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PLEA 2024: (RE)THINKING RESILIENCE

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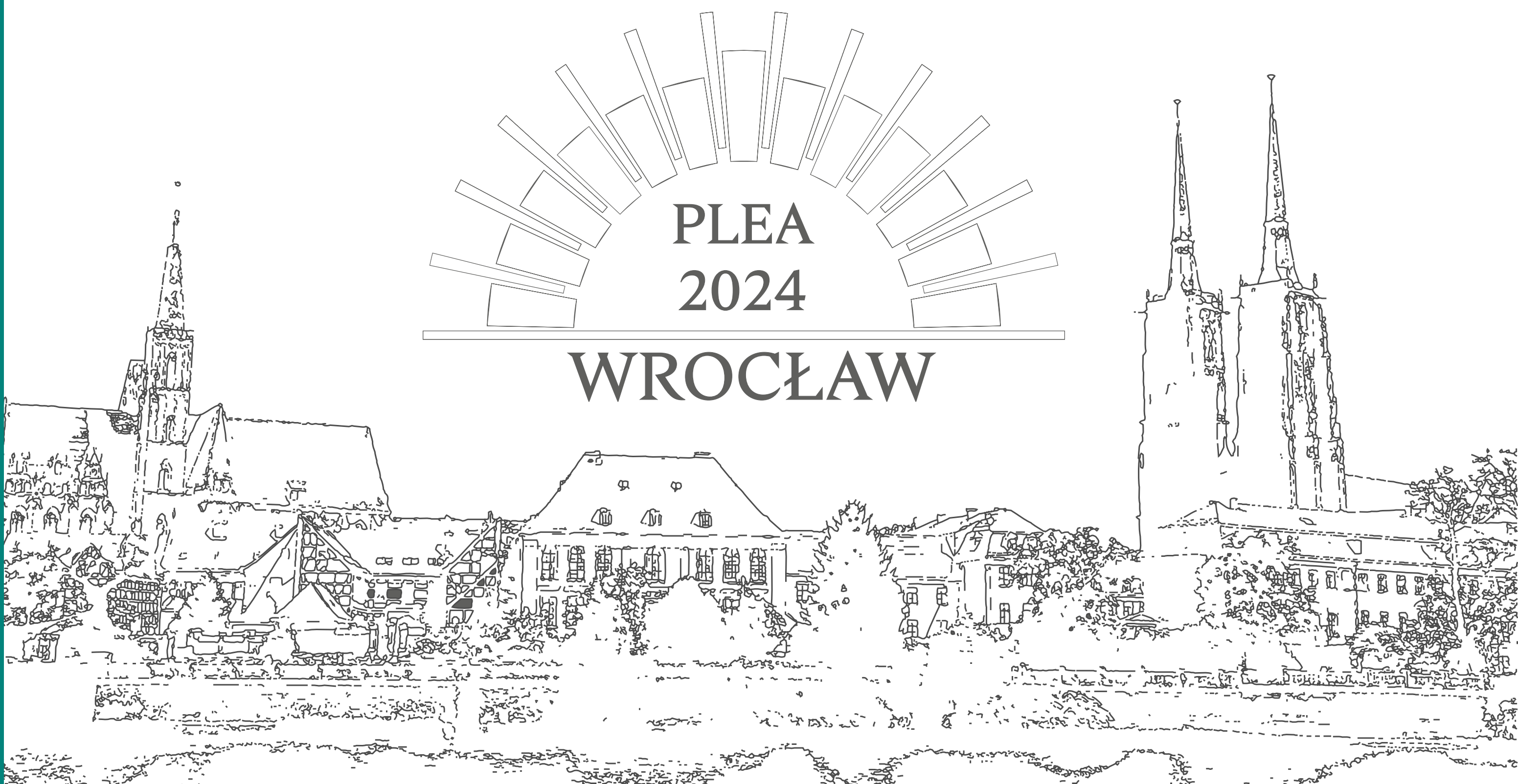
Editors: Barbara Widera, Marta Rudnicka-Bogusz, Jakub Onyszkiewicz, Agata Woźniczka



