High Energy Efficiency in Intelligent Housing built through Integrated and Industrialized Processes

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For almost ten years, in Madrid, the Municipal Housing and Land Authority (E.M.V.S.) has been regularly incorporating High Energy Efficient facilities to housing developments.

Therefore the EMVS, within the sphere of the I3CON Project will provide industrially manufactured integrated processes, as well as intelligent construction systems, for which we will use the usual technologies employed by the E.M.V.S. to which we will refer later.

The programme will be reproducible, and intends to research and develop new implementing and execution processes with results such as a 50% reduction of costs, a 70% reduction on execution schedule, and a 90% reduction of industrial accidents. We will work on this programme with open and pre-manufactured industrialized constructive systems, mobile industries with component production at the same construction site and with the participation of the future user from the very beginning.
Basic Criteria

This intends to overcome the inertia of usual construction, through a commitment for modulation, industrialization and optimization of the energetic capacity.

The buildings will count on a specially cared for design and construction based on North and South orientation, with crossed ventilation and external insulation above the requirements of the Technical Building Code, while incorporating the demanded air quality for an adequate standard of living.
We are taking advantage of bioclimatic passive architecture and the experiences learnt by the incorporation of elements such as solar chimneys…
Inner solar chimney
“Sunrise” building.
Phase-change materials applied on outer layers for the better use of thermal inertia.

...phase change materials (PCM), evapotranspiration, etc.

Energy production station with phase-change materials in water-heating, cold water and tank circuits.
To systematize the execution of what we now call heating and water-heating facilities of High Energy Efficiency with thermal solar energy, of centralized production and individual consumption, the EMVS has drawn up a **Technical Specification List** which, along with the **hydraulic diagrams** and recommended assemblies, gives architects, engineers, construction companies, fitters, energy managers, etc. an exact knowledge from the basic project phase, of the clearly defined system in each housing development.
Energy Efficiency of the Building

After having used High Energy Efficient facilities, extensively tested for several years in the housing buildings developed by the EMVS, in this new program we intend to take the next natural step, that is, the prefabrication of components and the systematization of processes.
Industrialization and Prefabrication of the Facilities

All the building facilities will be made at the assembly shop, being assembled at the construction site as prefabricated parts. The greatest complexity for prefabrication systems lies in the hot water heating and collection production area. We will pay special attention to the vertical technical centre, where individual energy and hot water measuring systems will be placed for every user.

Standardized prefabricated cabinets for temperature control, and for control of users’ energy and hot water readings with four and three units.
Basic concepts to be defined on the prefabrication of High Energy Efficient facilities

- Design criteria
- Minimum annual seasonal capacity
- Technology to be used
- Demanded renewable energies
- Energy savings to be achieved and reduction of pollutant emissions
- Energy management.
Design Criteria

The system is conceived as a heating and hot water system for individual consumption with centralized production, working with several low temperatures and condensation and not using mixtures inside the thermal production centre.

Thermal production centre with low temperature generators

Modulant burner from 25% of the power connected to condensation boiler
Minimum Annual Seasonal Capacity
The minimum capacity demanded is 140% over lowest calorific power of natural gas.

The annual seasonal capacity of the whole is the ratio that exists throughout the course of a year of operation, between the useful thermal energy sent to the building, and the used primary energy from fossil fuel.

Annual Seasonal Capacity = \( \frac{\text{Useful Energy}}{\text{Primary Energy}} \) = 140 %
In combustion, condensation and low temperature boiler burners will modulate with a 25% minimum, and this modulation will be achieved through telemanagement external signals.

In regulation, this is achieved automatically, through a programmable and telemanaged electronic switchboard, fitted with communication card and modem, controlled both by the energy manager and the EMVS.

