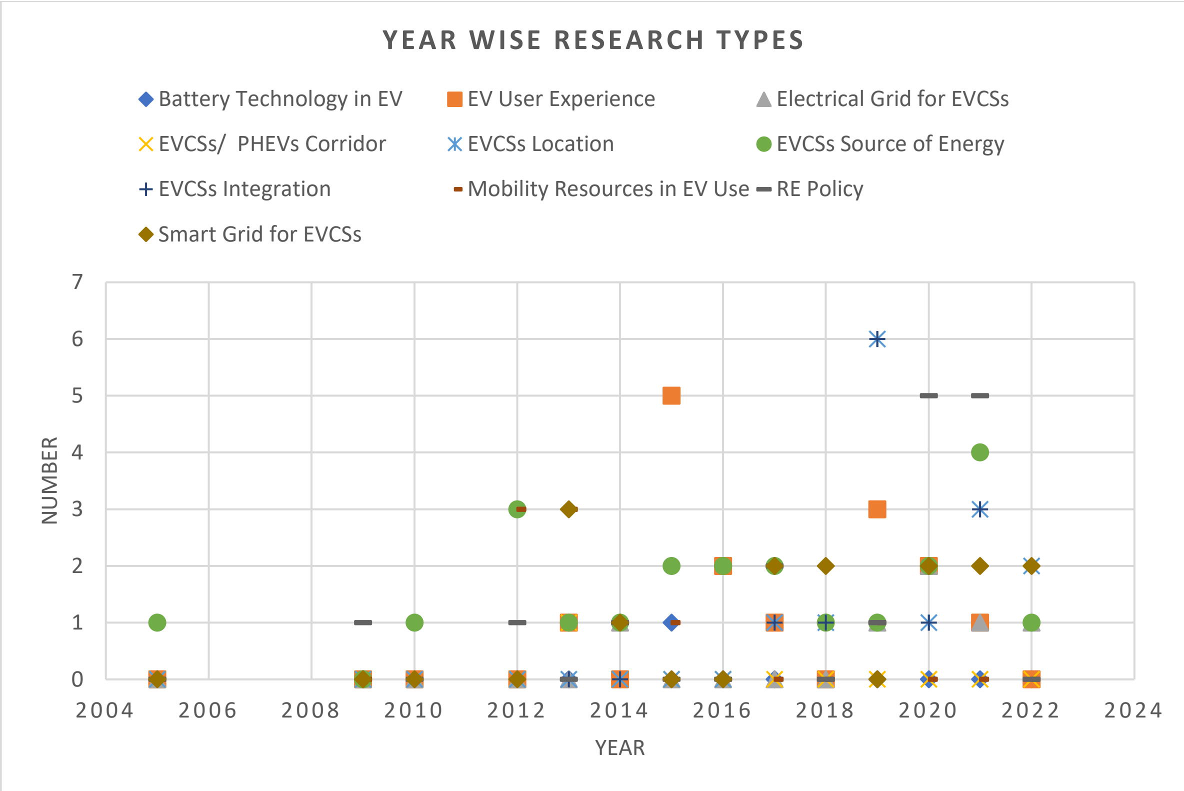

Figure 9. Chronological Order of Research Type.

Moreover, as the concept on network of charging [31] being considered, the presented review noticed a chain of inter-dependent studies on components as EVCSs location, EVCSs integration, EV user experience, source of energy, RE policy, smart grid of EVCSs and EVCSs/PHEVs (Plug-In Hybrid Electric Vehicles) corridor appeared in the year 2019 (Figures 8 and 9). This witnessed few direct but distributed knowledge on regional spatial planning. Thus, most of the research in Figure 7 depicts focus on EVCSs source of energy (20%), followed by EVCSs user experience (14%), RE Policy (14%), EVCSs location (13%) and Smart grid for EVCSs (13%). The closest EVI study in regional spatial planning context as found on corridor-centric approach, city planning EVCSs or PHEVs is of 1 percent only. Thus, inter-dependency calls to understand these associated components of regional spatial planning could be witnessed as package to integrating via regional spatial planning approach for REEVI optimisation.

In Figure 10, the year 2019 witnesses to have maximum collective research on REEVI package of system, support, and services. However, consistent advancement became evident on the REEVI system related studies from year 2010 to 2022 (Figure 11). In contrast, it is evident from Figure 11 that research on REEVI support found to have continuous development from 2012 to 2020. Interestingly, the REEVI services experienced discrete progress, distributed over various years. However, the recent timeline between 2019 and 2022 showed better consistency and improved research on REEVI services. Thus, the period 2019 onwards represents overall a good amount of knowledge development on the system, support and services of REEVI (Tables 4 and 5). Perhaps the package of REEVI needs closer review, fitting the integrated regional spatial planning hierarchy (Figure 5). Moreover, to identify the spatial gap on medium and long trips of EV at the city and regional scales to contribute in existing knowledge of renewable energy decentralisation and local potential inclusivity [16,17,117].

