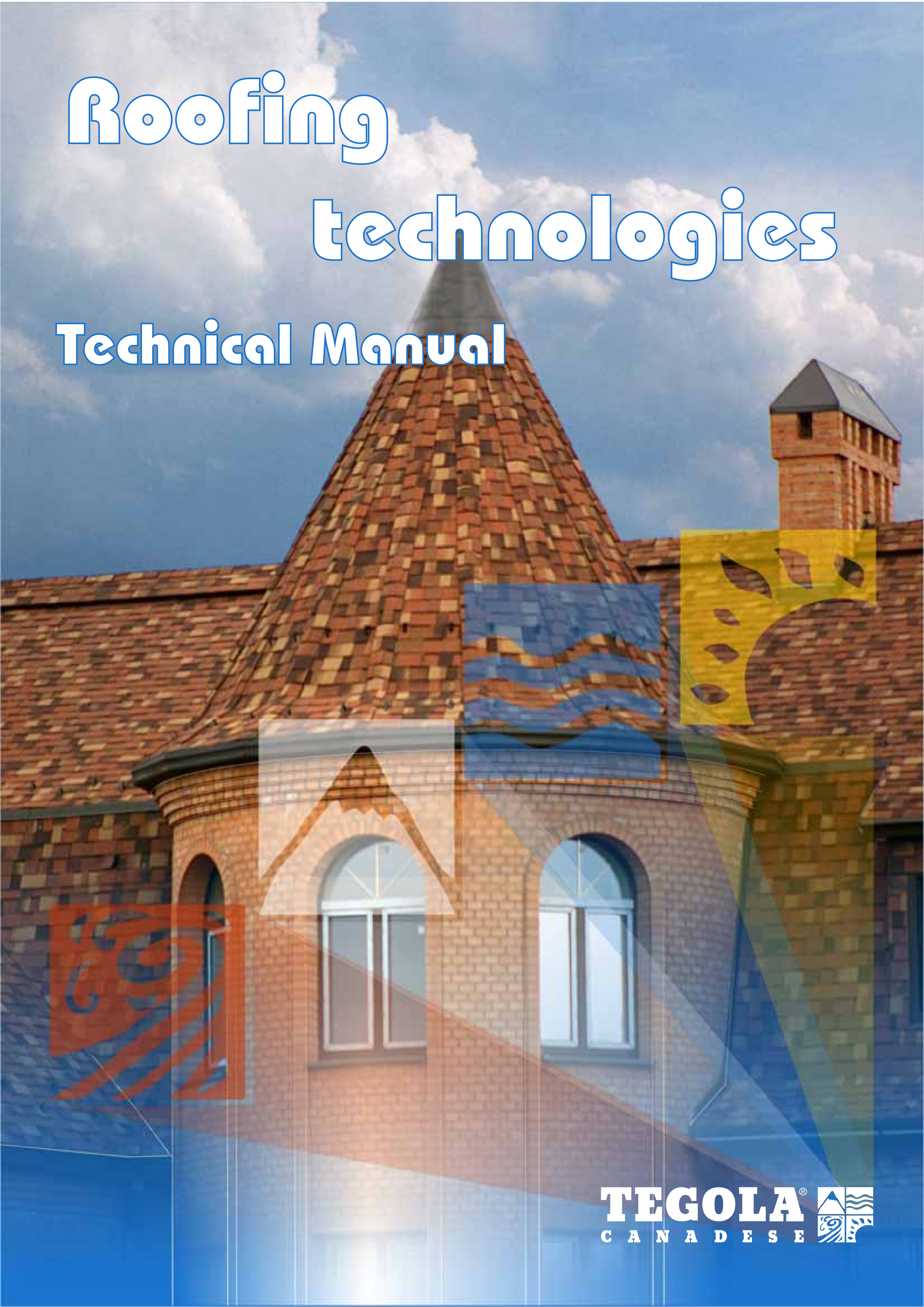
Roofing technologies

Technical Manual



TEGOLA® CANADESE

In building design and construction, roofing is often undervalued, despite the importance of the protection it provides against inclement weather, its aesthetic qualities, and its durability. Regulations and legal requirements are a valuable support for design because they provide a level of control within the industry. On the other hand, they leave the tasks of evaluating specific requirements and of identifying the most appropriate roofing approaches to the designer and to his experience. Roofing Technologies was born for precisely that reason: to create an opportunity for the sharing of information, to provide support to designers, and to improve both building quality and the "living comfort" of the end user.

