Appraisal of Energy Efficiency of Urban Development Plans: The Fidelity Concept on Izmir-Balcova Case

Y. Duvarci and A. K. Kutluca

***Abstract*—** Design and land use are closely linked to the energy efficiency levels for an urban area. The current city planning practice does not involve an effective land use-energy evaluation in its 'blueprint' urban plans. The study proposed an appraisal method that can be embedded in GIS programs using five planning criteria as how far a planner can give away from the planning principles (criteria) for the most energy output s/he can obtain. The case of Balcova, a district in the Izmir Metropolitan area, is used conformingly for evaluating the proposed master plan and the geothermal energy (heating only) use for the concern district.

If the land use design were proposed accordingly at-most energy efficiency (a 30% obtained), mainly increasing the density around the geothermal wells and also proposing more mixed use zones, we could have 17% distortion (infidelity to the main planning principles) from the original plan. The proposed method can be an effective tool for planners as simulation media, of which calculations can be made by GIS ready tools, to evaluate efficiency levels for different plan proposals, letting to know how much energy saving causes how much deviation from the other planning ideals. Lower energy uses can be possible for different land use proposals for various policy trials.

***Keywords*—** Sustainable Urban Planning, Energy Efficiency, Geothermal Energy, District Heating Systems (DHS), Energy Planning

I. INTRODUCTION

THE integration of energy parameters into the city planning practice has been underway but seems still to be awkward [1], [2]. Concepts of sustainable urban development and internalizing renewable energy concept have lately become popular in urban planning literature both to save energy and to create vibrant environments together. But, the inefficacy of related planning laws and regulations to include such progresses is one of the major obstacles before this energy integration. Likely, the sustainable and renewable energy parameters, the geothermal energy in specific, have not been established adequately in current planning practice (especially the development plans). Major problems of energy disintegration into planning in Turkish case would include; (1) lack of national and regional policies for effective use of geothermal resource, (2) mismanagement of geothermal resource and infrastructure systems, (3) misguided local politics and concerns, and (4) inefficient land-use allocation and compatible planning process. Due to this inadequacy, energy conservation can not be properly exercised. However, as explained in Table I, serious cut-backs from energy use are possible utilizing the relationship between various urban functions and energy [3]. There can be possible alternative planning approaches to integrate the energy inputs into development plans. To show the possibility of effective energy saving, it was attempted to show the betterment in a case study approach with a new sample land use proposal in comparison to the existing one regarding five planning principles, all being equally weighted. The study is constrained only to geothermal energy district heating system (GEDHS) for the respective case area. This study should be regarded experimental, due to its assumptive nature (such as the equal weighing principle between criteria).

TABLE I
ENERGY DEMAND OF DIFFERENT URBAN FUNCTIONS

Planning variables	Energy link	Effect on energy demand
urban form	travel requir's	variation up to 20%
land use design's	travel requir's	variation up to 150%
mixed land use	travel requir's	variation up to 130%
density	Transit feasible	variation up to 20%
Density & mixed use	Neighborhood Heat/cool feas.	variation up to 30%
Layout orientation	Solar feasible	variation up to 20%

Source: Owens, 1986

This study stems from the fact that, though some energy-efficient land use criteria already comply with the other planning criteria (such as openness around buildings, equal sunlight access, acceptable density for health and noise concerns, etc.), some may not so with the accepted city planning and zoning requirements, or, only to some extent. Thus, a real energy-sensitive planning would be a fine-tuned compromise between these criteria, as depicted in the

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conceptual sketch in Fig 1. But, what way should be followed to achieve this compromise.

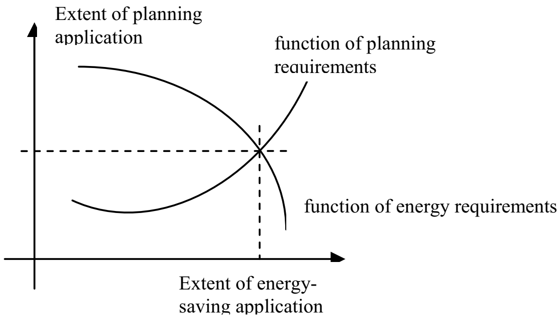

Fig.1. Compromise between the planning ideals and the energy efficiency

The question is: “What is the influence of effectiveness of land-use decisions to the efficient use of geothermal energy district heating (DHS)? In order to do that, how much change can we endure on the proposed development (implementation) plans?”. This study also aims to contribute to the literature in terms of (1) to show the significance of land use alterations on energy efficiency, (2) to explore the impacts of land use parameters on geothermal energy use, and the geothermal parameters on the land use, vice versa, (3) to introduce new “fidelity” concept for obtaining the best planning or policy options in competence with the efficiency concern. Since, besides the energy-efficient designs, being loyal to the original design (how far distortion from the original plan can be afforded), which is supposed to enclave other most important planning principles, is the desired one. It is also to show that, with this simulation media, there can be many possible alternative plan proposals to integrate the energy inputs into development plans, to track changes and to reach out the best solution space. Solutions are subject to change from one place to another. Authenticity (especially in choosing parameters) may be necessary for special needs of the place where problems may vary.

The variables chosen will determine the two competing outputs; ‘energy efficiency’ output and the ‘fidelity’ output, both measured in ratio values for comparability reasons to each other (such as the percent changes in energy saving against the planning ideals on a plan). The efficiency side is the maximum energy saving in GEDHS that can be obtained by new land use proposal, and the fidelity side is the degree to which minimum infidelity by the same new land use proposal that can be obtained in turn.

The “fidelity” concept is utilized to explain the deviation from the original plan’s proposed principles (assuming all the ‘blue print’ original plan’s land use proposals to be “ideal”, even if would not). Original development plan refers to the current plan in action. The infidelity of another alternative plan proposal is the degree to which it deviates from the existing land use proposals of the development plan. The five variables utilized are; Parcel Size and Vacancy for Drilling on Fault Line of which the measurement described by Pasqualetti [4] and [5], Heat Load Density of Buildings of which the measurement is described by Toksoy et al. [6], User Energy Density (Land Block Density Types) of which the measurement is described [7] and [4], and Residence Equivalence- Existing Building Ratio and Land-use Mix (Residence-Office Ratio) of which the measurement is described by [8].

The energy concepts are not well customized into planning process in detail with all parameters [2], such as effective energy consumption, efficiency, equality and conservation as the indicators of the relationship between energy and planning process in all levels; form, design and planning [9], [3], [1], [10]. There are strong relationship between energy and planning components which are land-use, built form, transportation, urban form, and infrastructure systems such as; (1) low density urban sprawl generates a greater need to travel than a more compact pattern of mixed land use where the physical separation of activities is small, as well as infrastructure costs [11], [12], [13], (2) the pattern of land use and transport infrastructure in an area is fundamental to local transport energy demand and its environmental effects [14], [15], [16], (3) the other important issue is the design, both urban and building scales for energy efficiency and energy consumptions [17], [18], [19], [20], [21], [22], [3], [23].

Being a site-dependent issue, geothermal energy includes quite special relations and contradictions to the land-use planning process than the other renewable energy types. The capacity, efficiency and the location of geothermal reservoir have been the major determinants of land use planning for places where geothermal energy is to be served. This determination basically depends on the temperature capacity (see Fig 2).

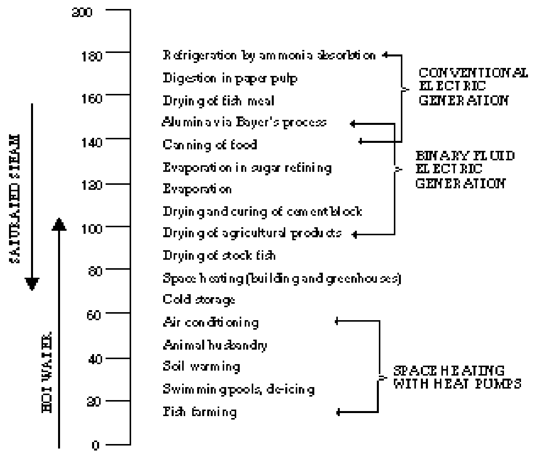

Fig. 2. Lindal Diagram

The thermal fluid of geothermal energy can be used in many areas; direct heating in residential (space heating, bathing, swimming), agricultural (greenhouse-farm heating, aquaculture pond heating, agricultural drying) and industrial functions (cooling, snow melting, chemical refrigeration) [4]. These applications can partly dictate the form of land-use planning (residential, agricultural industrial regions) that should be considered in all scales of planning. Therefore, unsuitable function choices disregarding these classifications may cause many sorts of costs and constitute problems in the effective provision of the geothermal source. Consequently, if the land use design were proposed accordingly at-most energy efficiency (which is %30) for each criteria concerned, mainly increasing the density around the geothermal wells and also the proposing more mixed use zones, we could have 17% distortion (infidelity to the main planning principles) from the original plan. The proposed method can be an effective tool for planners as a simulation media, of which the area size calculations can be embedded in GIS (but the calculations are done manually), to evaluate efficiency levels for different plan proposals, letting to know how much energy saving may cause how much deviation from the other planning criteria. Lower energy use could be possible for different land use proposals with various trials.

Before introducing the method and the case area results, a brief literature review will be provided on the past and the present efforts on relation between energy and land-use planning, renewable energy, geothermal energy, and sustainable urban concepts in the next section.

II. OVERVIEW ON THE ENERGY INTEGRATION MODELS TO URBAN PLANNING

As the cities are conceived as the systems consuming material and energy to output welfare, culture and comfort for humans, the best urban systems and shapes are questioned to minimize the amount of energy used. With the appropriate planning and design tools, costs can be reduced in considerable amounts in either infrastructure and in the total amount of energy used. Usually linear urban forms and high density had important contributions in reducing the costs of infrastructure, causing less travels and efficient use of energy. Sprawl, on the other hand, meant more service provision costs [24], [25], [26]. Basically those areas were studied: transportation management, land use planning, site planning and building design, and energy delivery systems. However, the current city planning practice does not involve an effective land use-energy evaluation in their 'blueprint' urban plans.