In an analysis over regional spatial planning hierarchy, showed more evidence of studies on local area and regional level (Figure 12) knowledge in the existing research body. The emergence of city scale research has been seen only in the year 2021 (Figure 12). This year also marked to have maximum research articles of 21 in numbers (Tables 4 and 5 and Figure 12), along with evidence of research on all the three hierarchical scales of spatial planning, i.e., local, city and region (Figure 12). Distribution of the REEVI package of studies related to SSS finds witness varying across all the years. The maximum number of research articles was found to exist in the system and support at the local level (Table 5). While studies on system, support and services were seen to be present at local and regional scale only until 2020, the city scale learnings were completely absent. Whereas research on system and services were carried out highest in the year 2021 found to cover the three-tier hierarchy.

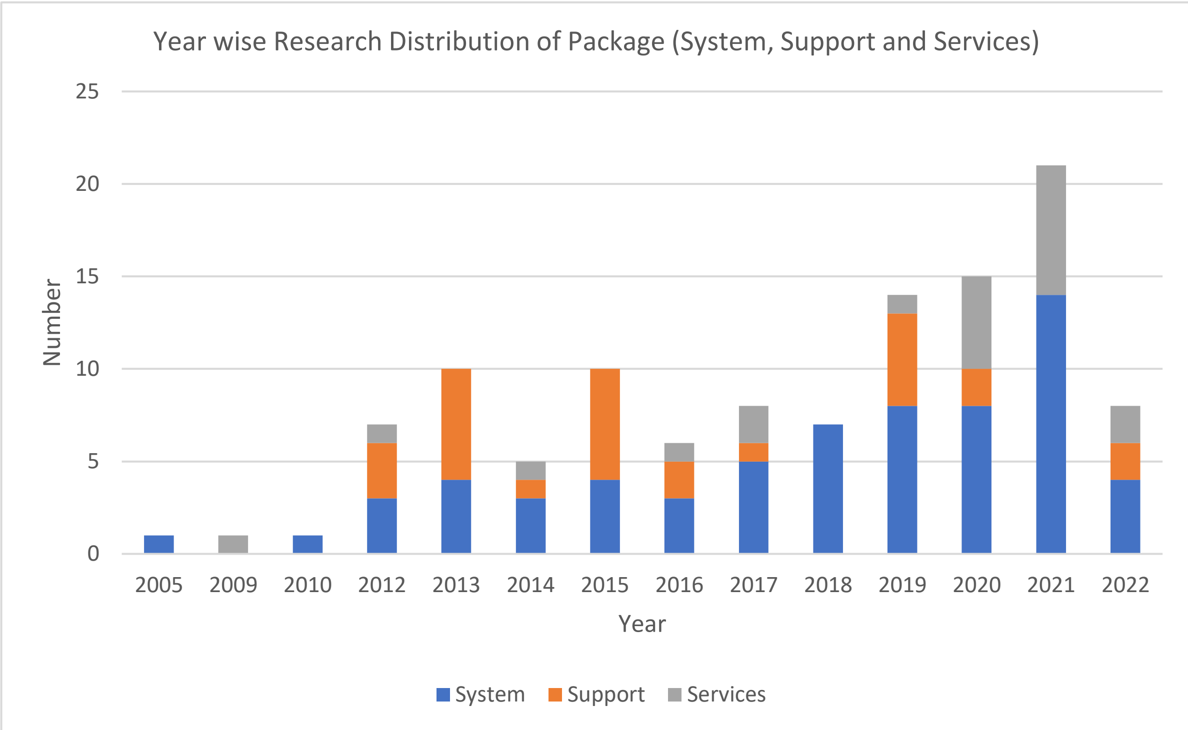

Figure 10. Year-wise Research Distribution of REEVI Package (System, Support and Services).

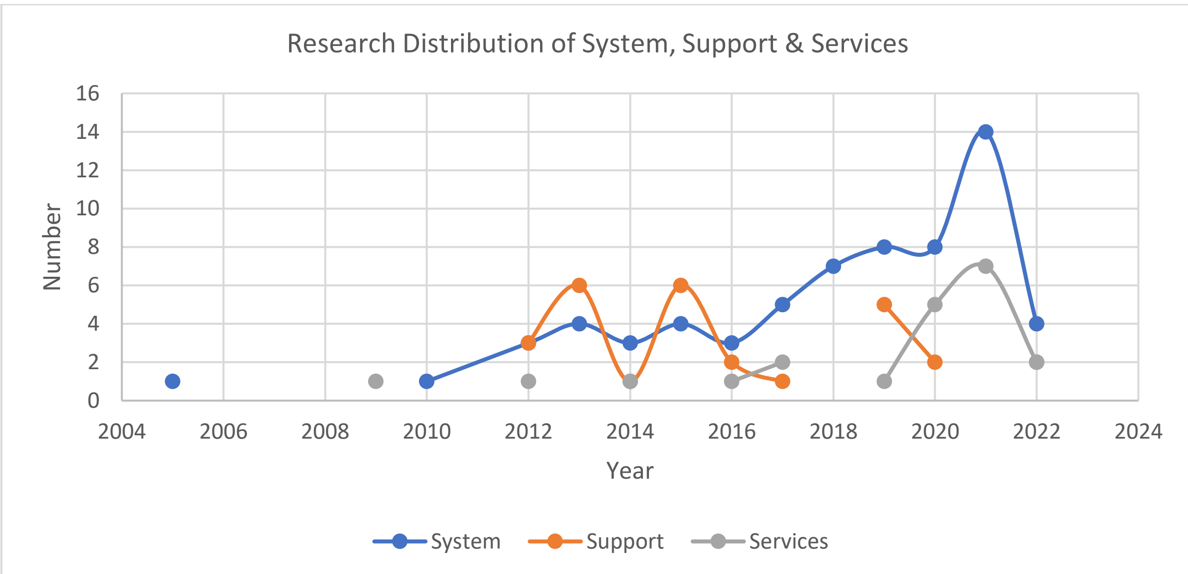

Figure 11. Research Distribution of System, Support and Services.