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(Re)thinking Resilience

The Effect of Rivers on Energy Balance at the Neighborhood Scale

A comparative analysis of four Rhodanian sites in France and Switzerland

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ABSTRACT: This research aims to compare the greenhouse gas (GHG) emissions of new neighbourhood projects near the Rhône River in France and Switzerland. The study considers the influence of the river on energy demand and resilience to climate change of 12 project-based visions across four locations, based on three design scenarios developed for each site in architectural workshops at the Ecole polytechnique fédérale de Lausanne (EPFL). Artificial weather files account for the river's effect, facilitating a comparison between scenarios with and without the river's influence. Methodologically, 3D digital models are used to calculate environmental impacts, integrating data from the Swiss material database and following the SIA 2032 Swiss standard. Findings suggest the Rhône River significantly affects building energy demand, showing a 3-6% fluctuation in demand, depending on water presence or not and 1-2% fluctuation for the global environmental impact. The study underlines the importance of considering climate conditions and water presence in urban planning and building regulations.
KEYWORDS: Environmental impact, low carbon neighbourhood design, multi-criteria assessment, project-based visions

1. INTRODUCTION

The objective of this research is to compare the environmental impact – greenhouse gas (GHG) emissions – of new neighbourhood projects located on four study sites in France and Switzerland near the Rhône River. For each site, three neighbourhood design scenarios (project-based visions) were elaborated during specific architectural workshops at EPFL [1].

The study offers a comparison of the environmental impact of the different urban typologies. By analysing the energy demand for building operation, we are able to explore the level of resilience of different urban typologies in relation to climate change and whether the presence of the river helps or worsens the situation.

The influence of the river has been taken into account by generating artificial climate files where the presence of water (Rhône River) and the effect of the buildings (urban form) are taken into account using open-source tools that are based on low computational cost methods (as opposed to full high-resolution computational fluid dynamics (CFD) simulations).

In order to be able to assess the influence of the river, two types of files have been obtained - for each site and urban design - one without the effect of the river and the urban form and the other with these effects. These files serve as input for the energy simulation by means of the calculation engine. In addition to the operating energy, the grey energy due to the construction has been integrated into the analysis, taking as a reference a type of construction that corresponds to the usual practice for contemporary buildings of the Minergie type [2] with wood-based construction typology.

2. METHODOLOGY

The approach uses as input data the 3D digital models of the project-based visions, in order to automatically obtain the surfaces and material quantities of the different construction components (e.g. glazed surface or opaque façade).

At the same time, the available roof and façade surfaces are automatically detected in order to evaluate the solar and electricity production potential on site.

Then, using the visual programming language Grasshopper [3], the reference environmental impact values of the KBOB building material database [4] and the guidelines of the SIA 2032 standard [5] are applied to calculate the environmental impact of each scenario expressed in terms of greenhouse gas (GHG) emissions.

The set of urban design variants is generated from the three different visions per each of the four locations: Sion (CH), Geneve (CH), Givors (FR) and Avignon (FR). In total, we analyse 12 different project-based visions (Figure 1).