The World Commission on Environment and Development (WCED) announced in its famous report, "In Our Common Future-Brundtland Report" in 1987, that "a low energy path is the best way towards a sustainable future", which is seen as the one of the basic dimensions of the sustainability definition. Later on, The UN World Climate Conference in 1995, Habitat II in 1996 (Istanbul), and Kyoto protocol in 1997 had similar concerns on the sustainable development issue, with the emphasis on utilization of new concepts and technologies. Some organizations interested in the sustainable city and integration of renewable energy, and land-use concepts. The United Nations Environmental Program (UNEP) developed a new energy program to improve energy integrated city perspective, and to encourage any similar steps and initiatives. According to OECD [13], sustainability should be aimed in future, emphasizing;

- more effective land use planning and regulations to promote the use of renewable energy forms and technologies,
- establishing different utilities to take on the deployment of renewable energy technologies, and
- integrating energy to transport management, waste management and pollution control to increase the efficiency of renewable energy sources.

By now, few European cities such as Rennes (France), Goteborg and Stockholm (Sweden), Newcastle-Upon-Tyne (UK), Aarhus (Denmark), Turin (Italy) have witnessed some Master plan works including city-wide district heating schemes and other collaborative works from various disciplines on the energy-integrated land use planning. In energy conservation especially two problems were addressed: transportation and electricity/heating systems, and, in the overcoming of the problem [9], the participation of those local actors was seen important: local government leaders, city planners, architects, and economists.

First, serious "urban equilibrium model" was developed [27], which was quite a complex with three sub-models; land-use, transport and the evaluation. Transportation energy impacts on urban environment were extensively studied [28], [29], [30], [31]. In urban scale, energy budget and dynamical systems models, and linear programming models are used. Especially, energy efficiency with urban form and transport systems were studied [32]. In regional scale, Nijkamp [33] described economic models based on representative energy demand-supply. Some applied models include Gotland Island (Sweden) [34] and the metropolitan city of Hong Kong [35] as the regional scale model examples. Some other modeling researches relating urban form to transportation, and urban heating systems, etc. were conducted [11], [14], [15], with the hypothetical proposals of optimum urban form as well [36].

All to these efforts, it is still necessary to identify clearer tools and set of measures for tractability of energy uses among the city planning policies (incentives and sticks) to achieve energy sustainability locally, which requires R&D, technology and methods [37]. Geothermal energy, not wired as electricity, has more local meaning than other types, and land use implications. It has political aspects in terms of localization of energy sources.

Planners also need to track the impacts of energy-saving tools on the land-use, and the impacts of land use changes on the energy-saving. These cross-impacts need to be measurable and visible for healthy evaluations. Pasqualetti [4], based on the case studies, found five results between geothermal energy and land use relationship:

1. (prevailing) Land use characteristics often play the decisive role in the success or failure of a geothermal development project (depending on the temperature of the resource).
2. Land use evaluations can be used as a screening mechanism in the identification of the sites where institutional conditions (land ownership, zoning, etc.) are the most compatible to geothermal development.
3. Sites identified to be the most suitable should be given highest priority for the development.
4. An approach should be devised and tested that can identify the best prospects among hundreds of communities that are co-located with geothermal resources.
5. The land use analysis should emphasize user energy density, zoning, parcel size, parcel vacancy and land ownerships.

III. DATA

The approach is tested in reality ground by a case study, which is a populous district of Izmir metropolitan area, Turkey, called Balcova. The settlement has distinct natural boundaries delimiting the case area from the rest of the city, which has a historically capacious District Heating System using the local geothermal resources by the footsteps of the Dede Hills (See App.II.a). Case area covers all geothermal heating service provided areas. The abundance of geothermal resource results from the active intersections of the faults in the region. The first technical researches in the region began in 1963. Balcova Central Heating System has begun to serve since 1996. The system has gradually increased the capacity with new drilling wells and enlarged its area recruiting new customers. Now, the site is the biggest geothermal system in the country with multiple uses including the greenhouses around. Currently, there are 11,057 residence equivalence (RE) and 5,965 RE high capacity units (hospitals, schools, hotels, etc.) involved. The system has reached 24,500 RE capacity with 157MW thermal energy capacity (20,500 RE in existing situation). By the end of 2008, this is expected to be 31,000 RE. The settlement is a typical residential quarter, including some public and commercial utilities. North side is bounded with fertile alluvial Inciralti “urban agricultural” zone and the Izmir Gulf beyond.

Especially the Aegean coasts of Turkey are rich in geothermal resources, but the utilization level is quite low compared to the richness due to the three reasons: (1)insufficient legal framework (especially on the renewable energy sources and the public-private partnership), (2)technological incapacitating, (3)lack of financial models to start and run the system. Yet, it is the fact that the price of energy is very high in Turkey, and new energy policies must be in favor of exploiting renewable energy sources, that will free the country from the foreign dependence, or using the existing resources efficiently.

Accordingly, the district of Balcova in the province of Izmir was determined as the “case area” in this study because it is one of the best models in Turkey with regard to the ever existing relation between geothermal energy source and built urban environment; there have been many academic researches regarding the condition and potential of geothermal energy; and because it has an advantageous location in terms of accessibility to the area during land and household surveys. Six neighborhoods in Balcova District were studied. The concern area covers region includes 6 of 8 quarters throughout Balcova District (See maps in Appendix).

The “Geothermal Zoning Plan” of Balcova is a separate document from the master plan, of which only the zone boundaries are demarcated on. The document has basically three elements: the physical environment, the geothermal project itself, and the community (the impacts of the project).

District Heating System (DHS) is the subject of the study as the other limitation. The concept and various design aspects were examined and the power generation, thermal utilization, industrial utilization and greenhouse heating types of geothermal energy are bestowed but not detailed. The concerned urban plan scale is the 1/1000 development plan that allows effective area calculations. Data collection and analyses are aggregated at block levels (in average contain 10-15 building parcels).

The stratified sampling technique is used as applied to non-homogeneous populations. A sample of 3% of household is taken in case area of Balcova District. This corresponded approximately 500 households over 17,000 households in total in the case area. The population is divided into homogeneous groups called strata. Samples are then drawn from each group randomly.

In collecting and analyzing the data, “Mixed Research Method” (closed-ended versus open-ended questioning, the data from governmental and non-governmental organizations) and “case study method” are used in, considering the usefulness of cross-checking of data accuracy, and its focus for numeric versus non-numeric data analysis [38]. Telephone interviews and mail survey are used for inaccessible respondents and quick gathering of simple data. Personal interviews are more useful for socio-economic impact assessments as it allows extensive questioning and probing. Approximately, 486 building blocks are analyzed out of 22,000 buildings. Majority of the settlement plan analyses are computed on AutoCAD and ArcGIS soft wares.

Surveys were composed of two parts. In the first part, individuals from households are surveyed. The second part involves in-depth surveys as observations and interviews with district governors and apartment managers. Specific data related to planning decisions are derived from existing plans of Balcova. Then, the data of relationship between existing energy plans and existing land-use plan are produced and appraised in GIS software programs. Then, differences between implementation plan and proposal geothermal energy efficiency integrated plan are determined.

The archived data collected from different public and private institutions, and organizations are shown in Table II;

TABLE II
DATA SOURCES FOR THE CASE STUDY

Data Sources	Type of Data collected
Izmir Geothermal Incorporated Company	written and visual data on its projects anticipated and its targets, geothermal infrastructural plans in its projects applied, energy quantities and capacities provided to buildings
Greater Municipality of Izmir (GMI) and Special Provincial Administration	future projects from this governmental units which are the partners of Izmir Geothermal Incorporated Company as well as the information obtained from the GMI regarding the effect of geothermal energy on the upper scaled plan for the whole of city of Izmir
Balcova Municipality	physical plans to be obtained before/after the project, and changes (if any) in the physical plan decisions
General Directorate of Mineral Research and Exploration (MRE)	reports and publications about Balcova geothermal regions, and knowledge about who worked in these areas for a long period
General Directorate of State Hydraulic Works (SHW)	data on ground waters and aboveground waters of Balcova
Turkish Statistical Institute (TSI)	data on population, working power, economical structure for the year 2000 (recent data) as included within the neighborhood of Balcova and the whole of Izmir
Health Group Presidency of Balcova	information on the occurrence of health problems/accidents regarding geothermal energy use as obtained from local health clinics, examination on Residential Determination Forms
Educational Directorate of Balcova District	socio-economical structure in Balcova based on education
Local Governors (Mukhtar)	examination on six executive offices in the application area, and change in population living in the vicinity before and after the project

Socio-economic data/parameters for case area in Balcova District:

(A) the household analyses of all members of a household,
  (1) the measures of general socio-economic condition,
    a. household size,
    b. income level,
(B) the household analyses;
  (1) the measures of building type;
    a. size,
    b. permit situation,
    c. technical infrastructure (especially, geothermal infrastructure system),
  (2) the measures of household's perceptions about geothermal energy and system;
    a. satisfaction from geothermal energy,
    b. reason of living there in relation to geothermal energy,
    c. knowledge of heating system,
    d. complaints from geothermal developments,
    e. expectation from geothermal neighborhood heating system

In aggregating data into spatial type, land-use type data are entered on the basis of blocks, even if data are collected from buildings.

