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Sustainability achievements in building regulations. The example of Bologna

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Abstract

The urban development in the last decades has meant for most cities a significant increasing of land consumption and waste of natural resources. Despite the process of urban sprawl is now being reduced, there is an urgent need for corrective measures to qualify the existing town, according to more sustainable principles.The city of Bologna has recently developed new tools, in order to promote a social and economic growth without affecting the urban and environmental quality. This article aims to describe the achievements of the innovative requirements in the new Town Planning Building Regulations, to analyse their effect, in relation to the reduction of use of natural resources and the improvement of environmental quality of the interventions.

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1. Bologna Municipality Urban Planning

In 2000, Emilia Romagna approved the Regional Law entitled: "General territory use and management regulation" (LR 20/2000) This law has deeply renewed the territorial government system, regulating relations between the local authorities in the urban planning process, according to the principles of subsidiarity and cooperation.

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At the municipal level, the urban plan is organized in three different instruments:

- Municipal Scructural Plan (PSC): is the general planning tool, conceived to outline the strategic development of the municipal territory and protect its physical and environmental integrity;
- Municipal Operational Plan (POC) is the tool that outlines and regulates specifically the interventions of protection, organization and transformation of the territory, to be achieved within the five years term, referring to what has been outlined in the PSC ;
- Town Planning Building Regulations (RUE): is the instrument that regulates all direct building interventions and non-substantive urban projects, which can be immediately carried out.

The Municipality of Bologna identifies sustainability as one of the most important issues for the territory development. The lands with their environmental, cultural, social and human differences, can not undergo any processes that destroy natural resources, without allowing them to be properly reproduced.

2. The Town Planning Building Regulations

The Town Planning Building Regulations (RUE), approved by the local administration on April 2009, is a tool by which the principles of sustainability are outlined at the urban scale and it represents an important innovation in urban planning, as it is characterized by a set of performance indicators without providing a description of the solutions to be adopted. In regards to environmental quality for buildings some improvements are foreseen, compared to the current standard regulations, starting from the site analisys and the need to integrate environmental requirements in the different phases of the construction process.

In the following section the building performances are briefly described, focusing on some strategic requirements such as reduction of winter energy consumption (E 7.1), urban microclimate and soil permeability (E 8.), water saving and reuse (E 9.1) and reuse of demolition waste (E 10.2).

For any requirement a quantitative evaluation of the achievements obtained by the pilot application of excellence performance levels is shown. This application is a small percentage of the overall building activity (10 buildings in 2 years), but it provides an innovative path. The achievement of performance levels, set for the class of excellence (for the above described requirements) allows up to 20% extension of the existing volume.

Table 1. The Performance Requirements of the Town Planning Building Regulations (RUE)

Objective	Requirement	Code
Site Adaptation	Building in Context	E 1.1
Mechanical Resistance and Stability	Mechanical Resistance to Static and Dynamic Stress, Vibrations and Accidental Stress Concentrations	E 2.1
Safety in case of Fire	Fire Resistance, Fire Reaction, Limitation of the Risks of fire Generation and Propagation, Evacuation	E 3.1
Hygiene, Health and Environmental Wellness	Unhealthy Emissions Control	E 4.1
	Electromagnetic Pollution Control	E 4.2
	Gas Evacuation	E 4.3
	Water Supply	E 4.4
	Sewage Disposal	E 4.5
	Watertightness	E 4.6
	Natural Lighting Control	E 4.7
	Surface temperature and operative temperature control	E 4.8

Objective	Requirement	Code
	Ventilation	E 4.9
	Protection from animal intrusions	E 4.10
Use Safety	Safety against falls, Bump and B*reak Through Resistance*	E 5.1
	Plant Safety	E 5.2
Noise	Acoustic Pollution Control	E 6.1
Energy Saving	Reduction of Energy Consumption on Winter	E 7.1
	Energy Gains Control	E 7.2
	Thermal Mass Control	E 7.3
	Reduction of Electric Power Consumption	E 7.4
Usability and Quality of the Living Space	Architectural Barriers Removal	E 8.1
	Interior Distribution and Spatial Organization	E 8.2
	Minimal Plant Equipment	E 8.3
	Green Care, Permeability and Urban Micro-climate	E 8.4
Water Resources	Water Saving and Re-use	E 9.1
Management and Recycling of Materials and Solid Waste	Prearrangement of Space for Separate Collection of Rubbish	E 10.1
	Demolition Waste Re-use	E 10.2
Building Management and Care	Users Information and Active Maintenance	E 11.1

3. Energy Saving and Use or Renewable Sources

The municipal energy consumption has grown progressively since 1990.