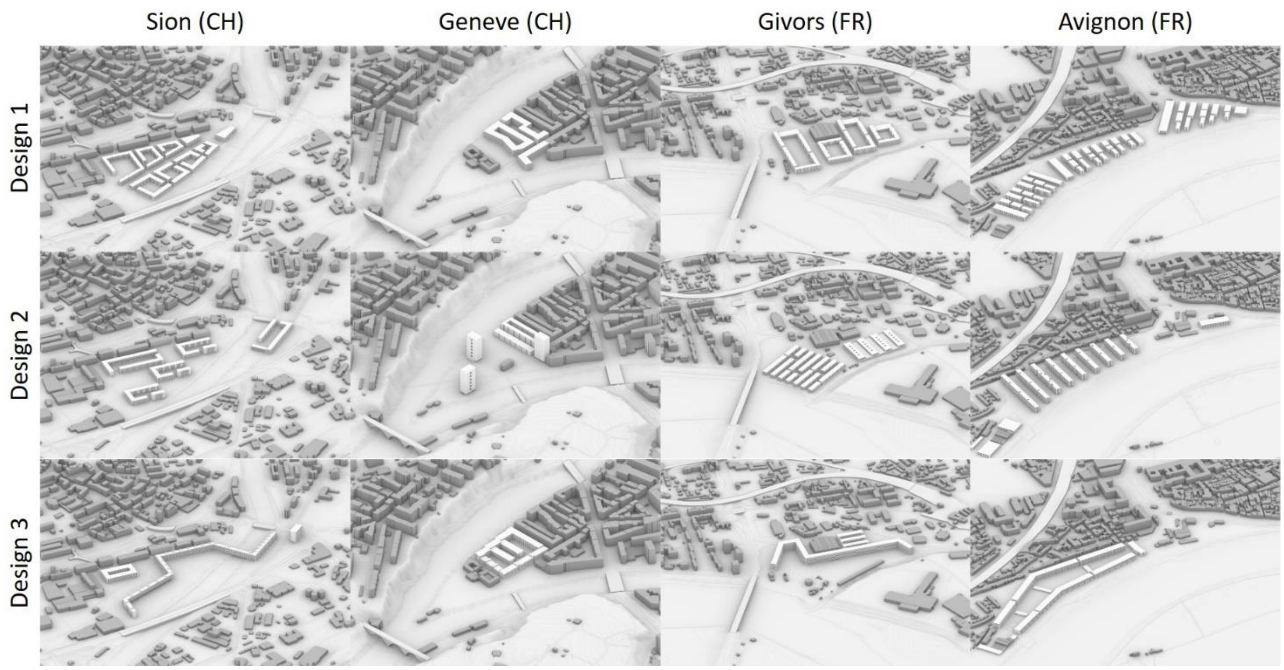

Figure 1: Overview of the twelve studied neighbourhood designs (project-based visions).