Data for Spatial and land-use parameters are:
(1) User energy Density
    a. Building classification
    b. Building height
(2) Zoning
  a. land-use type
  b. density decisions
(3) Parcel Ownership
(4) Land Ownership
(5) Parcel size, building block size and vacancy
(6) Land and real estate value
(7) The number of units in building block
  a. Building size
  b. The number of building units
  c. The number of building floor units
  d. Consumption energy value
(8) The number of users in building blocks
(9) The number of existing buildings and residence equivalent ratio
(10) Office- Residence Ratio

Balcova's current Implementation Plan (Development Plan) (1/1000), was put into action in 1989, does not originally involve energy inputs, though rich geothermal potential in the region) (See Fig 4). The area is rich in geothermal source that necessitated geothermal conservation zone. Also, the district was announced in 1995 as "Thermal Tourism Center and, the Construction Area for Tourism". Within the case study area, since 2002, 5 development plan changes have been approved due to the new drilling wells opened by the municipality for different neighborhoods and Geothermal Heating Centers (GHC) are constructed. The geothermal area is overwhelmingly occupied by residential developments; with different building types (from single detached terrace houses to multi-storey apartments with large autoparks) in different areas (including rehabilitated once-illegal settlements) (Appendix I. figures describe the current implementation of local master plan). In block style, there is a building style in which the height of blocks does not exceed 24 m, and the space between two blocks is not less than 6 m. In blocks, which are joined together at least 1500m^2 maximum floor area ratio (FAR) has been determined as 1.5 and maximum height as 24.80m.

For the health, socio-cultural and administrative building FAR is 0.30 and hmax. is 12.80m. And for public uses FAR has been defined as 0.60. FAR has been determined as 0.50 for education, health and socio-cultural functions. Finally, no planning decision is decided for the fault line passing through the study area in the current plan.

IV. METHODOLOGY

The research method is basically about the comparison of the existing development plan (supposed not to include energy integration) with new energy-sensitive development plan(s) (ideal in energy). As an approach, here, the existing plan is assumed to be ideal in terms of all other planning criteria other than the energy input, whereas the new plan proposal(s) might allow exaggerating in the energy ingredient in its content. Then, the process starts to seek an in-between solution area between the two types of criteria (one side being energy criterion, and other side being all other planning criteria) to achieve an "optimal solution" in the new plan(s). The tentative processing can be defined in four windows as in Fig 3.

	BASE PLAN	NEW PLAN PROPOSALS
ENERGY EFFICIEN.	1. current total energy use 3. compare two (current & new) plans 4. If less energy use foreseen in new plan than the current, then go to (5), if no go to (2)	2. propose new altern. Plan (according to energy effic.)
PLANN. PRINCIPLES	5. compare two plans for 'fidelity' 7. If new plan shows more fidelity than previous proposal, (and high difference betw. Energy-eff rate & non-fidelity rate) then go to (8), or to (2) for another trial, if not fidelity go again to (6) 8. End process & Nominate the best plan	6. modify the last proposed plan in (2), (according to planning principles proposed in current plan)

Fig. 3. New energy-sensitive plan evaluation process

A. COMPARATIVE EVALUATION OF ENERGY EFFICIENCY

A method trial is used for testing the hypothesis as an answering to the research question stated in the Introduction section. Along with the concept of developing a decision-support systems to the urban planning, energy utilization module of ArcGIS and a proposal for geothermal energy integrated land-use planning scheme were considered, with which alternative plans prepared along with energy-efficiency considerations could be appraised in comparison to the existing (original) plan. This, in a sense, is a simulation approach with which the analyst can make many trials (new plan proposal, modifications) to achieve the best solution.

Econometric and optimization models require firmly formulated logical and mathematical presentation and they can deal with only objective variable, functions and parameters [39]. Simulation models try to move from rigid mathematical formulation without neglecting logical evaluation. Simulation is not only a method which tries to solve technical and economic problems, but also a way of thinking and acting. Geographical Information System (GIS) are frequently used in simulations in urban planning studies.

The methodological novelty arises on the simulation and plan proposal evaluation approach where the "fidelity" to the mentioned original (base) plan's "ideals" while the cost effective use of geothermal energy integrated development plan (land-use plan) are to be provided. There is two-constraint optimization to be integrated into planning; (1) to maximize energy efficiency, (2) to maximize fidelity to the development plan. In a gaming style, the two constraints compete with each other and condition the planning. But, as an approach, priority is always given to the first constraint (ie, energy) over the second, as a principle. This optimization seeking will not be a mathematical optimization process, but rather a "manual" simulation approach. That is, first, the plan was let to get away from the originality of its proposals, if the discrepancy levels are reported. The originality of the proposed method also comes from its provision for the quantifiable (even if some data are originally qualitative), comparable and measurable results. Finally, it yields summary (general rates) results for both outputs to compare.

Simulation method for single case which is the evaluation of "new plan proposal" against original is chosen for the test method to show the novel approach's significant use. Because the case studies are the preferred strategy when the investigator has little control over events, and when the focus is on a contemporary phenomenon drawn from real-life context. The method proposed can help us to actively research the relationship among district heating plans and urban development plans interactively.

The discussion that the geothermal energy in Izmir could be used in a much better way is the major derive of the current study in search of improving the usual planning routine; thus, it was claimed that the existing master plan can be revised, for example, in more energy-sensitive way. Taking few criteria, geothermal energy district heating utilization in land use plan will be proposed and the net effects if five variables (And the Parcel Size and Vacancy for Drilling and Fault Line, Heat Load Density of Buildings, User Energy Density/ Land Block Density Types, Residence Equivalence- Existing Building

Ratio and Land-use Mix) are investigated solely based on area size calculations of the assigned land uses. The variables used, all derived from the literature resources, affect the energy efficiency of the system, which can be measurable and easily carried out in the GIS environment. For GIS practical use, the results are to be translated into graphical terms (map). Yet, the calculations were made manually to show the process step-by-step, which can be later GIS automata, rather.

The variable values are determined, even if collected at household or building level, to be block averages. The variable 'User Energy Density' (non-uniform block density) is about the general concentration of the settlement, which results in the need for shortened distribution length, meaning lowered costs. Mixed land use (residence and office ratio) demands certain mixture of land use for efficient energy utilization. Residence equivalence and building ratio refers to the efficiency of energy use when the size of the residence (for a typical household size) is ideal, which is around 100 m^2 for Turkey. Land ownership variable refers to the efficient energy use when the land belongs to public utilities, due to the less barrier effect in laying pipes, but high vacancy rates, and non-uniformity in private land. Parcel size and vacancy refers to disadvantage, for the land is not served, while to the advantage for it allows the sitting of new drilling wells.

All these variables are used for the energy use appraisal of existing and alternative plan proposals, each of which is explained later in the next sub-section. According to the formulation, f(K) the role of parameters, E_{base}, the total energy use (existing geothermal energy) and E_{new}, energy use in the proposed plan. All variables (criteria) are assumed equal in weights, even if would not be in reality, for the sake of calculation convenience. In further studies, this weighing issue can be thought. The calculation process is described below with a general formula as;

$$E_{new} = E_{base} \cdot fx(K) \qquad (1)$$

Basically, 'energy efficiency' is the problem of maximization of the sum of the energy output in total, which is the energy saving compared to the previous (base) case as a percentage (ratio) value. Contrarily, the 'Fidelity' is the minimization concern of the sum of deviations from the original planning principles in total (also ratio). The comparisons and evaluations can only be made on the basis of "proposal" cases to compare (as between an alternative and the base, or other alternatives proposed). The ideal result would end with, for example, a low (preferably the lowest) the score (such as 5%) of 'fidelity' against a high (preferably the highest) 'energy efficiency' score (as 60%). Thus, simply each proposal case (land use scenario) should be evaluated with these two scores.

Such modeling efforts and planning support systems are very important;

1) to see that it is quite possible to construct a planning support system that projects the future in a various scenario approach and at different geographic scales. Models deal with alternative land development patterns and work at both the broad metropolitan level and for small communities.
2) to see the possibility to integrate the outputs of these models with different types of visual presentations.

GIS (Geographical Information System) combines a computer's potential to classify and retain large amounts of data and perform composite computation speedily. Integrating mapping with location-specific data, GIS users are able to create maps and reports that use a community's own data to answer detailed and specific questions. So, GIS is a great tool for bringing information to decision makers in a format that answers the questions visibly. But, they can not relate multiple facts with multiple sites to answer complex questions or problems. GIS also provides a central site for collecting and managing location-based information, reducing information redundancy among city departments [40].

AutoCAD Map 3D software which is the detailed and specific CAD program is used in this study for storing, assembling, and composing the related existing development plans of case study area and used for generating the base plan for further analyses. This program is developed for creating and managing spatial data and it is important planning GIS platform. In this program, a map is composed of a set of layers, each of which represents a group of data from a particular source. The other software, ArcGIS (9.1) includes two main sub-modules; ArcMap and ArcCatalog, was used to create maps to convey, cross-examine the questions and shows result of the works. ArcCatalog provided data access and spatial data management tools, and used in reading and creation of metadata. In this research, this program are used for analyzing, query and mapping compositions related with input data which are output of the AutoCAD and SPSS software's. GIS is basically used in spatial computations in comparing actual and alternative plan land use proposals.

B. Alternative Energy-sensitive Plan Proposal

If the highest score is obtained for the energy saving as the differential between the proposed alternative case and the existing case, and the lowest score is obtained for the fidelity in turn, then that the plan proposal is the healthiest one can be assured to meet the energy criteria and the other planning criteria (principles).

Regarding the "original" plan as basis, a single trial of an alternative plan was conducted, which takes geothermal energy usage into account. The existing master plan (1/5000) for the district was in effect in compliance with the Izmir Greater City Municipality's 1/25000 plan since 1981 with some minor changes (additions). Thus, it is assumed that the existing developments, zoning and building codes on the region are the outcome of this plan. Both the existing and the alternative plan's land use proposals are to be compared to see whether any energy saving is observed by the alternative plan. The restrictions of proposing new plan are listed as follows; among would-be many, only five variables of both energy and planning that are the tangible ones were selected. These variables are also the ones for which efficiency values were observed in the literature. These are also the ones that can be mapped. For comparability of plans, the same populations of the same case area are regarded to utilize the same amount of total energy used per year. That means, a number of people (or households) is served and total energy amount is used yearly, which are reference points in comparisons. A fraction of 7% of the population does not use the GEDHS. This portion will be the same as for alternative plan proposals.

