Estimated reduction of energy consumption related to mobility in urban renewal projects

Case study in Lausanne, Switzerland

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The urban sprawl that characterizes most European cities relies highly on the use of private motor vehicle. As a result, there is a prominent increase in the energy consumption of the built environment. Therefore, the densification of existing urban areas located near public transportation is an interesting alternative to dispersed urbanization, provided that such process goes together with an offer of local services and facilities to promote the use of soft mobility. Analysis at neighborhood scale allows studying the influence of infrastructures, facilities and services on daily mobility choices. This analysis should create direct insights into how the combination of global and local parameters related to mobility infrastructures and urban developments affect mobility energy consumption. The latter can be calculated by two main different methods: the macro-scale methods, which are based on parameters defining the city, and the micro-scale methods, which use accurate data from individuals and infrastructures. The present paper shows an application of a novel intermediate method at neighborhood level developed by the Swiss Society of Engineers and Architects (SIA) to estimate the energy consumption related to mobility and attributed to buildings. The analysis of induced mobility by different urban renewal scenarios of an existing neighborhood in Lausanne, Switzerland, shows the importance of the number of car parks and of the human density (residents or jobs per square meter) as key factors related to mobility energy planning. Results also highlight the significant impact of changes in behavior, in terms of chosen mean of transportation and covered distances, on the potential for energy savings.

Keywords: Energy; mobility; density; urban renewal; sustainable neighborhood;

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ABSTRACT: The urban sprawl that characterizes most European cities relies highly on the use of private motor vehicle. As a result, there is a prominent increase in the energy consumption of the built environment. Therefore, the densification of existing urban areas located near public transportation is an interesting alternative to dispersed urbanization, provided that such process goes together with an offer of local services and facilities to promote the use of soft mobility. Analysis at neighborhood scale allows studying the influence of infrastructures, facilities and services on daily mobility choices. This analysis should create direct insights into how the combination of global and local parameters related to mobility infrastructures and urban developments affect mobility energy consumption. The latter can be calculated by two main different methods: the macro-scale methods, which are based on parameters defining the city, and the micro-scale methods, which use accurate data from individuals and infrastructures. The present paper shows an application of a novel intermediate method at neighborhood level developed by the Swiss Society of Engineers and Architects (SIA) to estimate the energy consumption related to mobility and attributed to buildings. The analysis of induced mobility by different urban renewal scenarios of an existing neighborhood in Lausanne, Switzerland, shows the importance of the number of car parks and of the human density (residents or jobs per square meter) as key factors related to mobility energy planning. Results also highlight the significant impact of changes in behavior, in terms of chosen mean of transportation and covered distances, on the potential for energy savings.
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INTRODUCTION

Reducing energy consumption is a goal for most European countries. In Switzerland, this goal has been embodied in the concept of the "2000 Watt Society" developed by the Federal Institutes of Technology. The average energy consumption per person would be reduced from 6,000 to 2,000 watts by 2150. [1, 2].

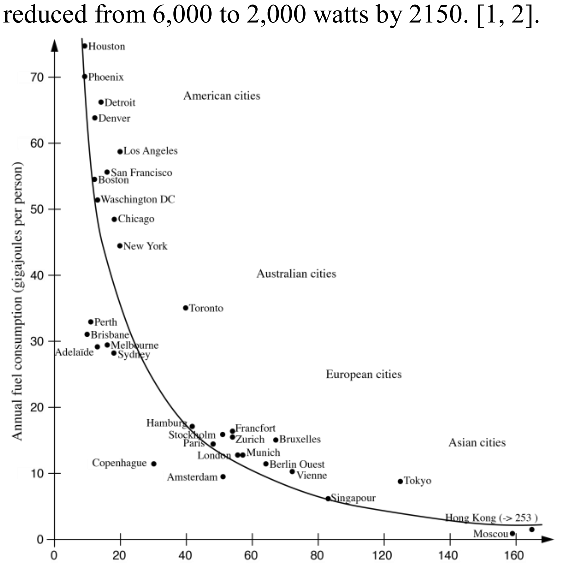

Figure 1 : Urban density ratio with the annual energy consumption per person (Newman, P. & Kenworthy, 1989)

Since mobility accounts for nearly 30% of Swiss energy consumption, action on mobility shows great potential for reducing energy consumption. In addition, urban density is presented as a significant leverage. As shown in Fig.1 [3], cities with higher urban density consume less energy per person. This is mainly due to the increase in distances travelled, inherent to the structure of a sprawling city. However, Banister (1992) found conflicting results that energy consumption was not only influenced by urban density but also by land use and socio-economic parameters [4, 5].