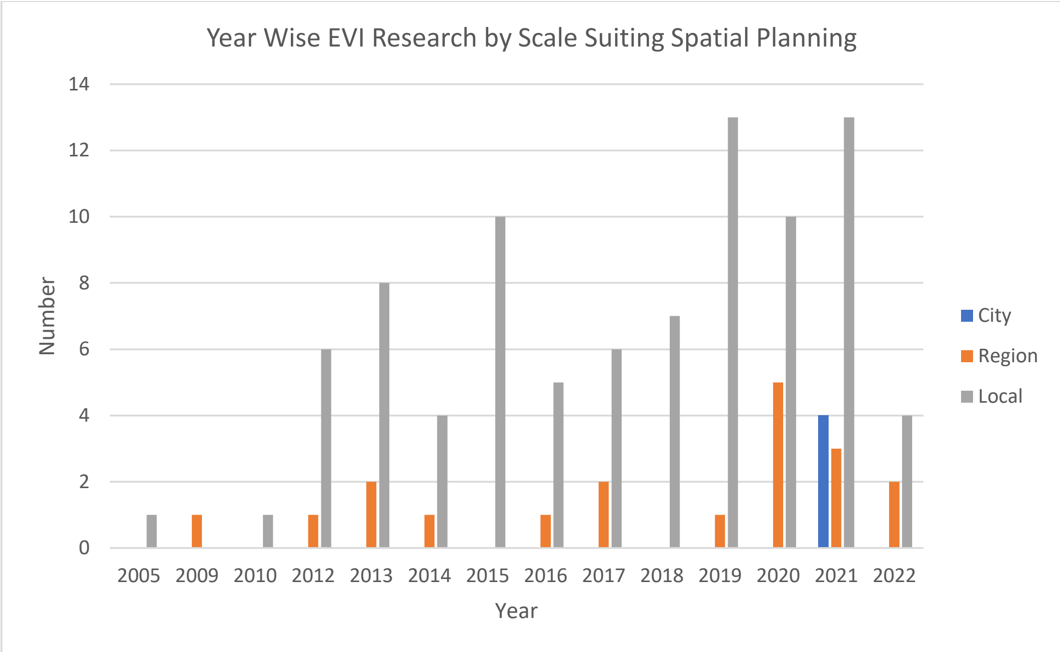

Figure 12. Year-wise distribution of EVI Research by Scale Suiting Spatial Planning.

Table 5. Year wise Spatial Hierarchy Distribution of REEVI Package (System, Support and Services).

Categories	**Local**			**City**			**Region**			**Totals**
Year	**System**	**Support**	**Services**	**System**	**Support**	**Services**	**System**	**Support**	**Services**	
2005	1									1
2009									1	1
2010	1									1
2012	3	3							1	7
2013	4	4						2		10
2014	3	1							1	5
2015	4	6								10
2016	3	2							1	6
2017	5	1							2	8
2018	7									7
2019	8	5							1	14
2020	8	2							5	15
2021	13			1		4			3	21
2022	3	1					1	1	2	8
Totals	62	25	0	1	0	4	1	3	16	112
Grand Totals		87			5			20		112

The existing REEVI services along the integrated regional spatial framework and hierarchy seems to be visible on-and-off during the timeline of research covered in Figure 12, However, Table 5 clarifies that the bulk share of the literature has an understanding of the policies and incentives only. Thus, the significance of these polices and incentives is of much aid to intervene at regional scale and its obviousness having issues of EVI delivering medium and long trips of inter-city and regional movement. As seen in Figure 13, the knowledge on policy and incentives of regional scale articles spreads across 21 countries, i.e., India, China, Spain, California, Singapore, New York, Austria, Malaysia, Slovenia, Kenya, Korea, Canada, Iran, Saudi Arabia, Egypt, USA, Nigeria, Qatar, UK, Pakistan and Tunisia. Moreover, Canada, USA, UK, China, Spain and California have seen to have explicit details on implementation of EVI. However, India recently formulated national level handbook on Electric Vehicle Charging Infrastructure (EVCI) implementation [20]. These details included EVI classification, location, land allocation, standards, guidelines, etc. were found to be available at regional level. However, the existing research has lean share on sectoral integration, spatial optimisation and regional planning perspectives leads to EVI challenges faced in the EV transportation and RE transition. A methodology to cater the gaps, discussion and conclusion on the review for integrated regional spatial planning approach to REEVI decentralisation and optimisation has been presented in the next subsequent sections.