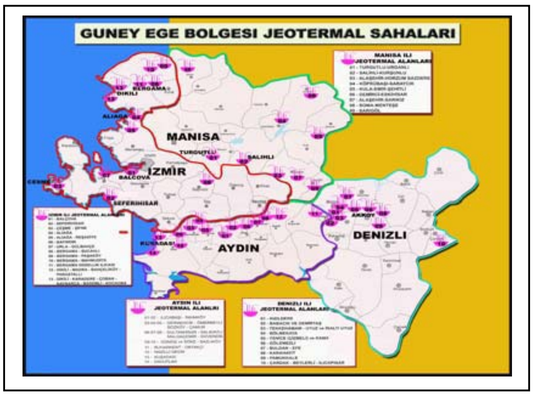

Fig. 4. Aegean Region geothermal resource fields

Especially the proposals for density increase and the land use type (in favor of mixed land use: ¼ office/home ratio) were emphasized in the new alternative plan, because they promise more efficient use of energy as frequently mentioned in the literature. How far deviation from the current development plan (or actually the existing land use) is proposed is measured with simple calculation for a particular variable K as;

$$D_{newLU} = \Sigma\,(A_{LU}^{new} - A_{LU}^{old})/\,A_{LU}^{old} \qquad (2)$$

where D_{new} is the total deviation as percent change on the new alternative plan from the original plan (for the $_{LU}$ land use type). A_{LU}^{new} is the total area of the land use type (for example mixed use) converted from original land uses. A_{LU}^{old} is the total area reserved to the land use type in the current plan.

For density case, if for example, FAR ratio is increased twice in the new plan than the original plan. In addition to land use change percentage, the amount need be multiplied by 2. The calculation logic is the same for the energy use change, where D_{newE} replaces D_{newLU} ,and A_E replaces A_{LU} . For the best (optimum) solution Efficiency can be defined as $maxE = D_{newE} - D_{newLU}$, where the left side represents energy efficiency (as %) and the right side the fidelity to original plan (as %). The E value is expected to be positive value. The bigger the difference, the better the solution, since the increase in the ratio of energy efficiency (energy use to be reduced), and the decrease in the infidelity ratio (deviation from the existing plan) are desired. Eq (3) shows the similar calculation for energy amount in total for the new alternative plan;

$$E_{new}= U_{base}\ x\ E_{base}\ x\ f(K) \qquad (3)$$

In the light of this tentative formulation, each variable has a self-formulation in integration within this general formula.

Parcel Size and Vacancy for Drilling and Fault Line:

The minimum distance for buildings to the drilling well is determined to be 20m radius. If there is an active fault in the vicinity, fault line conservation distance should be 30m. Two active faults (Agamemnon I and Agamemnon II) are observed in the area in the east-west direction and one (Yeniköy Fault) in southwest-north east direction (see App. II.a.). Thus, the affected residential units that should be removed (hypothetically) in the new plan are calculated as in Table III. In total 136 buildings (ie, 920 RE units) on the fault zones were to be transferred elsewhere, making 5,036,519 kcal/h energy use.

There were 84 units on the well drilling zones that should be removed (112 RE) making an amount of 617,386 kcal/h geothermal energy. Finally, 1032 RE must be carried to different areas in the alternative plan with 5,653,905 kcal/h energy to be utilized in another area. Finally, 1032 RE must be carried to different areas in the alternative plan with this energy amount to be utilized in another area.

TABLE III
INFLUENCE OF THE FAULT LINES AND WELLS

Influence Type	# of Blocks	# of Residence Equivalent (RE)	Total Energy (kcal/h)
Fault Lines	16	920	5,036,519
Wells	5	112	617,386
TOTAL	21	1032	5,653,905

Residence Equivalence and Development Plan Building Ratio:

This variable differs from region to region because the mean temperature of the region is an important factor in this value determination. The value for Balcova district was determined to be 100m^2 [6], depending on the average home size in Turkey. And for a 100m^2 unit, there is an energy need of 5490 kcal/h at an average temperature of 22^{o}C in Balcova, if the geothermal energy is to be used for the heating purpose.

The total amount of energy consumed in ideal RE buildings was determined to be 1,344,679 kcal/h. The non-ideal section (less or greater than 100m^2) constitutes a greater portion corresponding to 8220 units, and an energy amount of 99,914,942 kcal/h.

According to Eq. (4), $U1_{eb>re}$ is the number of units in the existing plan for the buildings having residence size greater than the ideal RE, $U1_{re>be}$ is the number of units of residences smaller than the RE, $E1_{eb>re}$ is the unit energy used (kcal/h) for the current plan buildings greater than the RE, whereas $E1_{re>be}$; unit energy used for the buildings smaller than the RE. f(K1) is the ratio of results for the existing development plan's buildings value over RE, since there is not any previously defined value for this variable, and E_{new}; total proposed energy used are determined as.

$$E_{total}= [U1_{eb>re} \, x \, E1_{eb>re} \, x \, f(K1_{eb>re})]+ [U1_{re>be} \, x \, E1_{re>eb} \, x \, f(K1_{re>eb})] \tag{4}$$

In this area in general, a restriction is to be brought on the size of units, that is reducing the size to 100 m^2, can make it possible for extra 4683 RE units to utilize from the same amount of energy (App. II.b., previous situation is App. I.b.). In other words, such a change in the plan creates a saving of 25,709,670 kcal/h in energy.

Heat Load Density:

Heat load density is a value derived from RE, which relates it to physical density. This ratio, which was adopted from the Gülsen's study [41], is derived by multiplying floor area ratio (FAR) in a block by 54.9 kcal required for heating 1 m^2. This value determined is the one centered by the density of block of parcels.

$$HLD = 54.9 \ kcal/hm^2 \ x \ FAR \tag{5}$$

Heat load density was divided into five different categories (see Table IV). For blocks, the value is over 60 kcal/hm^2.

TABLE IV
RATIOS OF HEAT LOAD DENSITY (SOURCE: ADOPTED FROM GÜLSEN 2005)

Heat Load Density				
Construction Type	**An Advantage of Cost of Heat Ratio**	**Cost of Heat Ratio**	**kcal/hm²**	**Availability for District Heating System**
Single Houses	0.88	Less than 0,12	Less than 10	Impossible
Buildings with 2 housing	0.88-0.80	0.12- 0.20	10- 18	Questionable
City center, commercial buildings, buildings with many housing	0.80-0.49	0.20- 0.51	18- 44	Applicable
City center, buildings with many floors	0.49-0.30	0.51- 0.70	44- 60	Available
City center, high rise apartments	Less than 0.30	Over 0.70	Over 60	Very available

It is found out that DHS is readily available and a rate of efficiency over 0.70 can be obtained. This value is usually reached in city centers and high rise apartments. According to the Table IV, the third category, values between 10-18 kcal/hm^2 seem feasible for efficiency. But, single houses category can be said unfeasible for the DHS, where an efficiency of less than 0.12 MW is obtained with an observed value of less than 10 kcal/hm^2. As a result, for the existing development plan, 12 building blocks that can be called single house blocks were determined consuming energy less than 10 kcal/hm^2. Here, 208 units in 63 buildings can be defined as unfeasible for the DHS. The total amount of energy used in these areas is 146,654 kcal/h. In the questionable group, there are 118 buildings on 18 building blocks. 545 units on these building blocks have a RE value of 373, and consume a total energy of 2,050,733 kcal/h. Total number of building blocks in available group is 50, number of buildings is 535, and the number of total units is 2661 (2657 RE) and the amount of heat consumed is 15,652,886. In feasible group, there are 920 buildings on 85 building blocks. 5239 units (6239 RE) consume a total energy of 34,193,468 kcal/h. finally be comes the very crowded group which is called very feasible group. There are 5467 units (8971RE) in 933 buildings on 115 building blocks consuming 49.215.880 kcal/h (see Table V).

According to the Eq. 6., $U2_{sg}$; The number of units of single houses, $U2_{2h}$; of buildings with two houses, $U2_{mh}$; of buildings with many houses, $U2_{mf}$; of buildings with many floors, $U2_{hra}$; of high rise apartments, $E2_{sg}$; energy value used (kcal/h) for single house, $E2_{2h}$; for buildings with two houses, $E2_{mh}$; for buildings with many houses, $E2_{mf}$; for buildings with many floors, $E2_{hra}$; for high rise apartments, fx (K2); the ratio of results for heat load density determinant, and the ratio of parameters are evaluated based on the Gülsen's study (2005), $fx(K2_{sg})$is 3.33 for single house, $fx(K2_{2h})$is 2.93 for buildings with two houses, $fx(K2_{mh})$ is 2.66 for buildings with many houses, $fx(K2_{mf})$ is 1.6 for buildings with many floors and $fx(K2_{hra})$ is 1 ratio for high rise apartments and E_{total} is the total proposed using energy.

$$E_{total}= [U2_{sg} \, x \, E2_{sg} \, x \, f(K2_{sg})] + [U2_{sfrh} \, x \, E2_{sfrh} \, x \, f(K2_{sfrh})] + [U2_{ga} \, x \, E2_{ga} \, x \, f(K2_{ga})] + [U2_{th} \, x \, E2_{th} \, x \, f(K2_{th})] + [U2_{hra} \, x \, E2_{hra} \, x \, f(K2_{hra})] \tag{6}$$

As a result of calculations, 0.67 were determined as the value of f(K2). And in case all the areas in the alternative plan to be very available (ie., 60 kcal/hm^2), an amount of energy 67,843,946 kcal/h will suffice. In short, an energy amount of 33,415,674 kcal could be saved. This corresponds to 6086 RE units (See App. I.c. and App. II.c. for comparison).