Tegola Canadese Technical Manual
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GENERAL INTRODUCTION: *THE EVOLUTION OF ROOFING AS A FUNCTION OF CHANGING NEEDS*

Public infrastructures and buildings express and represent the social and cultural state of a nation. Throughout history, each civilization, in its unique way, has reflected its culture in its “civil architecture” and “public works.” Though we may more readily recognize affinities with some cultures than with others, all have had the intention to provide designers and builders with the best and most efficient technology possible.

Going back even further in time, primitive humans identified in roofing that combination of elements that satisfied their basic need to create a shelter from the physical environment. It is with regard to roofingand specifically in the sense of refugethat first a technique and, later, a genuine building technology began to be developed. That technology, up until the nineteenth-twentieth centuries, remained more closely tied to the improvement of traditional techniques than to innovation (as building manuals from the late 1800s make clear). It was, in addition, still quite a distance from having resolved the question of habitability, and buildings continued to be essentially a form of protection from a hostile and aggressive external environment rather than places that offered pleasant accommodation and convenient services. The castles, the aristocratic mansions, and the ancient dwellings of European historical centers provide ample evidence of these facts: all of them “formally” fascinating as architecture, but certainly not from the point of view of comfortable living.

With the dawning of the industrial era and the discovery of new construction materials, new techniques and technologies began to emerge. These new technologies both supported and partly replaced traditional ones, but they were largely experimental solutions. They resolved traditional difficulties through the improvement of certain details and construction methods, but they did not create a more expanded vision of low-technology construction. What is more, they often had indirect and unpleasant effects on livability.

Even in more modern times, housing design continues to be concerned with appearance above all else. The purely technical question of the stratification of construction materials is relegated to a series of regulations that are derived more from hands-on experience than from scientific testing. Today it is easy to find instructions, examples, or tables that help us to define the amount of a building's winter-time energy consumption. What remains difficult is choosing the right solution to keep the housing unit comfortable during the summer when the problem is the oppositethat is, when heat is produced outside and the inside environment needs to be maintained at a comfortable temperature.

Additionally, builders and designers today hermetically enclose the internal environment with sealed or double-glazed door and window treatments, create bathrooms that are more perfect all the time along with kitchens that are worthy of a restaurant, and make no provision for the effective elimination of water-vapor production or for good air exchange within the environment. The roof is, so to speak, the building's “poor relation” and, as a result, it receives barely marginal attention.

In the sections that follow, we will examine the building envelope and, in specific, the “roof” element, evaluating its characteristics in order to optimize its performance and provide the end user with the best possible and most appropriate level of living comfort, depending upon the way in which the functional layers of the roof are distributed.

THE BUILDING INDUSTRY AND THE ENVIRONMENT

Two contrasting elements give rise to the need to define what is meant by environmental sustainability and, in particular, to define what can be done to contain the degradation of the environment: human beings, who require comfortable and healthy living environments, and the awareness that the building industry has a significant impact on the environment.

- Specifically, if we analyze a building's "life cycle," we can highlight the phases in which these effects are most striking:
- construction
- maintenance
- energy requirements for proper functioning of the building
- building closure/deconstruction or demolition

In order to better define the construction sector's impact on the environment, here are a few statistics:

- consumption of 45% of the energy produced in Europe
- 50% of air pollution
- 50% of natural resources finish in the building industry
- 50% of garbage in Europe is produced by the construction industry

Following an evaluation released by ENEA (National Agency for New Technologies, Energy, and the Environment), based on studies conducted over the last thirty years, a continuously expanding trend has emerged which has led some scholars in the field to speak of "Factor 4"in other words, of the need to increase ecoefficiency fourfold, thus substantially improving health and well-being on every level. We must set goals for ourselves that are high. At the same time, we cannot underestimate the first positive signs, such as a 10% reduction in CO_2 emissions. We are, nonetheless, aware that the challenge we face together is one that requires us to go much farther than we have in the past.

The Bruntland Commission Report, which provided the results of a study conducted between 1983 and 1987, cites the term "sustainable development" for the first time, defining it as the will to guarantee the development of society and the well-being of human beings by recognizing the limits of the environment to sustain such development. It is, in other words, a collective effort.