URBAN RENEWAL INFLUENCING MOBILITY

In order to meet the objectives of the 2000 Watt Society, the SIA (Swiss Society of Engineers and Architects) has set targets for energy in built-up areas in the 2040 Technical Specification. This document defines the energy objectives for 2050 for the embodied energy of materials, operating energy (heating, residential hot water, electricity, air conditioning) and mobility [6]. Tools for integrating mobility into urban planning are needed, despite the uncertainties related to user behavior.

This article adapts a methodology for estimating the energy consumption related to the mobility of a building's users to that of a neighborhood. The objective is to use a case study to understand the possibility of achieving the 2000 Watt Society goals in the area of mobility in an existing neighborhood through a densification project and to identify the parameters that apply to evaluating a project.

STATE OF THE ART

There are two main approaches to calculate the energy consumption related to mobility. The first one is a microscopic approach [7] based on data from individuals and the infrastructure. The second one is a macroscopic approach like the one proposed by Le Néchet, which calculates a city's energy consumption using a number of parameters specific to the city [5]. These two approaches can be adapted at neighborhood scale.

The methodology needed for the case study should allow both for calculating the energy associated with mobility and for evaluating it. The method should take into account the facilities set up for users' mobility.

Marique and Reiter [8] propose a microscopic approach at neighborhood scale in peri-urban areas in Wallonia. It uses statistical data (the distance of each trip based on the purpose of the travel: work, school, leisure and shopping, transportation mode, the frequency of the trips) and the energy consumption by mode of transportation specific to the context being studied. These results were echoed by the SAFE project, which offers an assessment tool for neighborhoods based on the trip performance index (kWh/pers. trip) per Belgian statistical area (neighborhood) and the planned number of workers and students [9]. This method is not thus directly applicable to the Swiss context and a preliminary statistical analysis would be required.

In Switzerland, the SIA offers in the Technical Specifications 2039: "Mobility - Energy Consumption of Buildings according to their Location" a method for calculating the energy consumption attributed to a building due to mobility [10]. This method also combines the two approaches. It provides a quantification of the average Swiss energy consumption for homes, activities (all business and services combined) or schools. Then, the method calculates the energy consumption by weighting this average consumption according to correction factors related to the context and the facilities.

Both methods provide estimated results based on many assumptions. A sociological study of the behavioral patterns of future inhabitants depending on the urban project would be required to apply a microscopic method. The Marique and Reiter method is specific to the neighborhood but it can only influence the evaluation by the number of workers and students. Finally, the SIA method considers a larger number of parameters, and values (average consumption and factors) are adapted to the Swiss context.

METHODOLOGY

The average consumption is derived from the calculation of people's overall daily mobility assigned to various allocations according to their reason for the trip. It is calculated for 2010 and for 2050 assuming that technological change will reduce the environmental impact of individual vehicles. The compliance with the goals by 2050 can thus be assessed.

Table 1 shows the modal allocation used to calculate average impacts. It is based on the 2005 Federal micro census for both allocations taking housing and activities into account [10].

Table 1: Swiss average modal distribution (pkm: person-km, IV: individual vehicle, Moto: Motorcycle, PT: public transportation, SM: soft mobility)

	pkm	IV	Moto	PT	SM
Housing	6'196	68%	2%	18%	12%
Activities	2’522	70%	2%	21%	8%

Table 2 shows the average predicted impacts for each type of allocation. The impacts for an individual vehicle vary depending on the occupancy rate of cars (1.6 for housing, 1.2 for activities). The impact of public transportation depends on the balance between busses, trains and trams [10].