User Energy Density (Land Block Density):

The parameter called user energy density or land block density was spelled in [4]. This is a type of variable depending completely of building density in general encompassing the type of building, due to the strong relationship between building type and the cost of energy. This variable can be evaluated in five different categories relating the building type to energy cost; this is 0.799 in suburban districts; 0.787 in high density and single family districts; 0.382 garden apartments; 0.432 in town houses or row houses; and 0.328 in high rise apartments.

9,311,927 kcal was consumed in total 1315 units (1708 RE) in suburban area. 52,780,447 kcal/h was consumed in 8006 units (9622 RE) for areas where high density single family groups exist, while this is 12,680,837 kcal/h for 1870 units (2310 RE) in garden apartments and 26,483,380 kcal for 2929 units (4600 RE) in high rise apartments.

In the Eq. (7), $U3_s$ is the number of units of suburban; $U3_{hdsf}$ is of high density, single family; $U3_{ga}$ is of garden apartments; $U3_{hra}$ is of high rise apartments; $E3_s$ is the energy value used for suburban; $E3_{hdsf}$ is for high density, single family; $E3_{ga}$ is for garden apartments; $E3_{hra}$ is for high rise apartments. fx (K3) is the ratio of results for user energy density, and the values are: $fx(K3_s)$ is 2.43 for suburban; $fx(K3_{hdsf})$ is 2.39 for high density, single family; $fx(K3_{ga})$ is 1.24 for garden apartments and $fx(K3_{hra})$ is 1 for high rise apartments and E_{total} is the total energy.

$$E_{total}= [U3_s \times E3_s \times f(K3_s)] + [U3_{hdsf} \times E3_{hdsf} \times f(K3_{hdsf})] + [U3_{ga} \times E3_{ga} \times f(K3_{ga})] + [U3_{hra} \times E3_{hra} \times f(K3_{hra})] \qquad (7)$$

The calculations resulted in the value of 0.53 as the value of fx(K3). In case all areas are filled with high rise apartments and the advantage of cost of heat ratio becomes 0.328, a 3,667,599 kcal/h of energy is quite sufficient for the present need. That is, 47,592,021 kcal/h of energy could be saved and this corresponds to 8668 RE units (See App. I.d. and App. II.d. for comparison). As in the previous heat load density parameter, due to difficulty in applying the above mentioned extreme values, rehabilitation studies must be carried out and suburban and high density single family groups must be turned into garden apartment groups. Calculations based on this view brought forward 0.84 as fx(K3) value, which is 16,201,559 kcal/h energy and 2951 RE unit value.

Mix Land-Use (Residence- Office Ratio):

Mixed land-use parameter was chosen as the last variable used in the study of master plan sensitive to geothermal energy. Observed energy efficiency values for this variable were taken from [42]. The mixture of houses and offices in a building has a direct relationship with the energy efficiency. The reason why these two different type of use should be in a building is to establish a balance among the utilization times of the energy because there is a completion of the use as the offices and shops are active during the day time whereas the houses are active at night. According to the Table V, single retail house is shown as the most energy consuming and the costly type of residence.

The ratio of ¼ (as 1 office /four houses) seems to be the best usage in a building (Table V). With such a ratio in one acre, the energy consumption per year is 4600 Million British Thermal Units/year (Btu/yr), and the energy cost is 48,500 US$/yr. This ratio seems to be the most appropriate one.

TABLE V
LAND USE MIX AND ENERGY COSTS

Building Type	**An Advantage of Cost of Heat Ratio**	**Energy (MMBtu/yr)** ***(for 1 Acre)***	**Cost ($/yr)** ***(for 1 Acre)***
Retail	0,999	61100	566400
Office	0,261	17000	168300
Housing	0,147	9392	99000
Jobs (Office)/Housing Ratio: 4/1	0,129	8200	83800
Jobs (Office)/Housing Ratio: 1/4	0,072	4600	48500
Jobs (Office)/Housing Ratio: 1/1	0,089	5500	57700

According to the analysis based on the implementation plan, office-residential using is accepted to be ideal. It should be certainly defined the proportion of office-residential use within the plan report or plan notes. Based on these, there are five different land use decisions in the study area. Within the 50 building blocks with office use, 467 buildings locate and totally 8,174,912 kcal/h energy with 1247 unit (1501 RE) is used. In the 41 building blocks with residential use, 350 buildings locate and totally 25,229,065 kcal/h energy with 3465 unit (4370 RE) is used generally in the GEDHS.

In total, 13,956,880 kcal/h energy is used with 2543 RE in locating in 25 building blocks. These buildings have both office and residential use with the ratio of residential to office is %25; and there are 17 buildings and 261,732 kcal/h is used with 47 RE where the office and residential ratio is equal. Lastly, the regions where the office over residential use is %25, are the most advantageous ones in terms of energy efficiency. 46,782,499 kcal/h energy is used with 8531 RE in 146 building blocks.

According the Eq. 8., $U4_o$ is the number of units of office, $U4_h$ is of housing, $U4_{o/h,4/1}$ is of office-housing (4/1), $U4_{o/h,1/4}$ is of office-housing (1/4), $U4_{o/h,1/1}$ is of office-housing (1/1), $E4_o$ is the energy value used for office, $E4_h$ is for housing, $E4_{o/h,4/1}$ is for office-housing (4/1), $E4_{o/h,1/4}$ is for office-housing (1/4), $E4_{o/h,1/1}$ is for high rise apartments. fx (K4) is the ratio of results for mixed land-use criterion, and the ratio of parameters are evaluated $fx(K4_o)$; 3.69 ratio for office, $fx(K4_h)$; 2.2 ratio for housing, $fx(K4_{o/h,4/1})$; 1.78 ratio for office-housing (4/1), $fx(K4_{o/h,1/4})$; 1 ratio for office-housing (1/4), and $fx(K4_{o/h,1/1})$; 1.19 ratio for office-housing (1/1), and E_{total} is the total proposed using energy determined.

$$E_{total} = [U4_s \, x \, E4_s \, x \, f(K4_s)] + [U4_{hdsf} \, x \, E4_{hdsf} \, x \, f(K4_{hdsf})] + [U4_{ga} \, x \, E4_{ga} \, x \, f(K4_{ga})] + [U4_{hra} \, x \, E4_{hra} \, x \, f(K4_{hra}) + [U4_{hdsf} \, x \, E4_{hdsf} \, x \, f(K4_{hdsf})] \quad (8)$$

Depending on the user energy density variable, fx(K3) is estimated as 0.64. and the energy need will be 65,057,634 kcal/h in the regions that the ratio of office/housing is (¼). Briefly 36,201,986 kcal/h energy will be saved which is equal to 6594 RE. Existing residential areas will be decreased because of the land use changes from residential to office. According to the estimations based on existing plan, 2578 (RE) unit of office should be transformed to residential use.

According to the existing plan results, 13,384 RE units were added to the study area and the heating needs of these units has been provided from energy of 73,489,935 kcal/h saved from the efficiency directives of the five variables mentioned above. Corresponding RE value in ideal conditions is 10,360 units. Separately, the corresponding rate of change (%) values of the above mentioned values is an increase of 29% in building density, a decrease of 14% in office areas in terms of land balance based on office-housing use, a 35% rise in housing areas, a rise 0f 11% in green areas, a 15 % transfer from private to public in land ownership (Table VI).

TABLE VI
VARIABLES AND LAND USE EFFECTS

Variables	**The Cause of Affects**	**The Affects to Units**	**Total Energy (kcal/h)**
Parcel Size and Vacancy for Drilling and Fault Line	Risky Area	1032 RE (decrease)	-5,653,905
Residence Equivalence and Implementation plan Building Ratio	Unit Size (m^2)	4683 RE (increase)	25,709,670
Heat Load Density	Density	*6086 RE (increase) (for extreme value)*	33,415,674
		5717 RE (increase) (for normalization value)	31,390,482
User Energy Density (Land Block Density)	Density	*8668 RE (increase) (for extreme value)*	47,592,021
		2951 RE (increase) (for normalization value)	16,201,559
Mix Land-Use (Residence- Office Ratio)	Land-use	6594 RE (increase)	36,201,060
	Land-use	2578 RE (decrease)	-14,153,220

V. FINDINGS AND DISCUSSION

Regarding the “original plan” as basis, a single simulation trial of an alternative plan was conducted, which takes geothermal energy use into account. Both the existing and the alternative plan land use proposals are to be compared to see whether any energy saving could be possible with the alternative plan. The restrictions of proposing new plan are listed as follows; Among would-be many, only five variables, which are the tangible measurable ones, were selected. These variables are also the ones having observed efficiency values transferred from the literature. These are also the ones that can be depicted on map visually. The choice of variables may differ in different context.

TABLE VII
COMPARISON OF TWO PLANS BY THE VARIABLES

Plan Parameters	**Current Plan**	**Alternative Plan**	**Changing Ratio**
Building Density	0.88 FAR (Single Family)	2.66 FAR (Single Family)	29%
	2.19 FAR (High density single family)	2.81 FAR (High density single family)	
	2.63 FAR (Garden apartments)	2.63 FAR (Garden apartments)	
	2.52 FAR (High rise apartments)	2.52 FAR (High rise apartments)	
Land-use Balance (Office-Housing)	526,400 m^2 (Office)	339,700 m^2 (Office)	14%
	1,172,500m^2 (Housing)	1,359,200m^2 (Housing)	35%
Green Area	300,112m^2	336,836m^2	11%
Land Ownership	212,060 m^2	248,784 m^2	15%

In total, when considering all criteria with no weight for any (assuming all criteria as equal), a 30% change in energy saving could be obtained in a single trial (so to say, simulation) against only a 17% change in the original land use and planning proposals. That is, a %13 difference value between the energy efficiency and fidelity criteria, which is to be maximized. The more the difference, the better the solution for planning. In the further trials more efficiency can be gained with a much lower deviation from current land use proposals (ie., with high fidelity plans).