In December 1997, The Kyoto Protocol delineated for the first time on a planetary scale the desire to safeguard the environment, but it wasn't until September 2004, with ratification by Russia, that a sufficient number of signatories was reached and the Protocol took effect (on 15 February 2005). Obviously, the Protocol has an impact on the building industry as well, requiring a decrease in energy demand through the construction of low-energy-consumption buildings.

In 2004, the European parliament approved the "Emissions Trading" directive, which requires European businesses to comply with an emissions ceiling by 2010.
Italy, among the first signatories of the Kyoto Protocol, acknowledged its commitment with the 1998 "CIPE" (the Interministerial Committee for Economic Planning) resolution, otherwise known as "guidelines for national measures and policies for the reduction of greenhouse-gas emissions." In the document later created by the Ministry of the Environment, "Environmental Action Strategies for Sustainable Development in Italy," the themes of the

CIPE resolution were taken up again and various points were clarified in order to create specific objectives in the area of thermo-technology and renewable resources. With regard to the construction sector, the document specified the implementation of a product's LCA (life-cycle analysis), referring to Presidential Decree 412/93 which required the reduction of electrical consumption for heating and air conditioning through maintenance approaches that reduce energy loss.

In February 2001, the European Community's "integrated product policy" Green Book appeared. Its goal was to direct the marketplace toward sustainable products and to promote integrated policy tools aimed both at the development of sustainable products and at raising the awareness of purchasers who appreciate the need for such products. The intention was to go beyond traditional methodologies for product design, which is currently based upon an analysis of production and manufacturing processes alone. When the European Community spoke of integrated policy, it had in mind new design methodology structured around a product's entire life cycle. The key to the development of products that reduce (maximize) the use of natural resources (meaning energy consumption) is to engage all of the actors who are involved in the production of manufactured goods (extended producer responsibility) in all of the phases of the life cycle of those goods and on all levels, from the local to the environmental-planetary. This holds true not only in the initial phase of the product's life cycle but throughout, resulting in an environmental impact that is both sustainable and consistent with users' needs.
To make changes in manufacturing and/or production processes requires working on a number of different fronts, beginning with the local. This takes place either because of changes in market demand or, more likely, because of the development of regulations that provide the means to popularize innovation in products and production processes in environmental terms, focusing attention on durability, maintenance, refurbishment/modernization, disassembly, and recyclability. Likewise, via shared responsibility it becomes possible to identify the main actors in the processes of consumption and pollution.

THE EUROPEAN DIRECTIVE
regarding the energy performance of buildings

The 2002 "Energy Performance of Buildings" directive is concerned with the energy performance of buildings and with the goal of reducing CO_2 emissions. The building industry is one of the main sectors affected by the directive because of its insatiable energy consumption (carbon dioxide emissions produced by heating systems are of particular concern). It should be kept in mind that buildings with high heat-insulation properties can reduce energy demands by as much as 60% through:

- Increased and more efficient use of insulating materials
- Correct positioning of the building with respect to the sun
- More effective relationships between glazed and opaque areas and surfaces that are in direct contact with the ground
- The passive use of solar energy with the positioning of glazed areas, which can be shielded during the summer, toward the south.
- The active use of solar energy via collectors and photovoltaic cells
- The use of high energy performance systems
- Ventilation

In addition, the directive requires that each member state in the European Community must, by 4 January 2006, create a method for certifying energy performance and set minimum reference standards for new construction and for renovation (those with usable surface greater than 1000 m^2 are affected). Since that date, all real estate contracts must be accompanied by a certification that attests to the building's energy consumption. The directive does not refer to specific design parameters or regulations, but leaves the drafting of specific guidelines to each country.

Two tools are used most frequently:

- the establishment of reference limits
- the introduction of building energy-use certification at the expense of the seller

The Italian government responded to the European Directive with Legislative Decree No. 192, 19 August 2005, whose objectives included the improvement of energy efficiency and the reduction of polluting emissions in the civil sector (residential and service industry), which absorbs more than 30% of the energy consumed in the country, and the orientation of construction processes toward more efficient solutions from the standpoint both of costs and of greater energy savings in the operation of buildings and of the systems installed in or associated with them.