Table 2: Impacts of various modes of transportation taking into account technical changes

kWh/pkm		IV	Moto	PT
2050	Housing	0.55	0.35	0.21
	Activities	0.67	0.35	0.20
2010	Housing	0.93	0.35	0.21
	Activities	0.74	0.35	0.20

The correction factors are obtained from a statistical analysis of the federal micro-census of 2005 [11] and vary depending on the allocation. They are:

- Location: located in downtown/business area
- Access and quality of public transport
- Distance to a shopping center
- Availability of a car
- Availability of parking for cars and bikes
- Availability of public transportation passes.

The case study will therefore apply this method at neighborhood scale and show the impact of an urban densification project.

CASE STUDY

The Fleurettes district in Lausanne is located close to quality public transportation: Central Station, bus and subway lines, which justify the area's densification in terms of sustainable urban development, based on the vision of a polycentric city that is well connected to public transportation [12, 13].

DEFINITION OF SCENARIOS

Previous work has shown the possibility to densify this neighborhood by making it progress towards greater sustainability, particularly with regards to energy reduction related to the buildings' operation [14, 15]. This paper proposes an analysis of the effect of these various scenarios on energy consumption due to mobility.

The first scenario (Fig. 2) offers a sanitation proposal for existing buildings, thus no change from the existing as concerns mobility. The second scenario (Fig. 3) proposes a densification according to the legal bases and respecting the existing plot demarcation. The third scenario (Fig. 4) offers a higher density while freeing itself from the constraints related to plots and construction regulations such as, for example, the requirements for parking spaces.

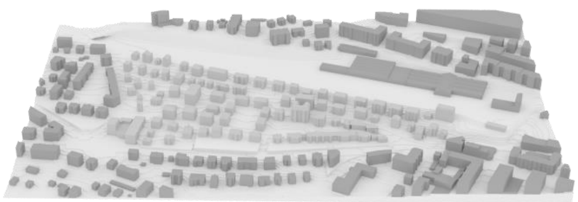

Figure 2 : Scenario S1

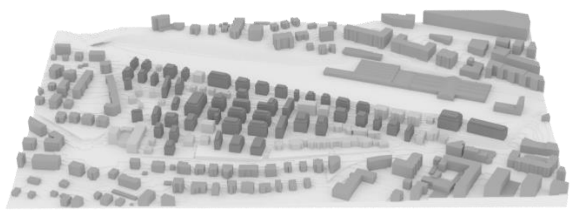

Figure 3 : Scenario S2

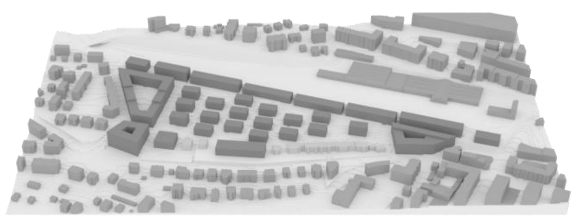

Figure 4 : Scenario S3

Using the method defined in the SIA 2039 standard to compare the mobility of various scenarios for a neighborhood requires combining a calculation of the current status, where the number of people and built up surface areas is known, with projects where assumptions about the built up areas are needed. A new housing was thus considered to consume 110 m² GFA (Gross Floor Area), and to be inhabited by an average of 2.2 people[i], and that each new job required 46m² of GFA[ii].

Depending on the method, the parameters that impact the assessment of mobility are:

- The quality of public transportation service, as defined by the Federal Office for Spatial Development (ARE) [16]. The method defines five levels: from A to D or Insufficient public transport services. It considers the type of the public transport: from national railways to local bus; the frequency and the distance to the station or bus stop. In our case study, it is the highest quality: A (efficient and interconnected means of transportation located near the users).
- The distance to the nearest shopping center: 300m.

These are constants for all three scenarios because they form part of the neighborhood's context. The data in Table 3 are variable according to the various scenarios.

*Table 3: Characteristics of the scenarios. *GFA: Gross Floor Area*

	S1	S2	S3
GFA* housing (m²)	55'356	71'313	98'000
GFA* activities (m²)	3'696	19'846	42'000
Number of inhabitants	1'032	1'395	1'953
Total number of housing units	544	665	895
Number of jobs	80	429	908
Parking spaces - residents	467	859	539
Parking spaces - jobs	31	34	202

Due to lack of information on car availability and on the ownership of a public transportation pass, it was considered that:

- The availability of a car depends on the number of parking spaces available. The housing units have a car if the project provides at least 1 space/res., and do not have one if there are no parking spaces for the units. According to the 2039 SIA standard, in intermediate cases the factors are determined by linear interpolation.
- The possession of a public transportation pass results from the number of parking spaces per unit or per employee as well as from the quality of public transportation. If the quality of public transportation is equal to B or better [16] and the number of parking spaces per job or housing unit is less than 0.5, users are considered to have public transportation passes. If there is a higher amount of parking spaces, a linear interpolation is performed. Finally, if the quality of public transportation is lower than B, the factor is equal to 1: the factor is not taken into account.