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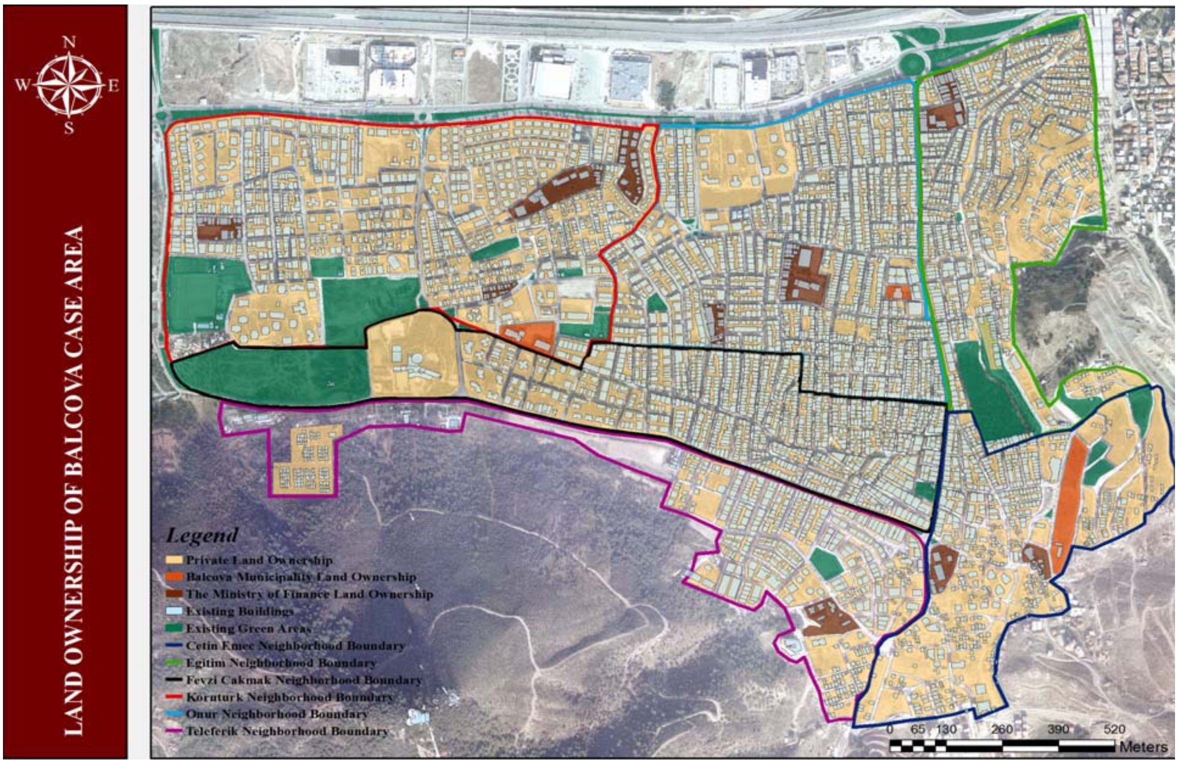
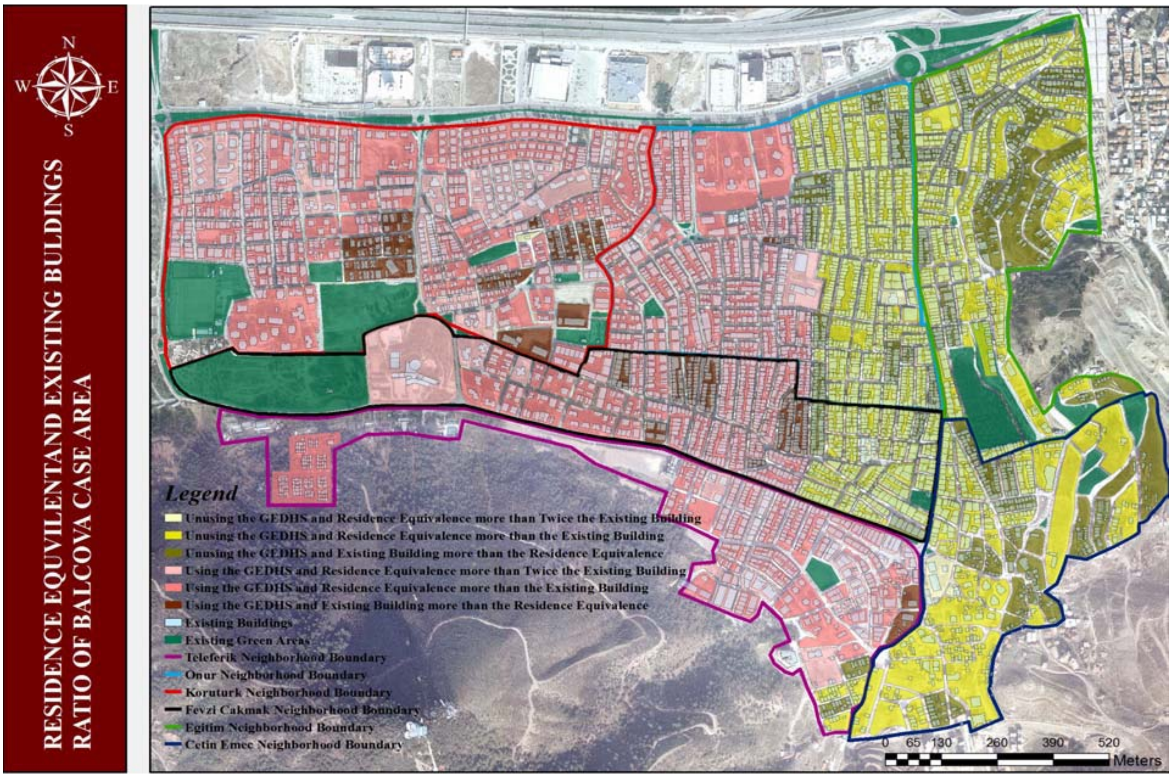
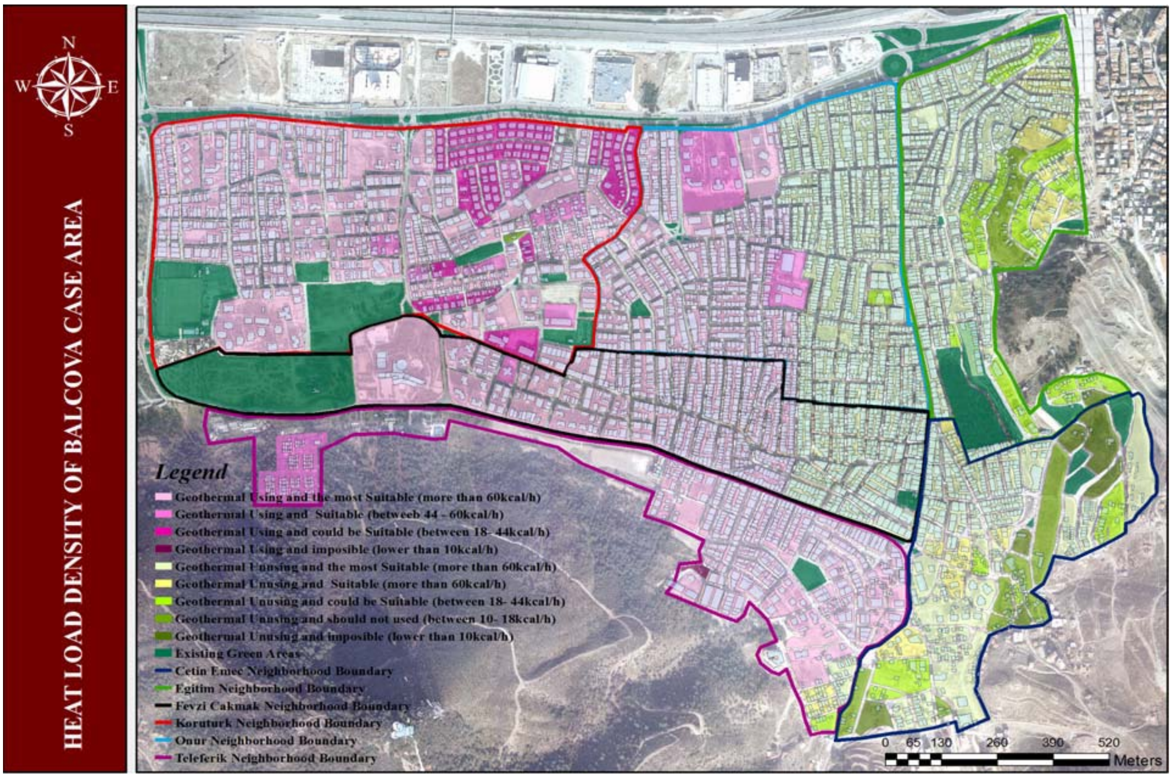
APPENDIX