Between 1990 and 2004 was the progressive increase of 19.6%, the residential sector is the one that gives te highest contribution to the total consumption with a share of around 37%. The largest share of consumption in our homes is represented by heating, with about 85%. Transport is the second sector, responsible for energy consumption, with 28% of total consumption, followed by the tertiary sector, which represents 23% of total consumption, the industry and agriculture which are responsible for a 12%.

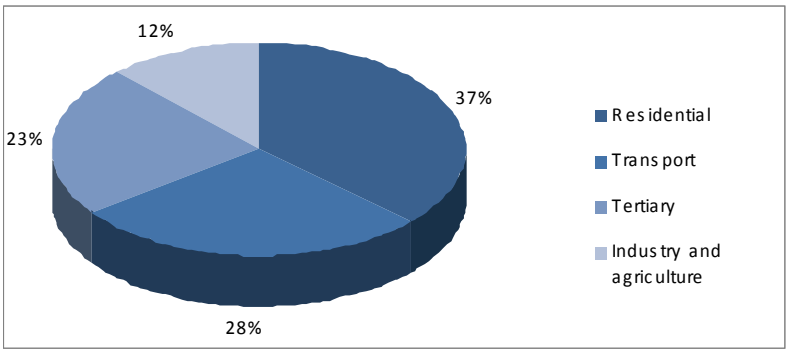


Fig. 1. Energy consumptions in Bologna. Source: Municipal Energy Plan (PEC)

Due to its impact on the energy consumption level, buildings play a key role in energy conservation and rational use of resources. For direct intervention, the Town Planning Building Regulations, in line with the requirements of the Regional Assembly in Resolution 156/2008, introduces the Energy Certification and Energy Performance index (EP), in order to guide designers and builders in choosing the best technologies and achieving high performances. In particular, the decisions are related to the insulation of the building envelopes, improvement of the heating plants efficiency, design and construction of solar photovoltaic and thermal panels.

For interventions of new costruction or house renovations, buildings must be designed so that they can be classified at least in Class C ($60<EP_{TOT}<90$ kWh/m^{2}year). This is the minimum requirement for all buildings, but some higher performances are needed to get a volume incentive, applying the standards of improvement and excellence outlined by RUE. In this case the Class B ($40<EP_{TOT}<60$ kWh/m^{2}year) is compulsory for the interventions that apply the improvement standards and Class A ($EP_{TOT}<40$ kWh/m^{2}year) for those that apply the standards of excellence. The classification efficiency of a building is made according to the total Energy Performance index (EPtot), obtained by the sum of the energy performance index for winter heating (EPi) and for the production of hot water (EPacs). To date, for the energy certification of buildings, the Energy Performance index for summer air conditioning (Epe) and Energy Performance index for artificial lighting (EPill) are still excluded from the EPtot calculation.

The heat losses of the buildings must be contained by ensuring very low levels of thermal transmittance for different parts of the building envelope, below the limits established in Resolution 156/2008 Regional Assamblyof Emilia Romagna Region. The limit value of the thermal transmittance for opaque components in Bologna, which lies in climatic zone E, is equal to 0.34 W / m^2 K. For transparent components, inclusive of 'frame, the limit to be respected is 2.2 W / m^2 K.

With regard to renewable energy sources, the RUE of Bologna provides for new constructions and whole houses renovations the installation of solar thermal systems, sized to cover at least 50% of the annual energy required to produce hot water. Simultaneously, the Regulation introduces a requirement to introduce solar photovoltaic systems for the production of electricity. In the case of residential buildings, the power to be installed must not be less than 1 Kwatt-peak/dwelling.