RESULTS

The target set by the SIA 2040 technical specifications for housing is 36 kWh/m2, and 64 kWh/m2 for activities. The target for housing is not achieved for any of the scenarios (Fig. 5). However, activities reach the goal in all cases (Fig. 6).

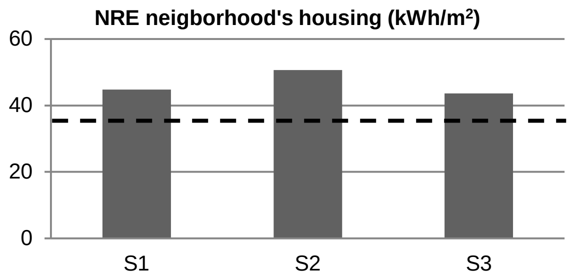

Figure 5 : NRE (non-renewable Primary Energy) assigned to housing per ERA m² (Energy Reference Area) compared to SIA targets

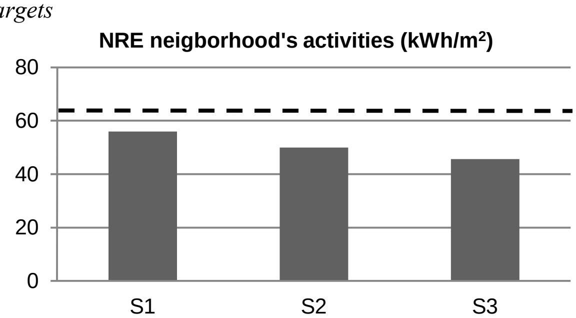

Figure 6 : NRE per ERA m² assigned to activities compared to SIA targets

The average area per capita justifies this broad exceeding of targets. Table 4 shows the average values for each scenario. If the Swiss average value of GFA/per capita (75m² GFA/res.[iii] was provided for the new buildings, the S2 and S3 would reach respectively 40kWh/ m2 and 33kWh/ m2. The latter would thus be compatible with the 2000 Watt Society objectives. The peak of S2 is explained by the product of all correction factors (Table 5). The number of spaces in S2 (Table 6) is actually higher because the number of parking spaces required by the law is greater than the number of existing spaces (0.67spaces/80m² GFA, versus 1.1 spaces/80m² GFA according to the General Allocation Plan (GAP) of the city of Lausanne).

Table 4 : Surface occupancy: average surface area per housing unit and per job for new and old buildings in the neighborhood.

(m²)	S1	S2	S3
GFA/resident	54	51	50
GFA/job	46	46	46

Table 5 : 2050 Correction factors for NRE

FACTORS	S1	S2	S3
Home	0.83	0.90	0.76
Establishment	0.80	0.71	0.65

Table 6: Parking spaces per user according to allocations

FACTORS	S1	S2	S3
Spaces/res. unit	0.86	1.29	0.60
Spaces/job	0.39	0.08	0.22

In our case, the project provides a double densification of the neighborhood. There is an increase both in the built floor surfaces and in the number of people per habitable m² (Table 4).

It is important to highlight the role of land occupancy. The energy per surface area unit can be reduced by increasing the surface area per person or by improving the conditions that promote behaviors that induce low environmental impacts. As the first option has collateral consequences in terms of urban sprawl and thus traffic generation, it is preferable to analyze mobility independently of land occupancy. It is thus necessary to calculate the energy consumed per person (Table 7).

Table 7: NRE per person in the neighborhood, attributed to homes and activities.

	S1	S2	S3
kWh/inhabitant	1'922	2'070	1'752
kWh/job	2'071	1'848	1'689

The target values in the SIA 2040 are defined by surface area unit. However, the calculations are based on the average consumption per person and the average surface area occupancy per resident and per job in Switzerland. Based on the same ratios of surface area per person, it is possible to convert the 2000 Watt Society objectives in NRE per person. The target value is 2,170 kWh/resident for housing and 2,365 kWh/job for activities.