BUILDING PRACTICES AND EUROPEAN DIRECTIVE 2002/91/CE

The main objective of European Directive 2002/91/CE is to improve buildings' energy performance. In addition, the directive provides guidelines for design that is more intelligent and sensitive to environmental considerations and to the reduction of emissions of harmful gasses.
The possibilities for intervention range from building technologies and types to approaches for the optimization of heating and cooling systems. In this context, a series of UNI regulations were included, which have proven themselves to be a valuable support for designers who need to measure progress in the reduction of energy consumption. What is particularly important is to conceive and plan buildings with effective passive-design performance. A design solution can be considered “passive” if it contributes to energy savings by reducing consumption from primary sources, optimizes heat gains, and naturally maintains a good level of comfort within the environment in question. What is required to achieve these results is a careful evaluation of the influence of and relationship between factors such as shape, mass, heat transfer of the building components, and percentage of glazed and non-glazed surface. In order to evaluate the effects of the above-mentioned parameters, one refers to representative performance indicators of internal comfort such as, for example, internal air temperature and the radiant temperature of the environment's surfaces. Still, the parameters that influence a building's behavior are not tied exclusively to its physical or morphological characteristics. Climatic factors, for obvious reasons, are also important, inasmuch as they determine the heat loads to which the system is subjected as well as potential heat gains.
Last but not least are the economic considerations involved in determining whether one solution should be adopted over another, and an evaluation of the benefits that derive from the investment of specific passive, active, or mixed solutions.

Physical characteristics

- Compact form
- Orientation and distribution both of the housing unit and of its various rooms

- Glazing systems, their relationship with opaque surfaces, their orientation, and their distribution in order to determine winter-time energy needs and to control solar radiation and the level of natural light in the summer.
- The presence of shielding and/or filter spaces (from brise-soleil or sunbreaks to fixed or adjustable porticoes during summer and winter)

Environmental characteristics

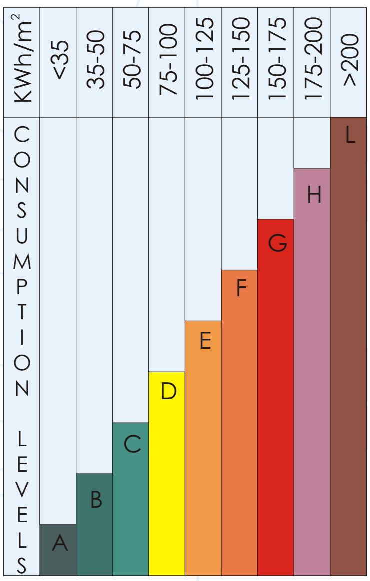
- The evaluation of climate data, referring to the UNI 10349 standard, specifically: temperature, solar radiation, wind, and relative humidity.
- The evaluation of the morphology and urbanization of the construction site, taking into account ground features, the presence of pollution (sound and environmental), the existence of waterways, and possible shading due to trees and/or surrounding buildings.

Building technology

- Thermal insulation for opaque areas and high thermal performance windows
- Passive use of solar energy by means of heat accumulators, spacers, etc.
- Integration of active solar technologies (solar collectors, photovoltaic panels)
- The use of high-performance technologies (heat pumps, energy-efficient lighting fixtures and home appliances).

THE ITALIAN SCENE

During this period, Italy enacted Law 10/91 whose goal is to reduce energy consumption. We are still awaiting, however, the relevant decrees that would effectively implement the law.
Ministerial Decree 02/04/1998 ("Procedures for Certifying the Characteristics and Energy Performance of Buildings and Connected Systems") requires all products to be certified, but the operative/normative reference standard today is Legislative Decree 19 August 2005, No. 192, which implements the 2002/91/CE directive related to energy performance.