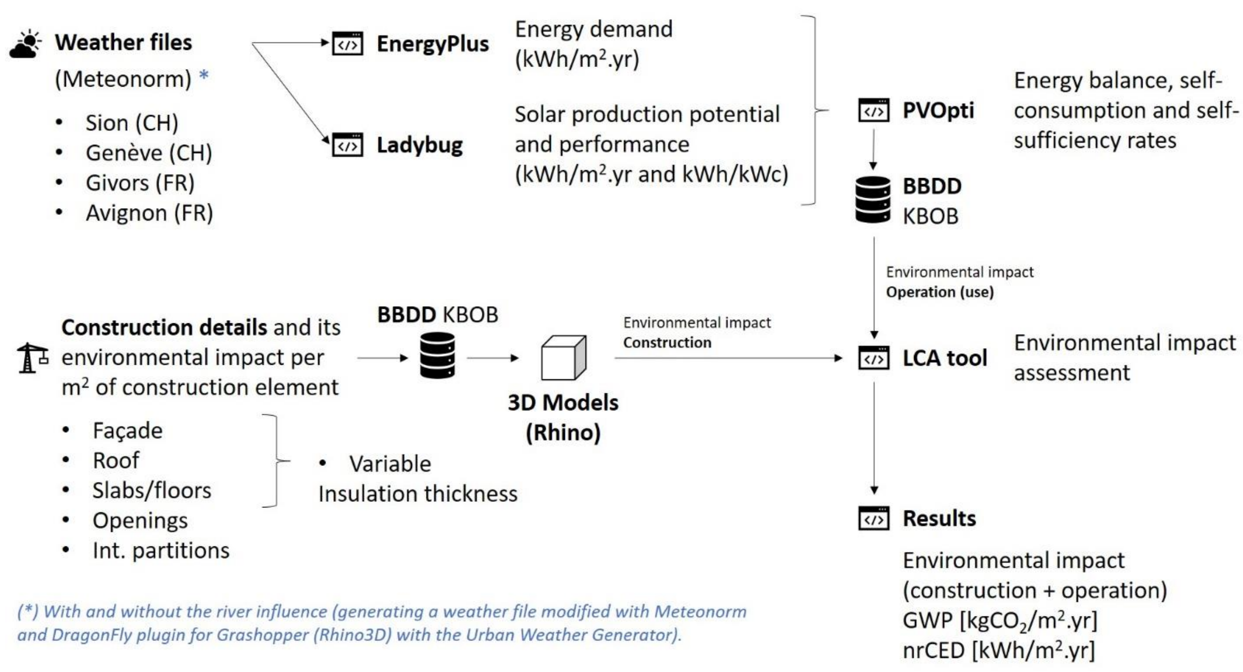

Figure 2: Overview of the workflow for the global analysis. GWP: global warming potential. nrCED: non-renewable cumulative energy demand.

This project has been developed following a five-phase methodology:

1) Analysis of the different study sites (two in France and two in Switzerland) and obtaining the different climate files with contemporary data (last 10 years). The files that take into account the presence of cold water (Rhône river) have also been generated.
2) For each site, 3 different project-based visions have been analysed based on a series of architectural workshops conducted at EPFL Lausanne (Switzerland).
3) From the 3D models, simulations of the energy potential and renewable energy production have been carried out to obtain the operating energy for each study site, vision and climatic situation.
4) Parametric definition of the building materials to be used, in order to perform the complete life cycle analysis, including the grey energy of the building materials.
5) Comparison of the results. In terms of resilience to climate change, it is based on the evolution of energy demand (heating and cooling) depending on the urban design and the weather file used (with or without influence of the urban context and river).

The workflow to be applied in this research is summarized in Figure 2.

3. RESULTS

We here present some results showing that the presence of the Rhône River has a non-negligible effect on the energy demand of the buildings. Both in summer, with a reduced need for cooling the buildings, and in winter with an increased need for heating in some cases.

3.1 Analysis of the different study sites and climatic conditions

We have generated climate files for each of the sites using Meteonorm software [6] and modified files have been generated that take into account the built environment and the presence of water.

For each of them, psychrometric charts – generated using Climate Consultant tool [7] – have been analysed to see the differences in terms of comfort zones combining temperature and humidity according to ASHRAE 55.

As an example, in Figure 3 the analysis done for the first site, Sion in Switzerland, is presented.

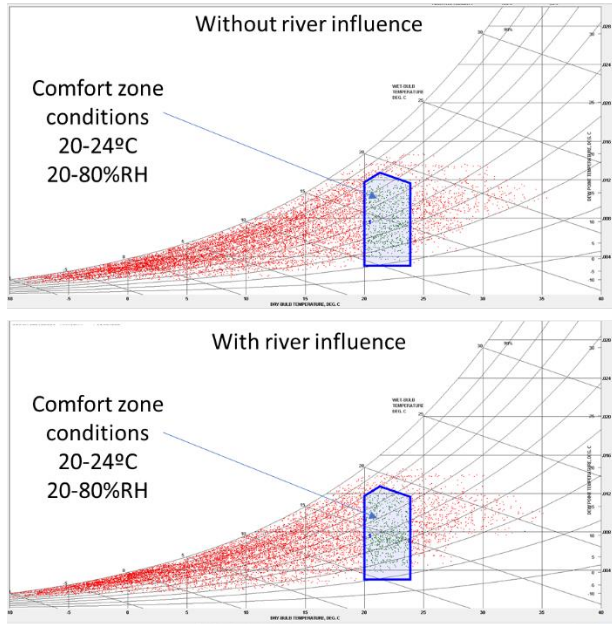

Figure 3: Psychrometric chart for the Sion site, with and without the influence of the water (river).