The scenarios are compatible with the 2000 Watt Society according to the SIA due to favorable public transportation conditions, downtown location, proximity to shopping and minimization of parking space. These results directly reflect the correction factors in Table 5, the land occupancy is not directly involved but in an underlying way, in determining the number of parking spaces per user.

The 2040 Technical Specification also requires calculating the project's values according to the number of vehicles in 2010 (Table 8). These values are not evaluated but serve as a reference, since the previously calculated energy consumption is based on assumptions of technical progress.

Table 8 : NRE per ERA m² (Energy Reference Area) assigned to homes and activities.

(kWh/m²)	S1	S2	S3
Homes	63	73	59
Activities	76	64	58

These values far exceed the target values, but they show the changes needed to achieve these goals by 2050.

With the aim of analyzing the influence of parking spaces, two other scenarios have been developed: the application of the GAP in both its extremes: minimum or maximum parking spaces permitted for the same gross built floor area. The minimum for housing is 1.1 spaces/80m² of housing and the maximum is double: 2.2 places/80m². For activities such as bank, post office, travel agency, medical practice, hair salon, etc., parking spaces can range from 0 to 1.54 spaces/80m² GFA activities.

Table 9: NRE attributed to housing based on parking spaces (Target Value: 2,170 kWh/res.)

	S1	S2	S3
Project	1'922	2'070	1'752
GAP max	1'922	**2'249**	**2'377**
GAP min	1'922	2'070	2'109

For housing (Table 9), when parking spaces correspond to the statutory maximum, the transposed target value per capita is exceeded in S2 and S3. If we evaluate the compatibility with the SIA 2040 objectives (Figure 7), we find that the target values are always exceeded. The low impact of the "Project" version of S3 (0.6 spaces/housing unit) is due to the number of parking spaces below that of S2 (1.29 spaces/housing unit).

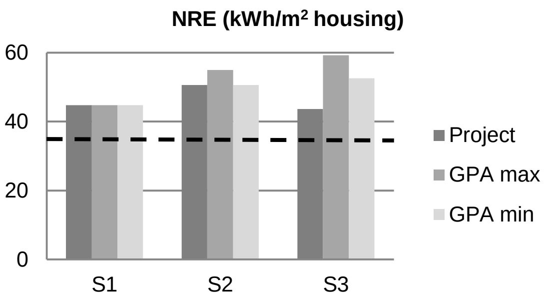

Figure 7: NRE allocated to housing based on parking spaces compared to SIA targets

As in the case of housing, the target value for activities is also exceeded (Table 10) in scenarios S2 and S3, when the maximum number of parking spaces allowed is required. This is because the number of parking spaces per job is between 0.87 and 0.89 for S2 and S3 respectively. The NRE for S2 is the highest because the impact of activities reflects the availability of bicycle parking spaces for the employees. As the SIA 2039 does not allow linear regression to determine this factor, the degree of intervention in S2 was considered insufficient to provide bike parking spaces for all the jobs.

Table 10: NRE assigned to activities based on parking spaces (Target value: 2,365 kWh /job)

	S1	S2	S3
Project	2'071	1'848	1'689
GAP max	2'071	**2'871**	**2'503**
GAP min	2'071	1'804	1'551

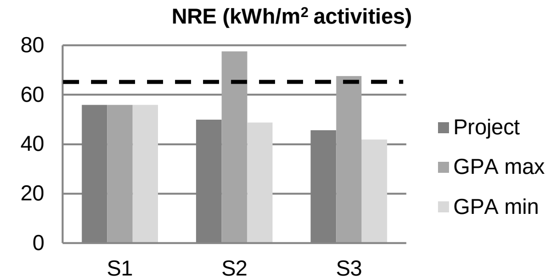

Figure 8: NRE assigned to activities based on parking spaces compared to SIA targets

If we evaluate the neighborhood in relation to the objectives of the SIA 2040 (Figure 8), the results show that the target values are exceeded if the legal authorized maximum is selected, even though the same assumptions in terms of land occupancy are kept.