3.1 Requirement: Reduction of Energy Consumptions on Winter (E 7.1)

This requirement aims to improve the exploitation of free energy contributions, produce energy from renewable sources, prevent the heat losses of the buildings in order to reduce the consumption of fossil fuel for heating and hot water. The requirement is different according to the type of intervention:

a) new construction or full house renovation;

b) building enlargement or extraordinary maintenance of buildings (limited to the portion interested by the intervention);

c) House renovation under 1000 sq.m. of grass surface area (SUL), or maintenance intervention that foresee new installation or renewal of the thermal plants, or substitution of the heating generator in existing buildings.

Main objectives, according the different types of intervention, are as follows:

- ensure a low value of energy performance index for heating and domestic hot water production (a);
- achieve an energy performance index corresponding to the upper classes of the energy certification (a);
- provide centralized heating systems with high seasonal average efficiency (a);
- reduce heat loss through the building envelope (opaque or transparent elements) (a, b);
- prevent condensation (a, b);
- exploit solar energy to produce electricity, hot water and for a possible integration of heating (a, c);
- adopt temperature control systems programmable for each heat generator and automatic temperature control devices for individual zones, able to take into account the free heating contributions (a);
- evaluate a possible connection to the district heating network (a);
- evaluate the opportunity to adopt passive solar systems, to improve energy efficiency (a);
- ensure a high average heating seasonal performance of the plant to be installed (c);
- develop the energy accounting and thermoregulation of heating for each dwelling (c);

Everytime the intervention changes the Energy Performance of the building it is necessary to elaborate the energy performance certificate, issued by accredited institutions.

By analyzing the actions that implement the performance levels of excellence, received by the Municipality of Bologna in the last two years, it is possible to estimate the annual savings compared to the legal limits. The results are shown in the following table.

Table 2. The energy saving for the analysed interventions

INTERVENTION	SAVING for Epi (KWH/ YEAR)	SAVING for EPacs (KWH/ YEAR)	TOTAL SAVING EPtot (KWH/YEAR)
INTERVENTION 1- Building A	17816,17	3163,82	20979,99
INTERVENTION 1- Building B	43802,84	8541,36	52344,19
INTERVENTION 2	17320,31	1455,01	18775,32
INTERVENTION 3	21426,68	3967,52	25394,20
INTERVENTION 4	47708,36	-2707,71	45000,65
INTERVENTION 5	13121,71	544,08	13665,80
INTREVENTION 6	12664,34	830,73	13495,07
INTERVENTION 7	70203,74	3399,37	73603,11
INTERVENTION 8	4272,58	504,56	4777,14
INTERVENTION 9	105151,42	-1225,34	103926,08
TOTAL	**353488,15**	**18473,40**	**371961,55**

Interventions respect the constraints declared in the Town Planning Building Regulations and they all achieve the energy class A (EP_{TOT}<40 kWh/m^{2}year) or A + (EP_{TOT}<25 kWh/m^{2}year).

4. Green areas and new microclimate strategies

The need for new spaces to be allocated for urban settlements, has generated significant changes in spatial planning of cities. Over the past fifty years, the share of urbanized territory of the Municipality of Bologna has more than doubled, rising from 19.3 km^2 of the First World War, to the current 47.7 km^2 , 34% of the total municipal area. The share of public green space is equal to 12.2 km^2 in size, of which 65% are due to green-equipped (32%) and urban parks and gardens (33%).

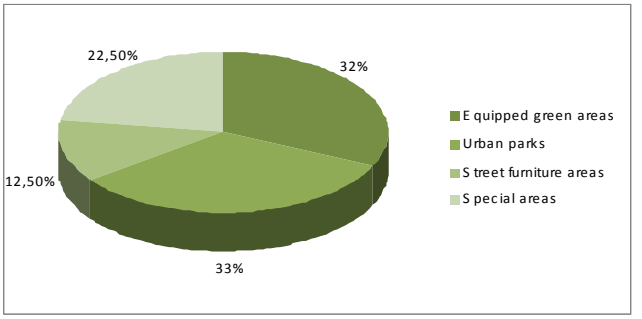


Fig. 2. Public Green in Bologna . Data elaborated from: "Sustainability in Bologna. Report 2008"

The important changes that occurred in Bologna area in recent years, not always proved to be coherent with the environmental sustainability criteria, with negative consequences on the quality of urban space.

With the new urban planning phase the Municipality of Bologna recognizes the importance of the green areas, taking into account also the soil permeability and the role for the urban microclimate improvement.