Table 1: Total of comfort hours per year for the 4 sites (Sion, Geneve, Givors and Avignon), with and without the influence of the water (river).

Scenarios/Site	**Without river**	**With river**
	Comfort hours	
Sion (CH)	708	699
Geneve (CH)	621	637
Givors (FR)	874	804
Avignon (FR)	983	883

The analysis of the climatic data with hourly data on the psychrometric charts shows that the presence of the river decreases the hours of comfort, mainly due to the cooling effect (in winter) and the increase of the ambient humidity (winter and summer).

3.2 Project-based visions analysis

For each site and project vision (scenarios), we have measured the different parameters that will serve as input data in the next phase, where solar, energy and environmental impact simulations are carried out.

Table 2 shows a summary of the data collected in terms of total floor, ground floor, roof, exterior wall and glazing area.

For each scenario a number of square meters of activity (or type of use) have been identified (residential, commercial and school/cultural), calculated according to the SIA 416. The different uses carry a series of simulation hypotheses that are defined in the SIA 2024:2015 [8] with use schedules for occupancy, lighting, heating/cooling, ventilation and domestic hot water (DHW).

Table 2: Surface dimensions in each design scenario.

Scenarios	Floor	Ground	Roof	Ext.Wall	Glazing
	m^2				
SI1	166,740	29,578	20,591	50,397	28,936
SI2	151,563	20,198	18,081	50,781	29,056
SI3	134,910	16,540	14,469	31,101	32,269
GE1	78,266	10,456	7,642	19,536	15,254
GE2	84,704	11,186	6,484	22,131	26,636
GE3	85,158	19,996	8,596	9,273	16,738
GI1	150,377	19,407	19,344	44,270	26,637
GI2	154,596	42,037	28,061	31,209	18,517
GI3	113,724	15,350	12,212	18,081	24,754
AV1	123,219	22,437	21,009	69,685	24,876
AV2	76,455	5,704	13,799	21,751	18,228
AV3	91,146	17,007	14,869	10,464	20,004

With this data, standardized simulations have been performed to allow comparison of the results. Table 3 defines the square meters for each type of use.

Table 3: Floor area per usage.

Scenarios	Residential	Commercial	School/cultural
	m^2		
SI1	99,218	14,366	23,578
SI2	93,813	19,497	18,055
SI3	88,142	8,052	20,550
GE1	50,293	13,229	4,288
GE2	54,688	12,272	6,558
GE3	44,355	14,893	4,288
GI1	82,185	38,539	10,246
GI2	68,074	30,521	13,964
GI3	61,212	26,916	10,246
AV1	63,979	10,054	26,749
AV2	37,313	13,478	11,865
AV3	52,664	19,185	2,290

3.3 Operational energy balance analysis

For each scenario and site, hourly energy simulations have been performed with the EnergyPlus engine and Designbuilder [9,10] calculation engine to obtain the total energy demand for lighting, heating/cooling, ventilation and DHW.

For all case studies, an all-electric HVAC system based on an air-to-water heat pump with a COP of 3.5 for heating/cooling and a COP of 3 for domestic hot water has been considered.

The definition of the heating energy demand limit is based on the SIA380/1:2016 [11], so we have been able to adjust for each case study in its specific context the insulation thickness that allows to respect this energy demand limit for heating. In this way, the case studies (two in Switzerland and two in France) have been contextualized. This limit value, which helps to define the efficiency of the thermal envelope, depends on the floor area, the envelope surface in contact with the outside and the average temperature of the building site.

Table 4 summarizes the limit values to be respected per indoor floor area.

Table 4: Heating energy demand limit according to SIA380/1.