Urban densification allows a higher number of people to live near public transportation, services, business and facilities. Hence, as shown energy consumption can be reduced thanks to changes in habits in terms of mobility. Table 11 shows the possible variations in modal choices and distances compared to the Swiss average to achieve the estimated reductions.

Table 11: Behavioral changes compared to the Swiss average.

	ΔDistance	ΔIV	ΔPT	ΔSM
S1	-	-13%	+10%	+3%
S2	-	-5%	+5%	-
S3	-6%	-15%	+10%	+5%

DISCUSSION

The evaluation of the neighborhood's energy consumption assesses a limited effect of the urban densification. Figure 9 shows an overall reduction in energy consumption, which represents the change in energy consumption that includes the neighborhood's future users. Thus it is possible to compare the scenarios in relation to the same reference: the mobility of the same number of people. All future users of the neighborhood were considered to have an average Swiss behavior in terms of mobility, which means that their mobility is not weighted.

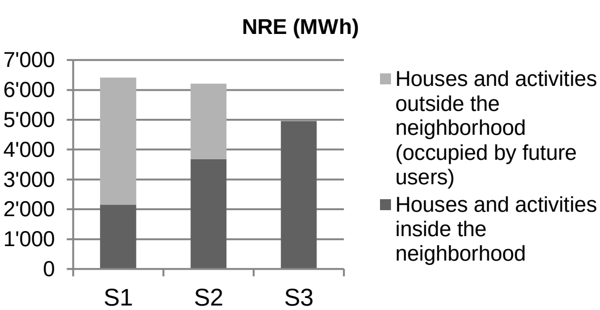

Figure 9: Changes in energy consumption due to mobility for the same number of inhabitants

In S2 the NRE is only reduced by 4%, whereas for S3, it is reduced by 24%. The previous analysis have demonstrate that the lack of bikes parking spaces available for jobs and the significant number of parking spaces required for housing prevent energy savings in S2.

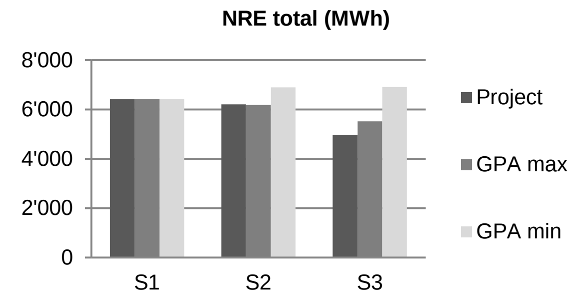

Figure 10: Overall NRE based on parking spaces.

Figure 10 shows the influence of the regulatory number of parking spaces for new buildings. In the third scenario the difference between the energy consumption can be 20% between applying the maximum and minimum number of parking spaces required by law.

CONCLUSION

The case study showed that for the given scenarios, the targets set by the 2040 SIA are respected for activities, but not for housings. The role of built density and its occupancy are key elements of energy planning, not only for mobility but also for embodied energy and operating energy. An analysis involving all the positions would be very relevant to this case study.

Estimates of changes in behavior highlight the coordination between the calculations according to the method and the measures that may be implemented to guide the neighborhood's renewal towards the 2000 Watt Society. A holistic vision, reducing distances and promoting public transportation modes, is required [17] to develop projects in favorable areas. The location and public transportation are not sufficient conditions.

Applying the SIA 2039 methodology for the neighborhood's urban renewal has highlighted two aspects. First, the need to assess the energy consumption per person. Second, the obligation to take into account the existing; to integrate the overall impact, going beyond consumption but including the energy saved due to the project. Other parameters related to the facilities and services should also be integrated in the future. Research is continuing in this direction.

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[i] SIA 380/1 standard for thermal requirements: 40 m^2/pers of ERA (Energy Reference Area) which translates into 50 m^2/pers GFA if ERA/GFA = 0.8.. Housing built in Zurich between 2000 and 2009 : 50 m^2 GFA/pers. and 2.2 people/housing unit [18] In Switzerland in 2000 the average household size was also 2.2 people [19].

[ii] Swiss average [10]: 46m^2 GFA/job = 37m^2 ERA/job, ERA/GFA = 0.8

[iii] 75m^2 GFA / res. = (60m^2 ERA / res.), ERA/GFA = 0.8