Graph.1

Energy consumption and environmental impact are oriented along two axes: one concerns production, on-site operations, and the deconstruction/demolition of building components; the other has to do with the management of the building during its useful phase.
This last point is extremely relevant today, because the resources used in all new construction (estimating building life at fifty years) are ten times greater than what is actually necessary for the construction of the building and for the production of the materials required to build it. As a result, low-energy-consumption buildingswhich, despite a greater initial cost, require less than 50% of current resources when they are fully operationalare increasingly used and studied in Europe. Because an explicit market demand does not exist for the construction of such buildings, designers and/or building firms tend not to invest in the costs of construction in order to bring lower-energy-consumption (but more expensive) housing into the marketplace. Nonetheless, the goal of research is the creation of highly energy-efficient buildings which guarantee an abatement of CO_2 emissions. In order to better understand this point, we can define a standard energy level for low-consumption buildings as between 25-60 kWh / m^2. This "range" diverges notably from the buildings that are actually constructed, even very recently, in which energy consumption is notably higherat least double. Over the years, buildings have been constructed in the absence of particular energy-savings criteria and

efficient maintenance has not been carried outfacts that leads us to a situation in which maintaining the design temperature (which today is ~20°C) entails significant energy waste. During cold weather, heat flow is observed from inside, warmer environments, toward external, colder ones. To compensate for this reality, the production of heat is required in order to maintain a constant design temperature (~20°C), which is defined as a building's heat requirement (UNI EN 832). Energy requirementssuch as the amount of energy provided by the heating system that is necessary to satisfy the energy demand (which depends upon the systems' energy performance)are thus defined.

A building's energy performance (directive 2002/91/CE) is the amount of energy needed to satisfy heating, cooling, and lighting needs. The calculation of energy performance takes into consideration:

- Insulation
- Type of heating
- Air conditioning
- The use of renewable energy sources.

In order to calculate heat flows in sustained operation, one must know the minimum external design temperature (UNI 10349) and the minimum internal design temperature according to use (Presidential Decree 412/93). The heat losses to be considered are:

- External transfer
- Transfer toward unheated rooms/areas
- Heat bridges
- Room ventilation

The procedure for the calculation of heat requirements is described in UNI 7357/74.

Heat contributions due to solar radiation and to internal loads (lighting, the presence of people, cooking) are ignored in this calculation; these latter are considered, instead, in calculating the FEN, the evaluation of the building's annual energy requirement (UNI 0344), one of the energy-performance indicators required by Italian Law 10/91.

The law establishes three criteria for determining a building's energy performance and consumption:

- Cd, overall thermal transmittance [W/m^{3}K]
- FEN, a building's annual heating-energy requirement in a single heating season [kJ/m^3 kg]
- ηg, seasonal heating efficiency rating (overall building-system efficiency)

Prior to Italian Law 10/91, the building envelope and heating systems were considered independent and successive elements of the design process: the characteristics of the building were defined first, and the size and requirements of heating systems were planned afterwards. Still later, system capacity, heat dispersion, and heat gains were considered.

It naturally follows, then, that the most efficient energy-savings strategy is to limit energy loss by means of adequate thermal insulation of roofing materials, even if such a strategy cannot be separated from an evaluation of heating systems themselves. Italian Law 10/91 anticipates this situation when it introduces the heat dispersion transmittance coefficient (Cd): the maximum allowance of overall thermal transmittance via the opaque and transparent materials used in the building, in steady-state condition and as indicated by the project's greater thermal gradient (minimum seasonal external temperature). By law, the Cd is a function of the location's degree-days (gg) and of the S/V ratio (dissipating surface/gross heated volume). In the case of autonomous heating, the Cd must be calculated for each individual dwelling.

Cd proj = Qtot/V (Ti-Te)

Qtot: sum of the heat dispersion via the building envelope
V: gross volume of the building

The new research frontier concerns the optimization of energy performance and the identification of alternative sources of "clean" energy in order to reduce environmental impact. The hope is that such research will lead to a reduction in "upstream" energy demand through approaches that are truly energy-efficient.

Not to be overlooked is the fact that greater investment during the construction stage could achieve the following results:

Energy savings ➪ comfort ➪ health

Obviously, the matter would be much simpler if a suitable marketing campaign were available to sensitize clients to the benefits involved:

Client ➪ demand ➪ marketplace offer

In any event, regulations are being created on a national and international level to that end. One example is the European EPBD Directive 2002/91/CE (Energy Performance of Buildings Directive) and Italian Law 10/91 (for which the relevant regulatory documents are still being created). First among these is Legislative Decree 19 August 2005, No. 192, which established the criteria, the conditions, and the procedures for improving buildings' energy performance and whose goals are to foster the development, the improvement, and the integration of renewable energy sources and energy diversification; to contribute to the reaching of Italian goals for the limitation of greenhouse-gas emissions imposed by the Kyoto Protocol; and to promote competition among the more advanced sectors by means of technological development. Essentially, there are three technical aspects that need to be analyzed and/or evaluated in new construction projects:

1. Thermal resistance for the containment of wintertime energy consumption.
2. Surface mass to limit energy requirements for air conditioning in the summertime.
3. The "breathabilty" of the roofing materials.