Scenarios/Site	1	2	3
	kWh/m^2.year		
Sion (CH)	30.34	29.66	28.31
Geneve (CH)	25.87	27.60	27.34
Givors (FR)	24.10	26.98	22.56
Avignon (FR)	24.48	21.56	19.17

Regarding the photovoltaic solar energy production potential, the assumption for the calculation is the use of 80% of the available roof surface with standard east/west oriented solar panels and an overall efficiency of 20%. The solar energy calculation was done using the 3D model (Rhino 3D) for each case study and the Ladybug tool [12].

The results of the final energy balance, without taking into account the presence of water and the urban context (using the different weather files generated in phase 1), are summarized in Tables 5 and 6, respectively, in terms of energy demand, electricity production, self-consumption (SC) and self-sufficiency (SS).

Table 5: Electricity balance (without river influence).

Scenarios	Demand	Production	SC	SS
	kWh/m^2.year		%	
SI1	35.7	47.1	22.30%	29.50%
SI2	36.7	46.7	23.60%	30.00%
SI3	35.2	36.4	26.80%	27.80%
GE1	38.7	30.7	34.70%	27.50%
GE2	38	28.4	36.00%	26.90%
GE3	39.2	25.3	41.70%	26.90%
GI1	38.9	40	30.20%	31.00%
GI2	38	19.6	52.50%	27.00%
GI3	38.3	27.4	40.10%	28.70%
AV1	32.9	79.5	14.30%	34.60%
AV2	35.5	57.4	20.80%	33.70%
AV3	38.1	40.1	29.30%	30.80%

Table 6: Electricity balance (with river influence).

Scenarios	Demand	Production	SC	SS
	kWh/m^2.year		%	
SI1	36.2	47.1	22.40%	29.20%
SI2	37.2	46.7	23.70%	29.70%
SI3	35.7	36.4	27.00%	27.50%
GE1	39.3	30.7	34.90%	27.30%
GE2	38.6	28.4	36.20%	26.70%
GE3	39.7	25.3	41.90%	26.70%
GI1	39.6	40	30.40%	30.70%
GI2	38.7	19.6	52.90%	26.80%
GI3	39	27.4	40.40%	28.40%
AV1	33.7	79.5	14.50%	34.20%
AV2	36.2	57.4	21.00%	33.30%
AV3	38.9	40.1	29.50%	30.50%

As expected, the overall electrical energy to meet the different types of consumption (heating/cooling, etc.) varies depending on the climatic conditions (with and without the influence of the river). In general, the demand is higher with the presence of the river, mainly due to the increase in heating demand and the higher humidity in summer which affects the efficiency and consumption of electricity for cooling.

3.4 Constructions elements and embodied energy balance analysis

In order to be able to calculate the environmental impact of building materials, the type of construction and the layers of different materials for the thermal envelope have been defined (Tables 7 to 11). For each material, the environmental impact has been taken into account according to the KBOB2022 database defined from Ecoinvent data [4].

Table 7: Definition of façade layers and their thickness.

	Layer	Th. (cm)
1	Wood (spruce)	1.5
2	PE vapour barrier	0.02
3	OSB-type chipboard	2.7
4	Expanded polystyrene (λ: 0.04 W/mK)	22 (*)
5	Wooden beam 12cm each 60 cm (Spruce)	12
6	Hard particleboard	2.7
7	Wooden batten 50mm each 60 cm (Spruce)	5
8	Wood (spruce)	2.4
** Varies according to the energy demand limit of each site*		

Table 8: Definition of roof layers and their thickness.

	Layer	Th. (cm)
1	Round gravel	5
2	Bituminous waterproofing sheet	0.8
3	Expanded polystyrene (λ: 0.04 W/mK)	22 (*)
4	Bituminous vapour barrier	0.3
5	Wood (spruce)	2.4
6	Wooden batten 50mm each 60 cm (Spruce)	12
** Varies according to the energy demand limit of each site*		

Table 9: Definition of internal floor layers and their thickness.