To the urbanization process is related a number of issues that adversely affect the quality of the settled areas. Of significant importance is the phenomenon called "heat island". Its main causes are listed below:

- physical characteristics of the surface;
- lack of natural permeable surfaces;
- increase of the exposed area, due to the presence of buildings;
- heat flow, generated by human activities and the energy they bring;
- increase in the concentration of CO2 in the atmosphere.

4.1 Requirement: green care, permeability and urban microclimate (E 8.4)

The Town Planning Building Regulations within this requirement aim to ensure the quality of the urbanized areas and optimize the urban microclimate. The buildings must provide solutions that improve environmental quality, ensure the permeability of soils and qualify the green areas of the settlements.

For new construction works, renovation work on the whole house or on external elements, the performances to be achieved are:

- increase of soil permeability, improvement of environmental quality and increase in green components of the settlements through the construction of green roofs;
- preservation of existing green areas;
- identification of most suitable green composition, especially through the use of native plant species.

Moreover, in the technical details of the RUE, the requirements to be met to get the building permit are described. To fulfill the requirement is necessary to evaluate an index of environmental quality, the so called RIE (building impact reduction). This index, applied to the building plot, measure the quality of the

intervention as regards the green and the soil permeability. The R.I.E. procedure must be necessarily applied to all new constructions and global renovations.

The index is defined as follows:

$$RIE = \frac{\Sigma Sv_i \frac{1}{\psi} + Se}{\Sigma Sv_i + \Sigma Si_j \psi \alpha}$$

where:
Sv_i = i-esima superficie esterna trattata a verde;
Si_j = j-esima superficie esterna non trattata a verde;
Se = superficie equivalente delle alberature;
ψ = coefficiente di deflusso;
α = coefficiente di albedo.

The RIE index, applied to the entire plot where the intervention will be developed, gives a number between 0 and 10. To low index values correspond surfaces which are completely or largely paved, with no green spaces; values close to 10 are obtained in presence of green areas, with no waterproofed spaces. In the case of urban areas, the R.I.E. usually takes intermediate values.

For new constructions and building renovations for residential use globally, the values that the RIE index must achieve, for different levels of performance are as follows:

- Basic Level R.I.E. ≥ 4
- Improvement level R.I.E. ≥ 5
- Level of excellence R.I.E. ≥ 6

The application of the RIE index to the projects that applied the excellence performance levels in the last two years, brought the following results:

Table 3. RIE Index.

INTERVENTION	RIE (minimum value)	RIE (project result)
INTERVENTION 1	4	6,1
INTERVENTION 2	4	6,43
INTERVENTION 3	Not applied	Not applied
INTERVENTION 4	4	6,06
INTERVENTION 5	4	6,19
INTERVENTION 6	4	6,17
INTERVENTION 7	4	6,1
INTERVENTION 8	4	6,26
INTERVENTION 9	Not applied	Not applied

It is useful at this point, to make some estimations of permeability index (permeable surface / plot area) and the percentage of added green roofs (green roof surface / plot surface).

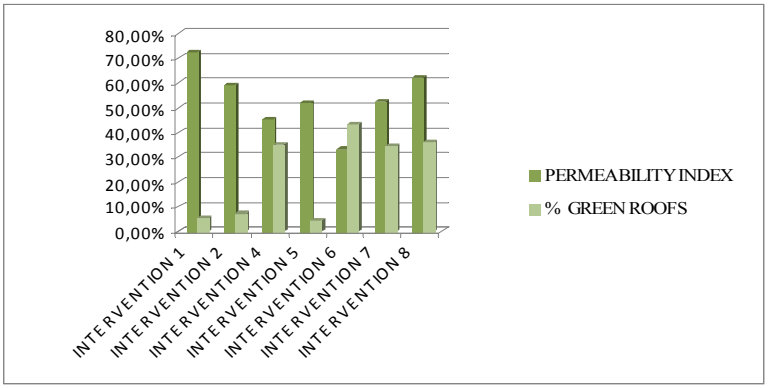


Fig. 3. Comparison between permeability Index and % of green roofs

Making a comparison in parallel, it is clear that, for low values of soil permeability, the green roof adopted in the projects is significantly increased, in order to achieve the required RIE index. The intervention No.3 and No.9 intervention were not reported in the chart, having obtained a waiver for the application of the RIE, because the ratio between the covered area and that plot surface is greater than 0.5.