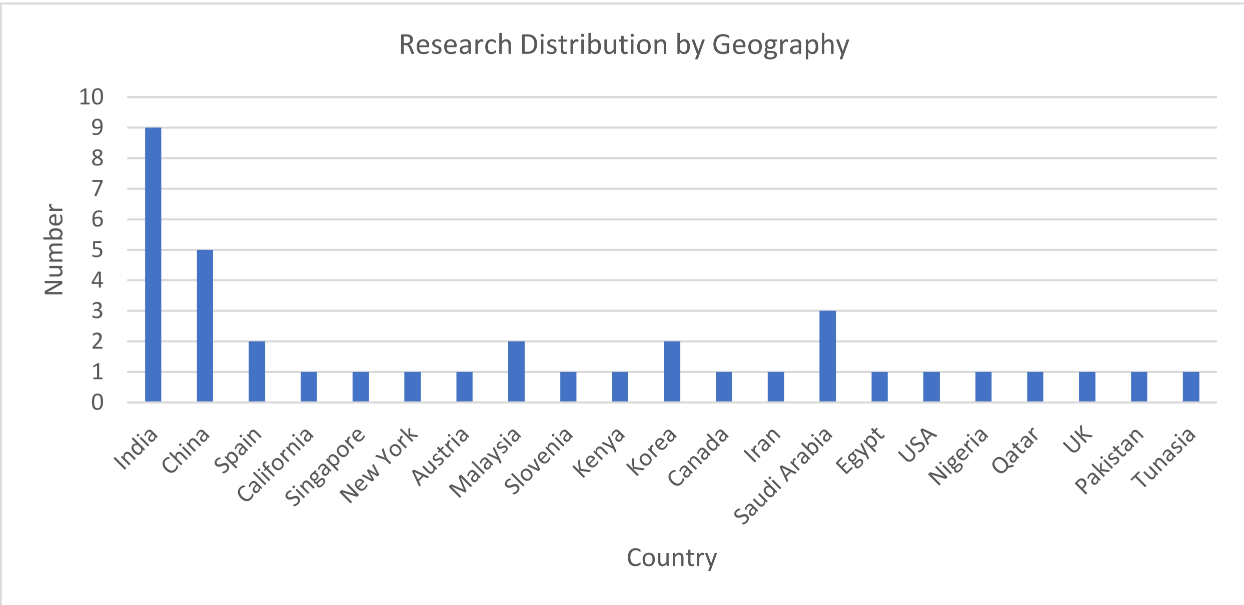

Figure 13. Research Distribution by Geography.

5. Proposed Methodology for Integrated Regional Spatial Planning REEVI-SSS Decentralisation and Optimisation

The presented review article sorts a multi-level–sectoral regional spatial integration of urban and rural planning, transportation, energy (renewable), infrastructure, environment and climate change, and sustainability [16,17,121]. Thus, this review revolves its thematic focus around transport sector as one of the significant contributors to deal with global energy demand to supply available locally as rational towards sustainable development [17]. Therefore, the research strategizes the energy decentralisation of local potential in the ongoing promotion of electric vehicle infrastructure and EV transportation.

In addition, this review toils on the demand and supply of renewable source of energy to EV transportation that the EV users struggle to orient to the need of the hour [52]. Such as inadequacies of refill infrastructure have been strategized in the review to complement medium and long trips of EVs.

Efforts on 'point location' of EVI were found to be carried on 'system' to ease the agitation by the EV users and in its transportation. Studies prevail to optimally locate 'system' of infrastructure found to be distributed at 'local area level' (knowns as public hotspots such as hotels, apartment buildings, workplaces, fuel stations, etc. [21]) which only caters to intra-city short run trips. The presented review entails the body of knowledge of 'system' to be mostly present and has potential at 'local area level' of EVI.

Similarly, REEVI system and support were mostly available at local area and city level only. Whereas missing linkages were also evident along the REEVI system and support optimisation that justifies the challenge to ply EVs at the regional level when reviewed under integrated regional spatial planning approach. Moreover, the REEVI-services such as standards, guidelines, norms, etc. were prevalent at the regional level. However, the studies on REEVI-services revolved around policy and incentives only to suit regional level renewable energy and EV transportation demand for EVI.

The presented review attempts to identify missing linkages in regional spatial planning hierarchy for the larger scope of REEVI, fitting the ongoing concept of public hotspots and renewable sources of energy. Nevertheless, this review points out the lacuna of medium and long trips of EVs lies in its EVI. As such, EVI source of energy and transportation consideration of connecting the hotspot point locations across the magnified hierarchical level, can facilitate the short, medium, and long trips of EV. In turn the hierarchical linkage as identified in this review can be amplified from intra-city level of short trips to inter-city level of medium trips as well as city and its regional level SSS for long trips to ease the EV transportation.

In turn fitting the findings in the integrated regional spatial planning hierarchy as presented in Figure 14, compiles that the presences of ongoing efforts exist across REEVI system, support and services has been highlighted in yellow. The studies exist on the system, i.e., EV technology, battery, EVCS, grid, renewable energy source. However, studies existing on hotspot fit the concept on regional spatial planning as activities of land use. Additionally, transportation and trips understanding has also been seen in the corridor investigation fitting under the spatial studies. It was observed that studies lack a larger understanding of spatial support of land uses such as work–home relationship, land-use intensity (interdependent function), highway facilities, roadside amenities, etc. Nevertheless, much research gap exists in the services under regional spatial planning of REEVI optimisation. These include hierarchy (local-city-region), nodes, settlement pattern, network, and cluster.