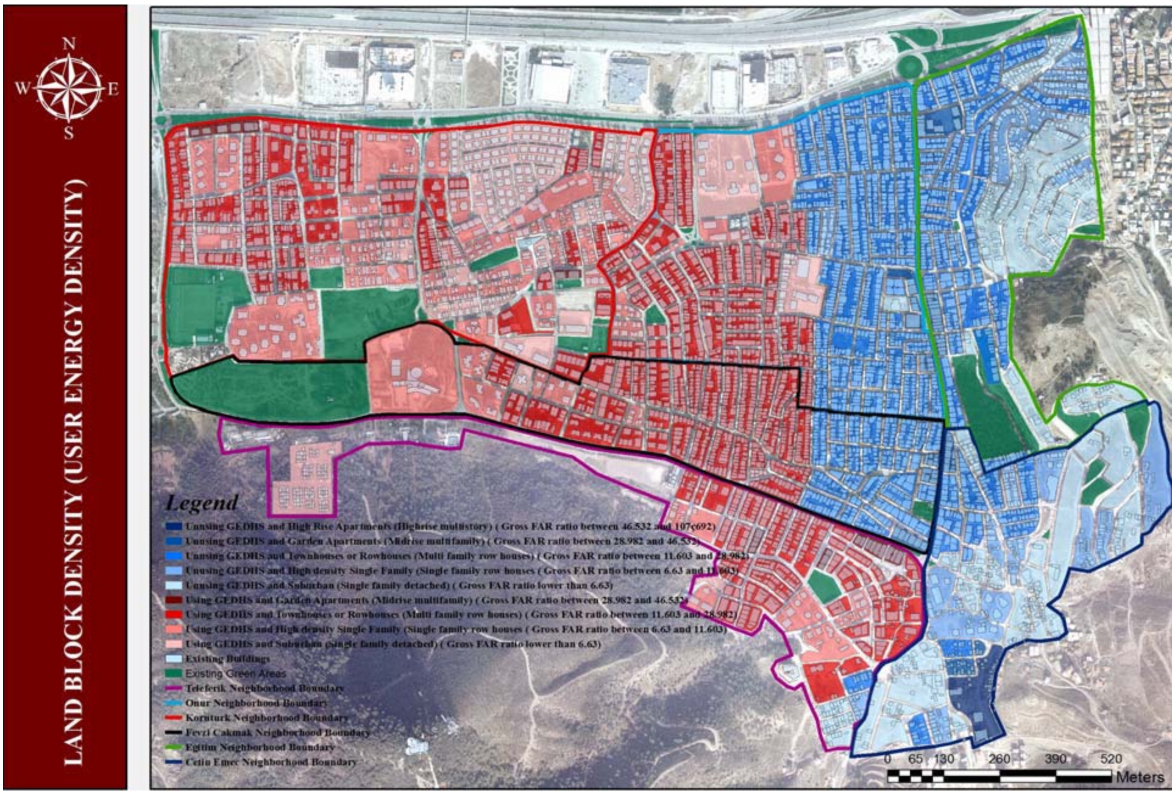
App. I.a. Land Ownership in the Case Area



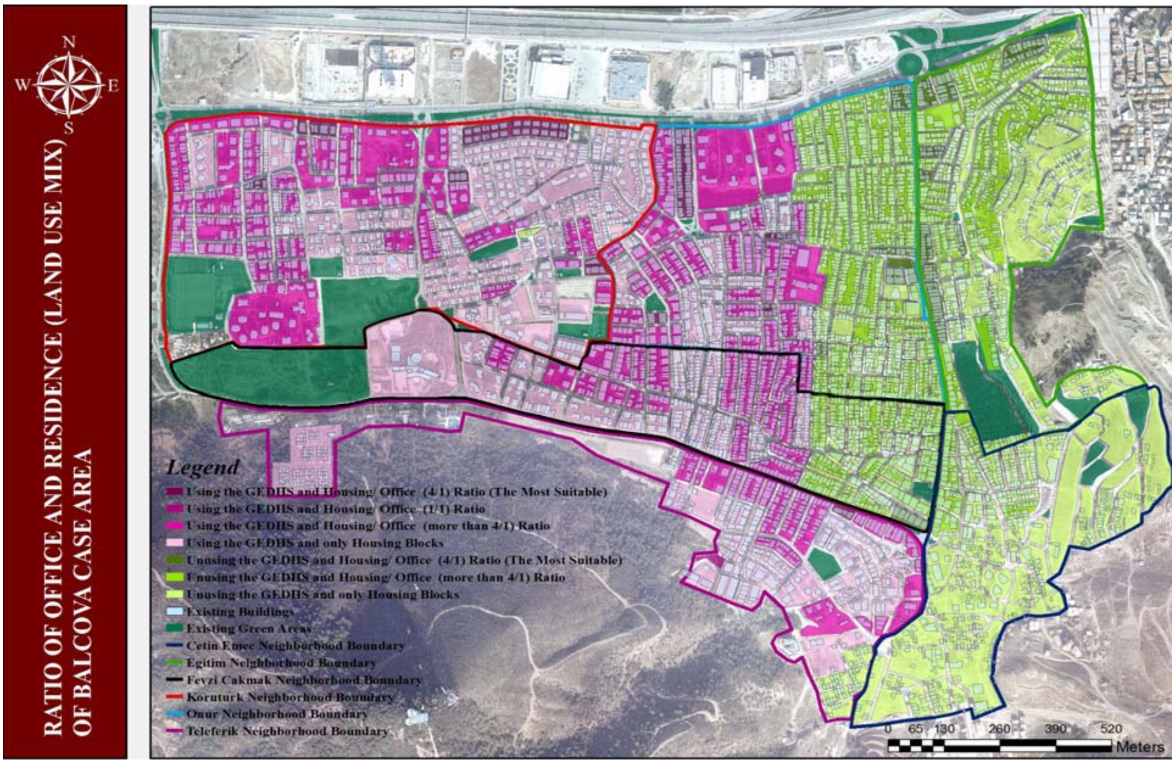
App. I. b. Residence Equivalance and Existing Building Ratio