The new Town Planning Building regulations, in a sense, requires the use of green roof designers to meet performance expectations. Only for projects submitted in the last two years the City of Bologna which apply levels of excellence, the total area of green roof installed is approximately 2200 square meters. This is an extremely positive, considering that the current use in this green roof is almost entirely absent.

5. Water Saving and Re-use

Water is essential for life on the planet. Our lives and our businesses are completely dependent upon this precious resource that, globally, is often limited. Climate change, global population growth, pollution, industrial development, are causing and will determine more and more a reduced availability of water resources, until situations of real scarcity are produced. B

In the graphic below the data on water withdrawals by sector in Emilia Romagna Region, and those at national and European level are compared.

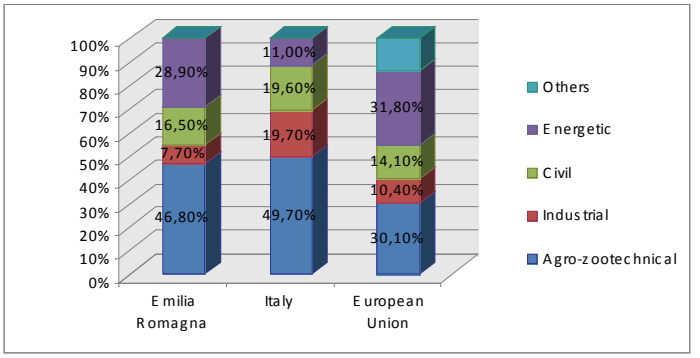


Fig. 4. Water withdrawals per sector in Emilia Romagna and comparison with regional and european standards. Source: Water Protection Plan, Emilia Romagna Region (www.regione.emilia-romagna.it).

The majority of water withdrawals are made by the agro-livestock and industrial sector, but considerable water savings can be obtained also by civil society. It is important to promote and disseminate a more sustainable use of water, especially considering that the use, in the civil sector, affects the most precious of this resource, the drinking water. In Emilia Romagna, each inhabitant consumes an average of 170/180 litres of water a day, much of this water is used to power the boxes of toilet and personal hygiene and only a small fraction (3 / 5%) is used for the purpose of drinking water.

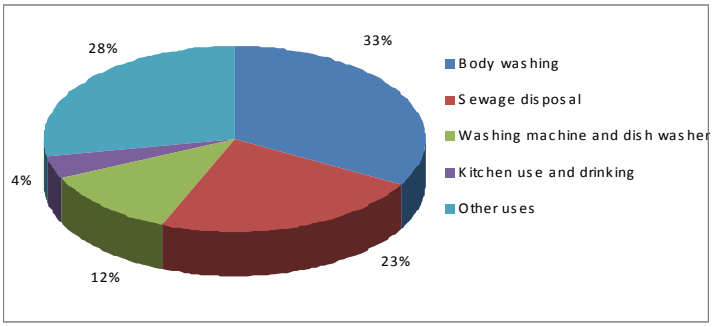


Fig. 5. Distribution of average daily water consumption in Bologna. Source: **http://www.comune.bologna.it/ambiente/servizi/**

The objective of the Municipality of Bologna, in line with the statements in the Water Protection Plan, is to lower the water consumption to 150 litres daily. For this purpose, important provisions have been introduced in the regulations of urban planning tools. For new constructions, the Town Planning Building Regulations diversified performance levels as follows:

- Basic Level 150 litres/ inhabitant/ day
- Improvement Level 130 litres/ inhabitant/ day
- Level of excellence 120 litres/ inhabitant/ day
- The levels of performance can be met by making one or more of the following interventions:
- installation of water saving devices;
- rainwater recovery;
- re-use of gray water.

5.1 Requirement: Water Saving and Reuse (E 9.1)

The Requirement E 9.1 encourages technological solutions that limit waste of water and allow the reuse of rainwater and domestic wastewater in order to reduce the consumption of drinking water.