Therefore, a conceptual methodology for Integrated Regional Spatial Planning REEVI-SSS decentralisation and optimisation has been proposed in Figure 15 considering the missing gaps and linkages of research when fit in the regional spatial planning setting of Figure 4. Conceptual methodology adopts the relevant parameters such as demography, hierarchy of facilities and services, transportation and settlement, settlement pattern towards integrated spatial planning REEVI optimisation. Thus, its specific data, as in Figure 15, can further analyse population demand and supply, regional scalogram, connectivity, accessibility, catchment, settlement distribution by the method of projection, availability of facilities/services, spatial standards and density. Further, the regional spatial REEVI evaluation criteria, i.e., creation of matrix, hierarchy of settlement, mapping of settlements and facilities pattern, identification of nodes, networking and clustering can ensure integrated spatial planning REEVI decentralisation and optimisation through development of order of REEVI services. The regional order REEVI services may range from a lower order service-III of basic and service villages to higher order REEVI services of regional centre.

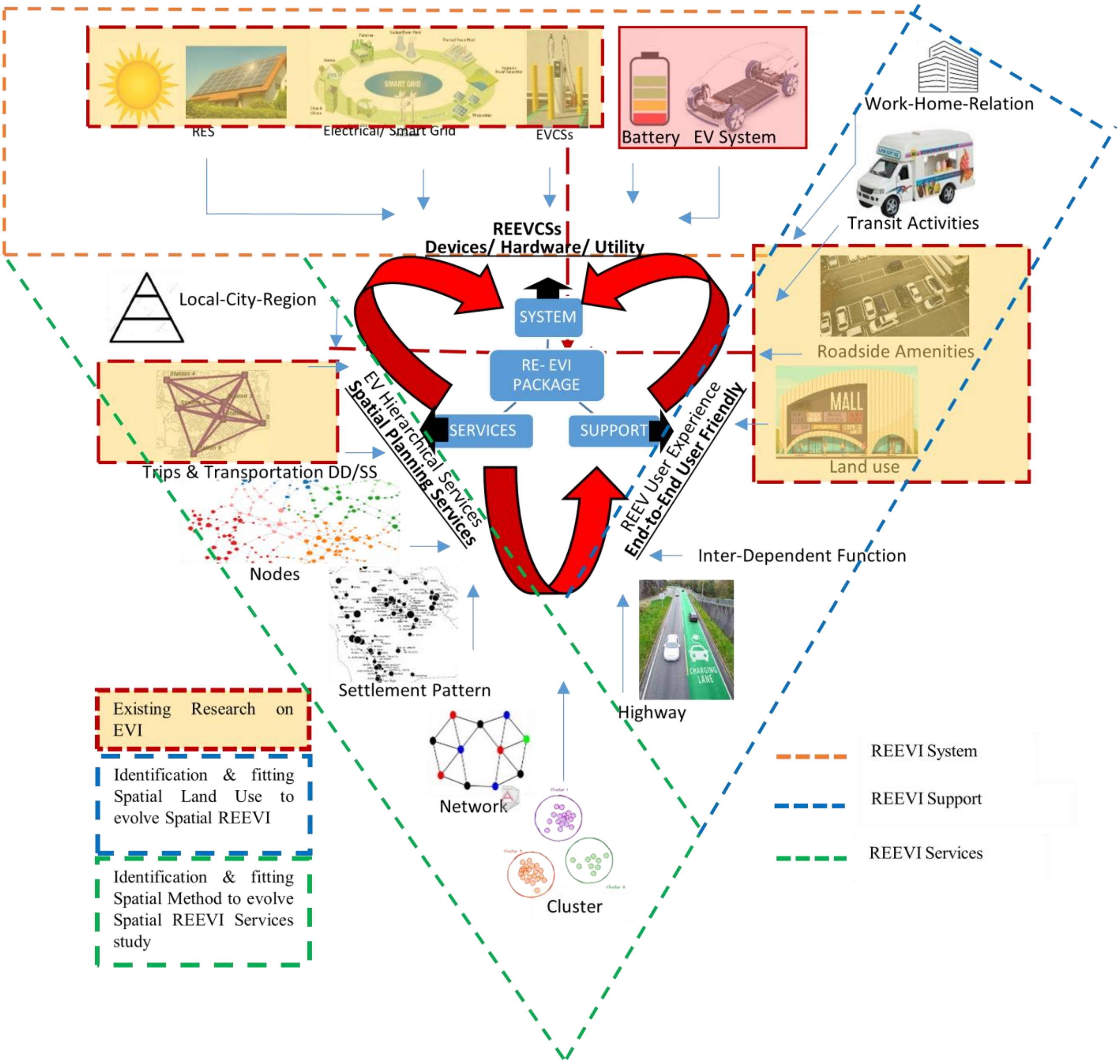

Figure 14. Review on Gaps and Findings on Integrated Spatial Planning Approach to REEVI Optimisation.