THE BUILDING ENVELOPE

In recent years, building-envelope systems have seen remarkable evolution, both in terms of the appearance of new building components and systems and in terms of the greater attention that is being paid to the problem of reducing energy consumption and increasing environmental health.
This evolution involves wall structures, roofing, and door and window frames and moldings. As far as the overall impact of these considerations on building systems is concerned, it is important to say that, unlike the situation in Italy, the overall European trend is toward hyper-insulation approaches that make the use of solar energy increasingly feasible. This requires, moreover, the development of design applications that are not strictly focused on construction techniques, but which take particular account of the development of integrated architectural-technological models. In Italy, one unique aspect concerns extreme differences in climate from one area of the country to another. Such a reality necessitates the development of design and building techniques that are equally diversethe opposite of what is currently taking place. If technological developments in the building envelope, therefore, appear important, what is still missing is the diffusion of a "design culture" that is capable of combining technological potential with architectural approaches that are consistent with climatic realities and environmental-quality goalsall of which is connected to the concept of sustainability.

“Agenda 21,” produced by the CIB (the International Council for Research and Innovation in Building and Construction), sums up the current situation and suggests development strategies. The theme of sustainability is the document's driving theme, and “Agenda 21” touches on many aspects relevant to sustainability in the building industry. Among these are:

- Economic sustainability (marketplace demand, life cycle, value analysis, construction processes, management, etc.),
- Functional sustainability (internal environmental quality, technical performance, durability, etc.),
- Environmental sustainability (natural resources, biodiversity, tolerance of nature and resources, environmental load, etc.),
- Human and social sustainability (social stability, constructed environments, transportation, health, aesthetics, cultural aspects, etc.).

Particularly relevant to the goals of this manual, “Agenda 21” identifies the following strategic actions:

- Integrated approach to design
- Improvement of environmental standards
- Modification of building processes and designs.

Such actions make clear that innovative development within the sector cannot be based solely upon the invention of new products, but requires the reconceptualization of the entire arc of the building process: from planning and design to management and deconstruction/demolition. This, in turn, requires the creation of a management framework without which the concept of sustainability (sustainability consciousness) cannot help but be sterile and unworkable:

As far as the building materials and components sector is concerned, one observes a fairly consistent and dynamic innovative approach, though it is not always aligned with the requirements of development objectives.
This development makes available to designers a variety of technologies that expand the possibilities for technical development and performance in the planning of innovative building-envelope systems that are more fully oriented toward environmental considerations.
On the other hand, we are also seeing the positive development of research in the building sciences, particularly with regard to environmental physics, the durability of materials, and the use of tools for modeling and predictive simulation of the operational behavior of systems and components.
The bases exist, then, to make building design more aware and more responsible. Unfortunately, it must be noted that the potential for innovation and development inherent in such possibilities appears to have only a marginal impact on current standards in building and architectural design. Design practices continue to move in the direction of repeatable approaches, of building systems that do not take new goals into consideration and whose levels of reliability, instead, implicate maintenance and management costs that are hardly consistent with the concept of sustainability and which have a major impact on development. There is a need, then, to develop professional approaches in which integration among designers, engineers, and producers is strengthened, and which make use of advanced design tools (especially those relevant to environmental concerns).
In specific, we are referring to the quality of enclosed environments and to the durability of building systems, both of which have a major impact on the ability to confront new goals and whose primary tool is a new approach to technological and architectural design. The technical elements that are most clearly implicated are obviously those that make up the building envelope. The behavior of the building envelope is very complex and is tied to its function as a mediator among the multiple stresses that derive from both the external environment and internal environmental conditions (which, naturally, must be reliable and as consistent as possible with human needs). Conceptually, then, the building envelope becomes the first tool, of a