	Layer	Th. (cm)
1	Particleboard	2.4
2	PE vapour barrier	0.02
3	Wooden beam 12cm each 60 cm (Spruce)	12
4	Wooden beam 12cm each 60 cm (Spruce)	5
5	Stone wool, ρ:30kg/m3	8
6	Wood (spruce)	1.3

Table 10: Definition of ground floor layers and their thickness.

	Layer	Th. (cm)
1	Cement screed, 85 mm	8.5
2	Acrylonitrile-butadiene-styrene (ABS)	0.001
3	PE vapour barrier	0.02
4	Expanded polystyrene (λ: 0.04 W/mK)	22
5	Bituminous waterproofing membrane	0.4
6	Concrete foundation slab	25
7	Reinforc. (2%) of the concrete beam slab	2%
8	Lean concrete	8
** Varies according to the energy demand limit of each site*		

Table 11: Definition of internal floor layers and their thickness.

	Layer	Th. (cm)
1	Hard particleboard	1.25
2	Stone wool, ρ:30kg/m3	5
3	Wood frame 5cm each 60 cm (Spruce)	5
4	Hard particleboard	1.25

3.5 Global environmental impact (operational and embodied) comparison

Compiling the data and the calculations made during all the preceding phases, the global environmental impact (Life Cycle Analysis) is obtained for each of the scenarios without taking into account and taking into account the presence of the river.

Firstly, table 12 presents the environmental impact for the operational (use) part (due to energy consumption) expressed in terms of GHG emissions. For this operational part, the differences between taking into account or not the water presence (Rhône River) near the urban area is about 3-6% increase/decrease in demand.

Secondly, table 13 presents the global environmental impact for the operational (use) and construction (embodied) part expressed in terms of GHG emissions.

For the global impact, the differences between taking into account or not the river is about 1-2% increase/decrease in demand.

Table 12: Environmental impact results for operation (use) of the buildings, with and without water presence.

	Without river	**With river**
Scenarios	$kgCO_2/m^2$.year	
SI1	1.80	1.86
SI2	1.90	1.96
SI3	2.20	2.26
GE1	2.77	2.84
GE2	2.80	2.87
GE3	3.04	3.10
GI1	2.33	2.41
GI2	3.12	3.20
GI3	2.81	2.89
AV1	0.18	0.27
AV2	1.27	1.35
AV3	2.25	2.34

Table 13: Global environmental impact results for operation (use) and embodied (construction) of the buildings, with and without water presence.

	Without river	**With river**
Scenarios	$kgCO_2/m^2$.year	
SI1	4.76	4.82
SI2	4.85	4.90
SI3	4.96	5.01
GE1	5.46	5.53
GE2	5.79	5.86
GE3	5.71	5.76
GI1	5.13	5.22
GI2	6.08	6.16
GI3	5.35	5.43
AV1	4.02	4.10
AV2	4.29	4.36
AV3	4.94	5.04

These results should be considered as preliminary as the project continues and a more complete analysis is planned integrating a CFD study using Envi-met [13] for the creation of modified climate files taking into account the urban form and the presence of water and vegetation. Likewise, we will integrate climate files that take into account the different horizons (2030 to 2100) and various RCP (Representative Concentration Pathway) climate change scenarios.

4. CONCLUSION

For the moment, our efforts have been concentrated on the analysis using modified climate files through a simplified workflow and low computational cost open-source tools (namely Ladybug and Dragonfly). It is observed that it is in the operational part (use) that the river has the greatest impact.

However, our intention for the research project is to show how climate change (through RCP files), the presence of water (river) and vegetation can have an impact on the results, having for example a higher/lower need for insulation, better/worse outdoor temperature/humidity conditions that would allow passive strategies, or making the overall environmental impact higher or lower.

Considering global warming, a first hypothesis to investigate is whether the river could have a strong positive influence, in particular against the urban heat island effect. Future work will also deepen the study of the interactions with urban form and environmental parameters (vegetation including its type, wind, etc.). The methodology already developed and presented in this paper provides a solid framework for these upcoming steps.

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