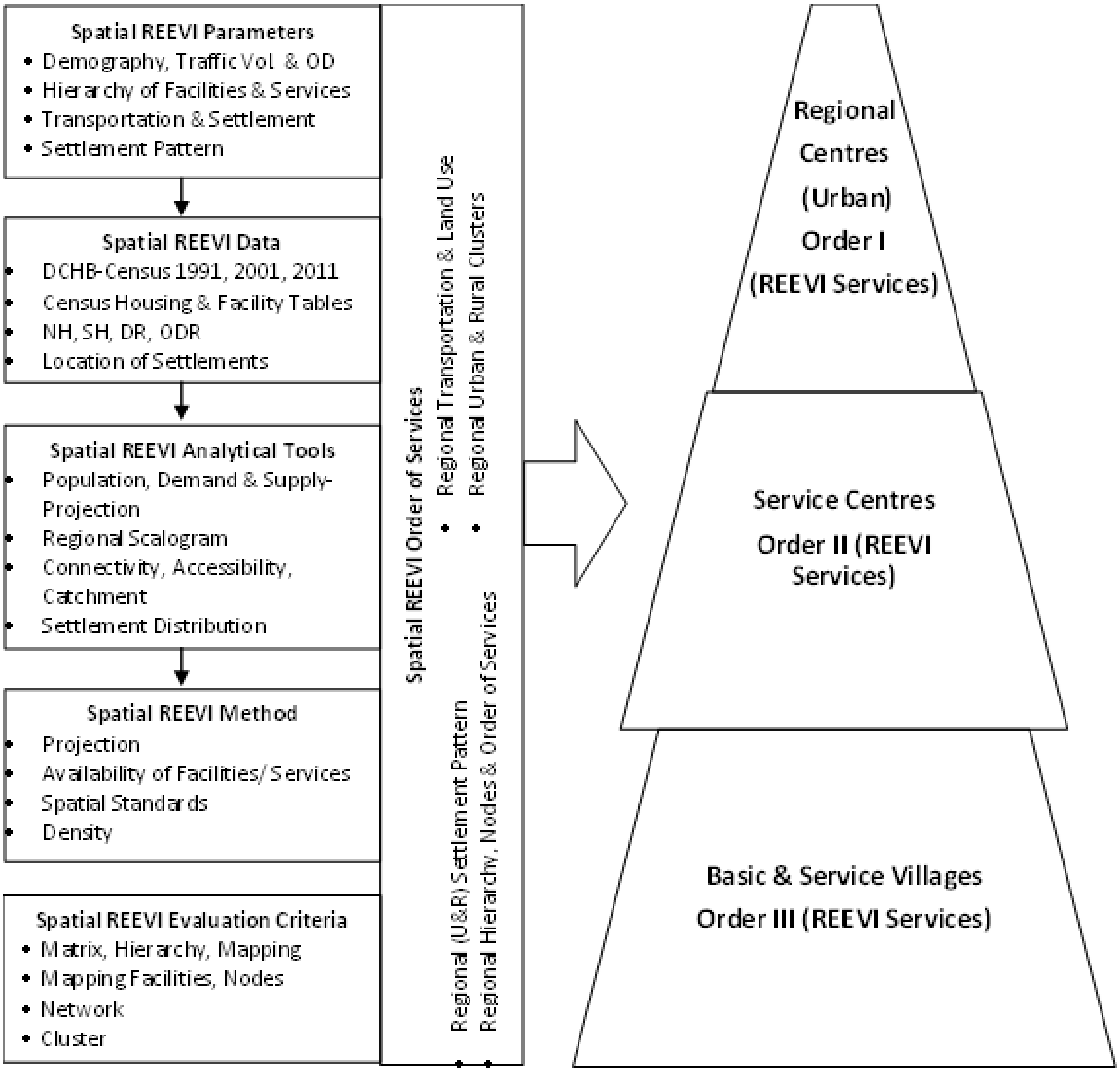

Figure 15. Proposed Research Methodology Concept for Integrated Regional Spatial Planning REEVI Decentralisation and Optimisation.

6. Discussion

Although 70% of the environmental footprint comprised is from developed countries, the United Kingdom has an ecological footprint of 3.1, whereas India with 0.4. Birmingham with ecological footprint 5.2216 (EF/cap), contributed by sectors of housing (1.52), transport (0.83), food (1.22), consumer items (0.61), private services (0.45), public services (0.37), capital investment (0.24) and other (0.01). So far, the literature shows a calculated greenhouse gas emission imprint of settlements, cities, built-up, land-uses and transport sector. A sustainable way of development happens when a trade-off or carbon trading is done of greenhouse gas (GHG) emitters [129].

It is evident from literature that renewable energy decentralisation and spatial assistant packages are required to bridge the socioeconomic effects of COVID19 in the immediate to later term. Although the research focuses on electricity, whereas decentralisation of renewable energy wraps holistic study across different field, for example, heat with its huge share in consumption than electricity. Thus, it signifies towards multi-sectoral integrated study for energy decentralisation with an added promotion of energy conservation in reference to competing market pattern around home convenience, comfort and time saving [130]. Concurrently, investment in the infrastructure, technology and competencies is believed to decarbonise the economy [16]. Regional studies observed to bring settlements' decentralisation through integrated planning towards equitable distribution of public goods and services. Therefore, the provision of SSS needs its spatial infrastructure revisit to emerging demand to decarbonise the urban and rural land uses and transportation sector.

Planning of settlements, cities, built-up, land-uses are potential spaces for the installation of solar panels and potential renewable energy sources to create the trade-off. Alternatively, a unit increase in built up can generate equivalent solar energy if made compulsory in the building bylaws and development control norms [131]. Implementation of RE harvesting mandates can be part of national building codes and standards [132]. A spatial planning approach can provide insight into zonation, regulation, and implementation of RE in built environment. Thus, an integrated spatial planning approach to discuss RE sourcing EVIs has been focused in presented review. As presently researched upon, this review visualises that the SSS spread across local area level, city level and regional level. The review collectively calls the SSS as package of REEVI. Where the REEVI package of SSS are available along the three hierarchy, i.e., local area, city, and region to access charging under integrated regional spatial planning framework. However, there exist certain challenges such as missing regional spatial gaps and linkages that hold potential to ease medium and long trips of EVs transportation as resolved in this REEVI decentralisation and optimisation review.