Also in this case the requirement is different depending on the type of intervention.

a) new constructions, building renovations and maintenance involving the entire sanitary water and heating system

- installation of specific devices to limit the use of drinking water;
- compulsory installation of individual consumption counters for each dwelling.

b) new constructions and building renovations

- it is compulsory to provide conveyor, filtration and storage of rainwater from the buildings roofs. Rainwater will be used for compatible uses within the building or in outdoor spaces.

c) new constructions:

- evaluate the possibility of grey water reuse, by analysing hygienic, economic and functional sustainability. In case of feasibility, the grey water will be used for compatible uses within the building or in outdoor spaces.

By analyzing the actions that implement the performance levels of excellence, received by the Municipality of Bologna in the last two years, the results are represented in the chart below. The BAU is the minimum performance level required by RUE. The projects are positioned at a lower level compared to 150 litres / inhabitant days, resulting in significant water savings.

Table 4. Drinking water savings in the analysed interventions

INTERVENTION	RAINWATER RECOVERY (litres/year)	REUSE OF GRAY WATER (litres/year)	REDUCTION THROUGH WATER SAVING DEVICES (litres/year)	TOTAL SAVE OF DRINKING WATER (litres/year)
INTERVENTION 1	657000	1389555	Data missing	2046555
INTERVENTION 2	13323,96	Not foreseen	151840	165163,96
INTERVENTION 3	141944,85	135000	368000	644944,85
INTERVENTION 4	210240	Not foreseen	1261440	1471680
INTERVENTION 5	87500	Not foreseen	158543	246043
INTERVENTION 6	Not foreseen	611667	291270	902937
INTERVENTION 7	1150483	681144,75	Data missing	1831627
INTERVENTION 8	62607	Not foreseen	54750	117357
INTERVENTION 9	1104782	3295950	Data missing	4400732
TOTAL	**3427880,81**	**6113316,75**	**2285843**	**11827039,81**

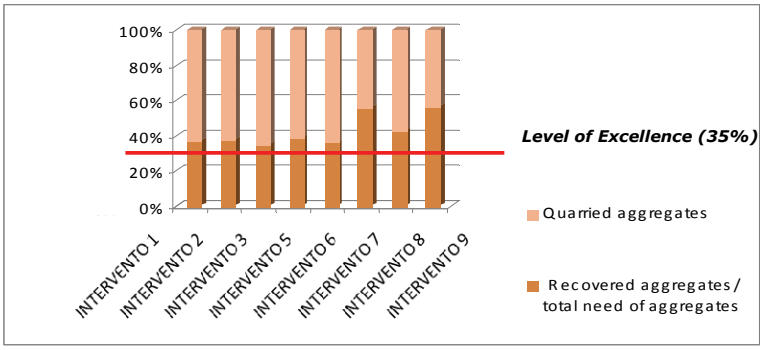
6. Reuse of demolition waste

In Town Planning Building Regulations, with the requirement and 10.2, a big attention is given to the management of construction and materials demolition waste. The RUE requires that the aggregates produced during the demolition will be reused as a priority on the same site. In case of technical impossibility, economic and environmental reuse of inert materials on site, the alternative is to use inert materials from plants that make recovery and recycling. The quantities, specified in the Regulations, for different levels of performance are as follows:

- Basic Level the target is not indicated
- Improvement Level 15% of the total volume of aggregates required for the implementation of interventions
- Level of excellence 35% of the total volume of aggregates required for the implementation of interventions

Evaluating the requirement for interventions which apply the levels of excellence and received by the Municipality of Bologna in the last two years, the situation is represented in the chart below.

Fig. 6. The management of the aggregates from demolition waste



The intervention 4 is not mentioned because, at the current stage, the project documentation does not provide the volume of aggregates required for the implementation of the intervention and the calculation of the percentage of reused aggregates or recovered ones.

7. Conclusions

The experience of Bologna shows that some little changes in the building regulations can bring significant results in terms of reduction of natural resources. This requires a technical assistance to the technicians, especially in the first stages of the application, and a strong economic motivations, which is represented by the volume incentives to the existing buildings that are demolished and re-built. This operation doesn't increase soil consumption but allows to qualify dilapidated buildings achieving high levels of environmental quality, according to the principle that a certain prize can be given to those interventions that achieve a mimor environmental impact, bringing advantages both to the private owners and to the whole urban environment and civil community.