passive nature, to determine the comfort level of the enclosed environment.
The wide availability of knowledge in the building sciencesalong with the number and variety of products and technologies that market dynamics have made accessiblemay be confusing. On the other hand, they clarify the opportunity to formalize approaches to the construction of roofing. Quite naturally, roofing is capable of defending the internal environment from the elements and/or climate conditions but, at the same time, it must also recognize that the contained environment is not permanently stable. Indeed, human beings and their indoor activities tend to alter the hygrothermal conditions related to personal comfort.
Consequently, the building envelope must become not simply an enclosure but rather a kind of mediator, a permeable separating layer capable of defending the internal environment without isolating it from the external one.
There is, in addition, a uniquely Italian aspect of the situation that encourages development in precisely this direction. Compared with other European countries, Italy's climate is characterized by a remarkable degree of variability. It becomes necessary, as a result, to study new models for the building envelope that are capable of developing, according to specific local needs, passively or actively, an approach that depends, as we've already observed, upon a potent synergy between architectural formalization and technology.
But if traditional building-envelope systems react passively to environmental stresses, today it is possible to render their performance responsive and dynamic, by means of systems capable of reacting differently to daily and seasonal weather dynamics. In these so-called dynamic insulation systems, the roof is directly involved in managing the expulsion of exhaust air, in what becomes a functionally integrated system.

The most interesting aspect to mention, as far as the situation in Italy is concerned, is Italy's remarkable distance from the standards of thermal insulation that have been under development for some time in Europe. As can be seen in Table 1, the trend is moving in the direction of hyper-insulation. If this trend will sooner or later involve Italy as well, single-layer roof construction systems based on concrete slabs or concrete with cellular clay infill blocks, whose mass significantly limits their performance, will clearly not be an effective solution because of the difficulty of integrating ventilation systems into them.

Table 1
(buiding reserch and information)
1992 data

Data related to building practice (1992)

	The Netherlands	Germany	Switzerland (Zurich)	Hyper-insulated buildings
External walls	K=O,4 W/m²K Mineral fiber in air gap 70 mm	K=O,4 W/m²K Mineral fiber in air gap 50 mm	K=O,38 W/m²K Expanded polystyrene or mineral fiber in air gap 80 mm	K=O,2 W/m²K Expanded polystyrene or mineral fiber in air gap 150 mm
Roofing	K=O,3 W/m²K Expanded polystyrene 100 mm	K=O,35 W/m²K Mineral fiber 150 mm	K=O,25 W/m²K Mineral fiber 175 mm	K=O,15 W/m²K Mineral fiber 250 mm
Ground surfaces	K=O,5 W/m²K Expanded polystyrene 70 mm	K=O,5 W/m²K Expanded polystyrene 60 mm	K=O,35 W/m²K Expanded polystyrene 75 mm	K=O,3 W/m²K Expanded polystyrene 100 mm
Windows	K=3 W/m²K (double glass)	K=2,8 W/m²K (double glass))	K=2 W/m²K (triple glass)	K=1,5 W/m²K (double glass)
Wind penetration	6ac/h a 50Pa Natural ventilation + blowers	4ac/h a 50Pa Natural ventilation + blowers	4ac/h a 50Pa Natural ventilation + blowers	Mechanical ventilation with recuperators

It is equally important to observe that even with the other techniques that are most widely used in Italy, such as the hollow wall construction used for buildings with frame structures, the difficulty of controlling heat bridges is present to a greater or lesser degree.
In high-insulation systems, the accurate control of heat bridges is basic, both because energy-related effects become relevant on a percentage basis and because of the exacerbation of tensile distortions (cracking and deterioration) and condensation and related phenomena.
Innovation, as a result, must move in the direction of systems without thermal heterogeneities.
From a conceptual point of view, innovative development approaches tend to replace single-layer construction systemswhich require that a single construction element provide all of the building envelope's “services”with systems in which the various functions that the roofing material must carry out are distributed among specific functional layers. It is obvious, then, that the optimization of performance becomes difficult in single-layer, multi-objective design systems where a multiplicity of functions must be carried out. In addition to greater functional clarity and, thus, greater ability to control performance, multi-layer systems offer advantages from the point of view of maintenance, of ease of deconstruction/demolition, and of sorting of materials for recycling.
In addition to the optimization of specific performance, the use of layers equipped with specialized functions, with reduced interactivity among layers, also makes it possible to calibrate the functional load with respect to the performance load and to add new innovative functions.