Additionally, regional spatial planning integration can relieve the medium and long trips of EVs, calls for further detail identification of an appropriate study area and scale, parameter and indicator, methods, analytical tool, evaluation criteria, etc. Thus, important spatial parameters such as regional settlement pattern, regional transportation, regional land-use studies can be further researched. Such a highly mobile corridor needs deliberate research attention on renewable energy source nodes, transport connectivity, networking, service planning and development [92,133]. Additionally, research on scalogram could further provide direction towards delivery of REEVI optimisation in nodes and hierarchical facility and services planning. Regional models of networking and cluster planning could further explore for the provision of regional services, network of charging infrastructure, policy and incentives [31].

Results of the research fraternity highlight the significance of policy and incentives, scope, stakeholders and types of decentralisations remains close to country, geography as well as region specific. However, connotations guided by the empirical diversity of the region can enrich the further understanding of the real-time analytics. Ambiguity exists in defining the citizen energy, civic energy, community energy, energy communities, prosumer, under the energy decentralisation (ED). Dominance seen in asset ownership of wind and solar PV in countries of North America and Europe irrespective of spatial distribution of new civil society actors, private sector actors. Additionally, evidence of the control of incumbent actors by means of collaboration are functional towards achieving ED at local authority level. Therefore, sociotechnical transition became evident with entrance of per incumbent role in bringing technological additions in restricted community [134] participation. Moreover, private sector players are usually more involved in each commencement by the civil society [135]. These are experienced in shared ownership, technology delivery, or in delivery of services such as legal, financial, energy exchange and multiplier effect.

In the light of existing research, the necessity of deregulation does not suffice inclusivity and participation for energy transformation. It is witnessed in USA and South Africa to deploy renewable energy in lack of deregulation favouring in community and governance mobilisation resulting in new types of people's and local participation. Simultaneously, entrants prove to develop business models in competitive marketplace with mix of different regulatory edge. Fundamentally, combination of institutional mechanism and policy holds direct influence on the local capacities in innovation, access, finance. Additionally, the impact of risk and financial feasibility seems to be low. It is said to infuse latent concept and skills in political leadership and legitimising an alternative narrative. Success of project highly depends upon effective identification of local advantages and mitigating risk in support of the national level policy mechanism and fundings. Arching dispersion is additionally allowed by propitious and coherent policy blends that patchily need program private enterprise and judicial transformation.

Where the local energy market remains at the formative stage can be enlightened in further research. The opening up of the local actors in traditional business model depending on the bulk electricity sold while adding the new entrants in the market. As such, the general energy model remains unquestioned in distribution of social benefits to larger community [134]. Moreover, integration of digital equipment in flow of information in the duality of physical (including financial) and virtual neoliberal urbanisation and spatial planning. It can more likely support in smart grids for virtual power plant creation, peer-2-peer markets or vehicle-to-grid technologies [16]. This review does face challenge on charging speed and duration of charging as in the existing body of knowledge. Any breakthrough in battery technology can further enhance the ED via integrated regional spatial approach to REEVI-SSS.

Review study can push the local stakeholders in local [17] dedicated energy infrastructure such as solar, wind, etc, to achieve target of Sustainable Development Goals (SDG) under RE in India. Further, the research may find way forward on energy transition from non-renewable sources to renewable sources strategies through an integrated regional spatial planning approach of distributed standalone [16] local energy [117] driven EVI pattern and model, for example, solar electric vehicle infrastructure (SEVI). Additionally, Renewable Energy Based Hybrid Vehicle Infrastructure (REHVI) could be a future possibility. The review and modelling can be adopted for Hybrid Vehicle Infrastructure (HVI) and REHVI. However, other demands of RE along with EVI can be integrated for further studies of REHVI. Revision of development control regulation (DCRs), policy, standards and measures can add to decentralise and optimally locate REEVI in an integrated regional spatial framework.

Moreover, parallel development of data infrastructure such as sustainable rooftops or building façade, built-up/open area could be scope of studies. Nevertheless, policies, framework and incentives would also flow in context to community participation in developing countries as India, such as RE harvesting, RE trade-off, RE trading, willingness to trade RE in order to refill EVs and future transportation infrastructure [136]. Research on community specific studies can provide detailed insight depending upon the nature of settlement such as rural vs. urban, hilly vs. plain, etc. Where urbanism having variety of complexity can dwell upon specification of small town, city, metropolitan, mega-cities, etc.