App. I.c. Existing Heat Load Density

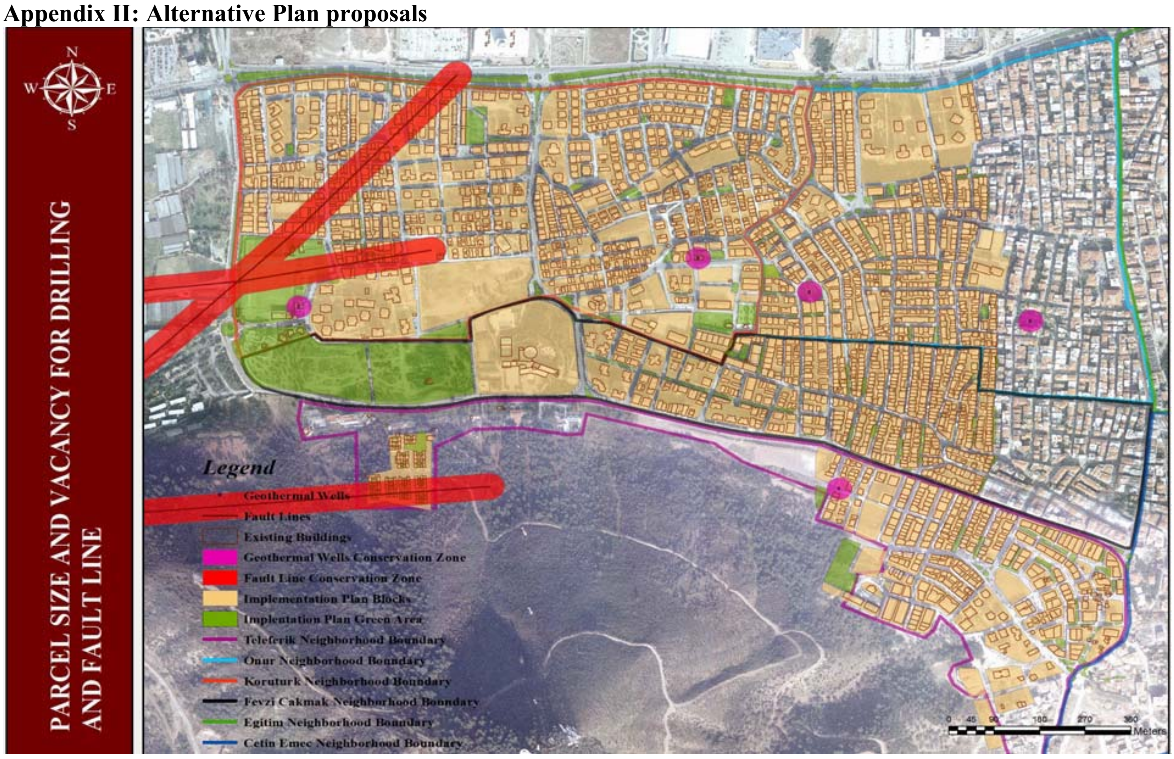


App. I.d. Existing User Energy Density

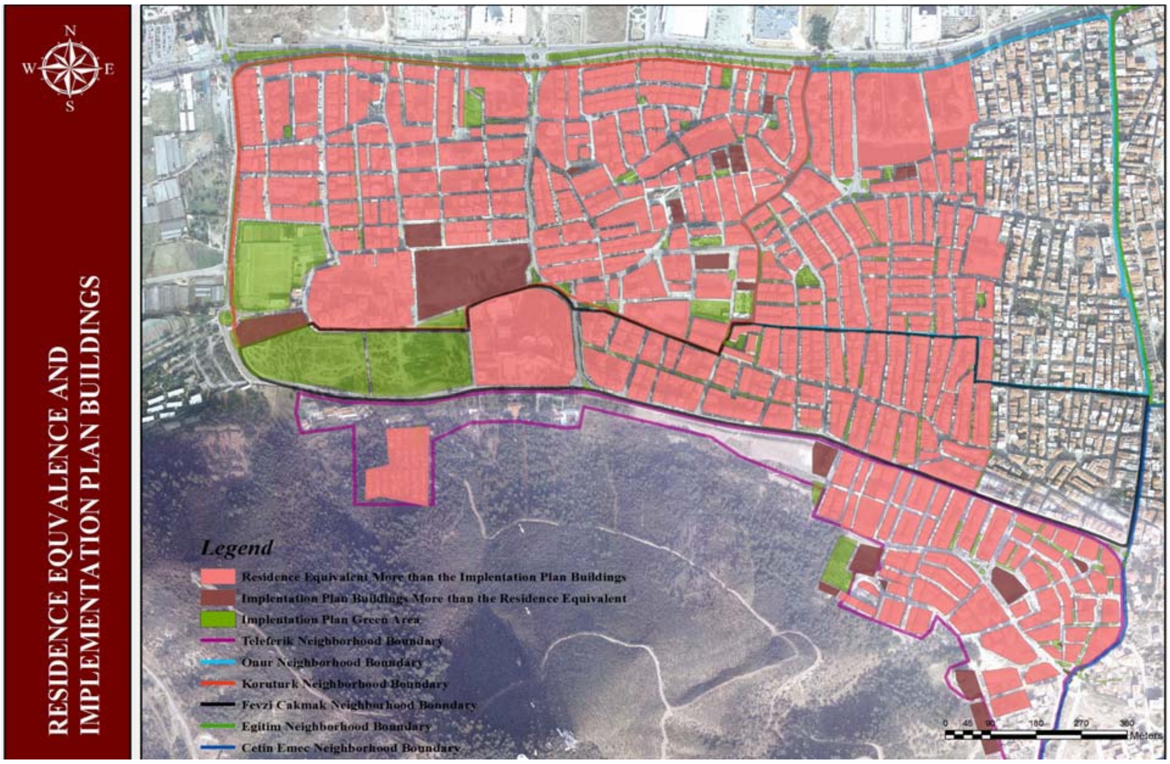


App. I.e. Existing Land Use Mix

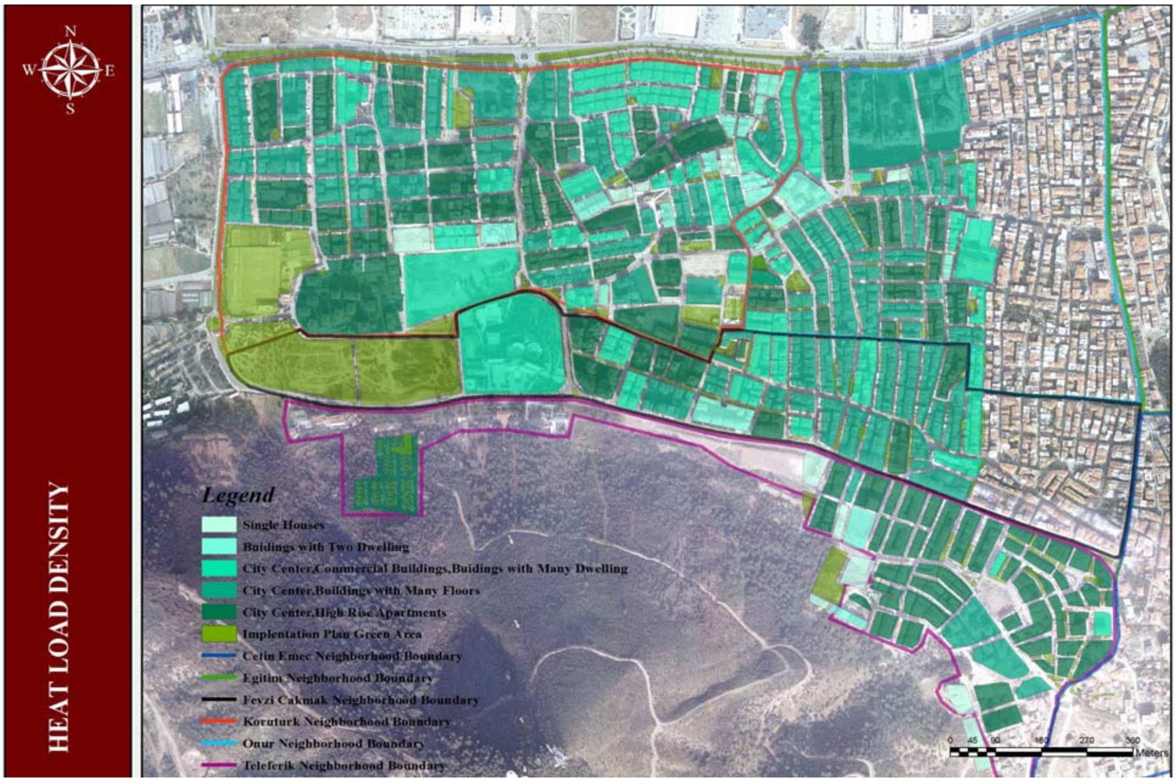
Appendix II: Alternative Plan proposals



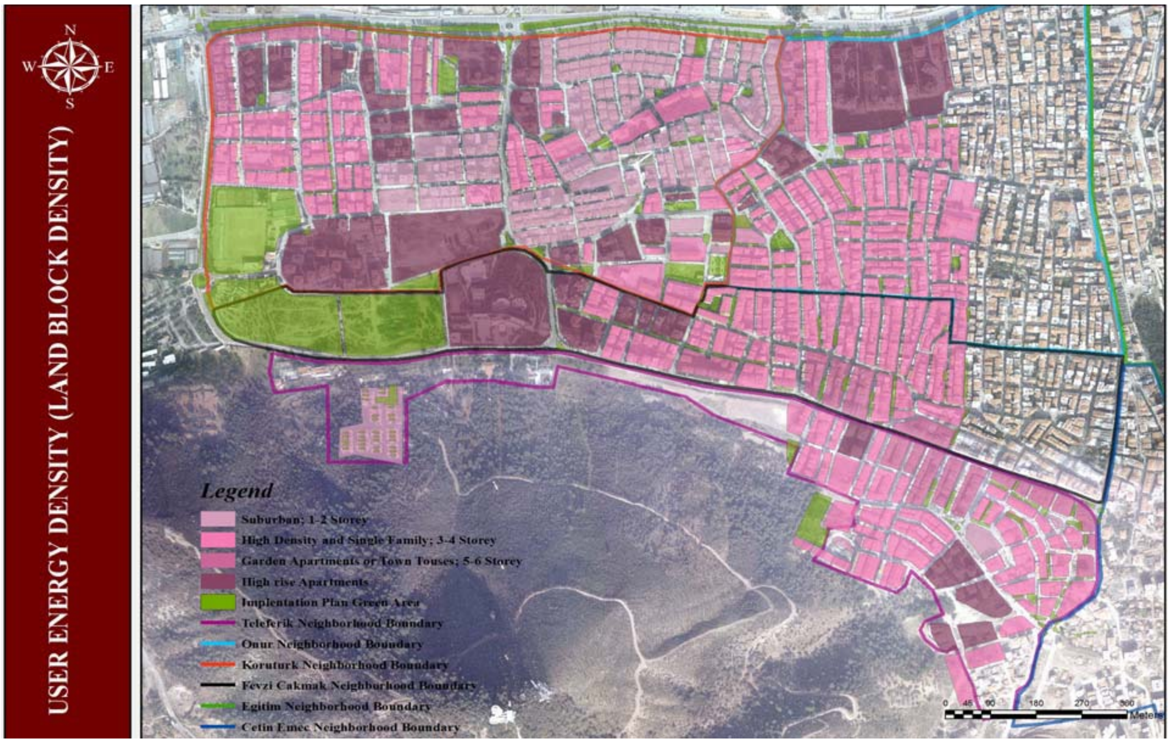
App. II.a. Parcel Size and Vacancy for Drilling Wells, and Fault Line Zones



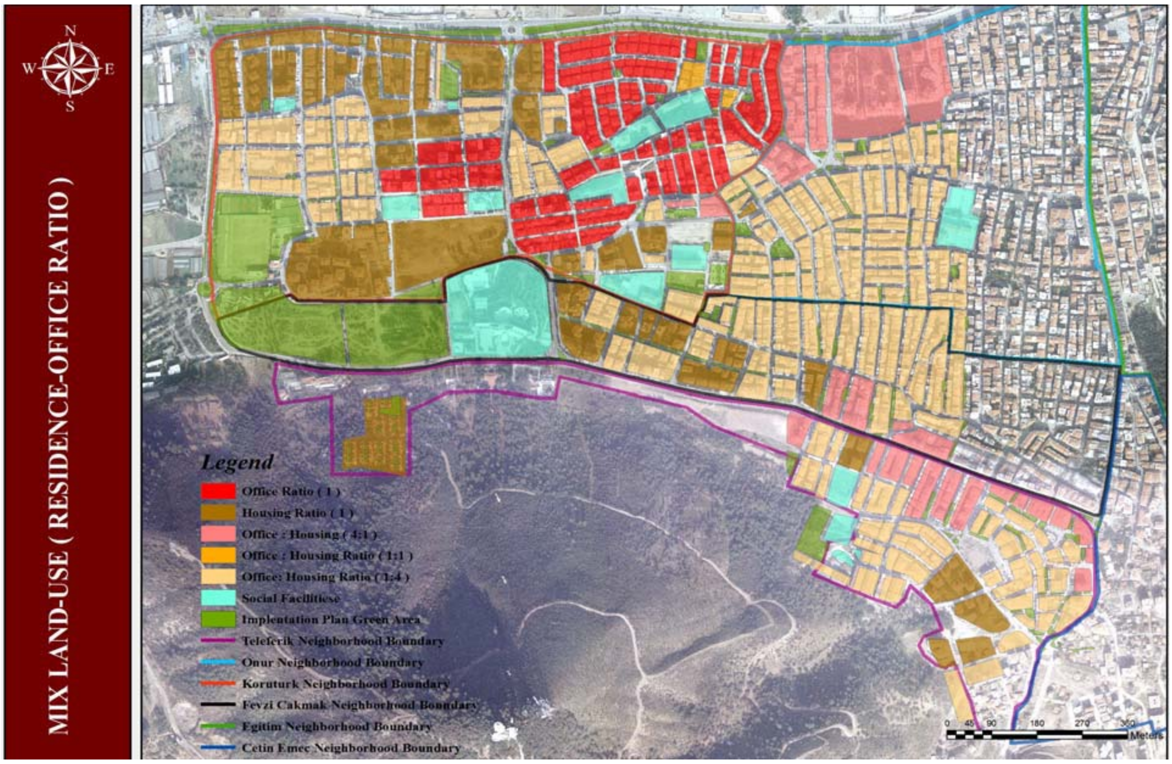
App. II.b. Residence Equivalence and Alternative Plan’s Building ratio



App. II.c. Alternative Plan’s Heat Load Density



App. II.d. Alternative Plan’s User Energy Density



App. II.e. Alternative Plan’s Proposed Land Use Mix