Literature shows of loaded responsibility on rural bodies appealing of equality towards centralised management and effective national regulatory framework in France. As such, there is a large gap between localist rhetoric and institutional reality [123]. Although problems of ownership, co-benefits, scale and intermittency exists when debated about the ED for and against. Researchers narrate the need of varying policy, decision making, support, mechanism and structures at regional and national scale to suit the need, interest, and views of stakeholders. Along with the institutional bases of public, private and civil society the analysis depicted contrasting institutionalised social pattern of behaviour and seeks for energy justice. In this direction, the proposed Renewable Energy Committee (REC) argues on the entitlement of legal space to operate with knowledge to change associations amongst the state, market, and society. Additionally, lack of diligence in implementing rules enabling incumbent strategies towards ED shows the resistance in policy formulation via lobbying and regulatory capture. However, state-level institutional context and state-level policy and regulation are believed to reform the incumbent governmental strategies towards ED. In turn, it ultimately transforms the geographically influential models for decentralisation in REEVI. Moreover, the case of California and New York reflected to generate more conducive political opportunity such as offtake prices for distributed generation. Furthermore, it resulted in regulations driven ownership of distributed generation assets by utilities with large share of community in local PV installations [16].

Apparently, the local energy market continues to shape as in the existing body of knowledge. Deliberate attempts require to open the market to local stakeholders based on traditional business and marketing model. According to the researchers, depending upon volume of demand and supply the new actors continue to enter the market. Where these efforts show potential in spatial distribution of social benefits without concerning the usual energy model. This can be seen in the emerging digital tools that open avenues to streamline the accessibility of information in the flow of physical (including financial) and virtual public goods and services. For example, the same is witnessed in sharing and distribution of smart grids for virtual power plant creation, peer-2-peer markets or vehicle-to-grid technologies [124]. More recent research on prosumers makes it evident that distributed ledger technology provides flexibility, security and faith amongst stakeholders in the energy market [137–139]. It necessitates additional empirical research across the world to investigate the real opportunity in duality (physical and virtual) of digital neoliberal urbanisation and regionalisation.

7. Conclusions

Decentralisation of energy infrastructure stays in the level of participation, the socio-political characteristics. To promote spatial expanse of distributed dealings and participation by prosumers enhancing the distributed ledger technology. Such possibilities are identified in integration of different technology, economic, social, environment and institution. Building on these consensuses, regional spatial integration is required in the concurrence of high-level definition for RE decentralisation. Thus, the action and engagement within the production, consumption, business, planning and regulation of energy requires in proximity to the final consumer, away from central control.

The presented paper throughs light on the conditions of energy transformation in enabling policy and regulatory frameworks to identify REEVI packages to multi-level–sectoral regional spatial integration, urban and regional planning, transportation, energy (renewable), infrastructure, environment and climate change, and sustainability.

The presented review study brings out tentative regional settlement hierarchical integrated methodology for REEVI in the missing linkages and gaps of spatial planning to ease EV trip challenges faced at inter-city–rural connectivity in the regional study.

This review concludes that a lot of efforts are going on to ease the anxiety of EV users to promote its transportation in access to charge lies in RE transition. Inclination towards EVs suffer the issue of battery range, refill charging/re-charge, refill/re-charge duration. Currently, individuals charge their EV at their house overnight as seen in the present body of evidence. Research fraternities have emphasised the EVCSs to be deployed in a big way. They identify various locations of EVCSs through RII ranking. Further, the location for EVCSs installation at city level has been addressed through traffic pattern and trip analysis. Additionally, the highway and corridor approach has been much beneficial to add the EV transportation easement at regional scale.

The present review views integrated regional spatial gaps to add to the ongoing attempts. Studies already persist on the point location of hotspots of EVCSs. The spatial approach has been viewed in EVCSs installation as identified at location of hotels, apartment buildings, workplaces, fuel stations, universities, shopping malls, supermarkets, restaurants, hospitals, airports, amusement parks, movie theatres, train stations, libraries, zoos and stadiums via RII ranking. Additionally, the EVCSs locations as perceived by this paper fits in the land use that only caters the short trips at the city level. Thus, this article addresses the missing spatial mobility and energy transition need of EVs which attempts to link the regional spatial hierarchy. Regional or district scale has been identified to facilitate medium and long trips with linkages of EVCS locations to settlement patterns at the local level.

Two of the sustainable issues are addressed in this paper to contribute to the ongoing attempts of energy decentralisation and local inclusivity for EV transport. First, it provides infrastructure needs of EVs via RE-dedicated EVCSs. It also caters to the process of regional spatial integrated REEVI-SSS planning on the other hand. The review fills the essential gap of ongoing studies to facilitate medium and long EV energy and transportation at regional level. This could be applied and replicated, especially in the case of developing countries that lack much infrastructure as a component of renewable source of energy or to implement renewable energy infrastructure under energy and transportation transition for sustainable development goals.

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Abbreviations

DCRs	Development control regulation
DRE	Decentralised renewable energy
ED	Energy decentralisation
EV/s	Electric vehicles
EVCI	Electric vehicle charging infrastructure
EVCPs	Electric vehicle charging projects
EVCSs	Electric vehicle charging stations
EVI	Electric vehicle infrastructure
GHG	Greenhouse gas
HVI	Hybrid vehicle infrastructure
ICT	Information, communications and technology
OD	Origin destination
PHEVs	Plug-In hybrid electric vehicles
PV	Photovoltaic
REC	Renewable energy committee
REEVCSs	Renewable energy based electric vehicle charging stations
REEVI	Renewable energy based electric vehicle infrastructure
REHVI	Renewable energy based hybrid vehicle infrastructure
REI	Renewable energy infrastructure
RES	Renewable energy system
SDG	Sustainable development goals
SEVI	Solar electric vehicle infrastructure
SSS	System, support and services

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