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Technology to be used

*Condensation boiler with vertical condensed collector.*

*Radial flame burner of low nitric oxides emission (NOx).*

*Telemangement and monitoring centre*
In measuring and thermal centre control, energy metres for heating, hot water and thermal solar energy are placed in the boiler room.
In measuring and dwelling control, for heating, mechanized two-way valves and energy metres are fitted in each dwelling, set with the environment thermostat usually installed in the living-room of the dwellings. For hot water, volumetric metres are set in each dwelling.
In accelerator pumps, twin pumps will be installed in the circuits in order to allow the system to continue working in case of damage, with variable speed in the heating circuit and in the recirculation circuits of the boilers.

Variable speed twin pumps
In radiators, these will be measured with a temperature differential of 40°C between the average temperature of the radiator and the environmental temperature of the room (input to radiators 68°C, back to boiler 56°C, with calculation outer temperature of -3.7°C, and inner design temperature of 22°C)

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\begin{align*}
68^\circ C + 56^\circ C - 22^\circ C & = 40^\circ C \\
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In insulation, thicknesses prescribed in current regulations will be increased by 10 mm; likewise all the valves will be insulated as well as pump bodies, bridles, energy metres and any other hydraulic element of the installation. It will be finished in 0.6 mm thick aluminum sheet.
In hot water, thermal solar panels are to cover at least 75% of the hot water production, along with pre-heating of cold water filling.

In heating, supporting this service with solar energy, even at night from the surplus energy of the hot water, that is, once the water heating necessities are covered, the accumulated energy will be diverted for heating production.
In electrical household appliances, thermal solar energy for water heating for conventional (not bi-thermal) **washing machines and dishwashers** through the fitting of mixing valves at their feeding point.

In security, a heat cooler element will exist in the thermal solar energy circuit, to prevent its temperature rising above 110ºC. Likewise, mixing valves will be installed at the hot water exit to prevent overheating of consumption water.

*Heat cooler element to prevent overheating on solar circuit*
Energy savings to be achieved and reduction of pollutant emissions

**Annual seasonal capacities** estimated for this programme, will be higher than the ones currently achieved in buildings developed by the E.M.V.S. that have been occupied for several years, in which this energy generation system has been installed.

This performance will be monitored and permanently measured in the installed energy metres, and will be more than 140%, so that the energy savings derived from the facilities’ energy efficiency, not counting the minimum building necessities that will be detailed in their appropriate description and energetic certification documents as prescribed in the new Technical Building Code, will be as pointed out on the following charts:
Comparative between the EMVS system and individual boiler system (with and without solar contribution)
Extrapolation of Programme Results to 10,000 Houses during 10 Working Years

The following chart represents energy and emission savings that should be achieved in 10,000 dwellings during 10 working years, comparing the system used by the EMVS to conventional facilities.

From the previous chart we can infer that, given that an average dwelling in Madrid disperses about 4Kwh of thermal energy in winter, with the achieved saving in 10,000 houses during 10 years with these systems, we could supply with heating to almost 48,000 dwellings all in one winter.
Energy Management

Optimized energy management, starts once the facilities are finished; the Energy Manager, which is usually the installation fitting company, will assume the responsibility of maintenance and exploitation of these facilities, 24 hours a day (24,7), 365 days a year, assuming to be in charge of:

Fuel needed, to feed heating and hot water to each dwelling, along with registrations and financial deposits with the distribution companies.
Cold water needed, for hot water consumption, as well as the water necessary for filling the circuits, and the supply of antifreeze for the thermal solar energy circuit.

Telemanagement, the telephone costs of the service.
Metre reading and invoicing, carried out monthly by the energy manager for each user of the housing development, individually, according to consumption.

The guarantee, through which the energy manager will repair or replace, at his cost, all the damaged or obsolete elements and units of the communal facility (boilers, burners, storage batteries, pumps, solar panels, pipes, etc.) during the life of the signed agreement.
Intelligent Building Control and Monitoring

For the achievement of an intelligent building control, as indicated before, control systems will be used, distributed with incorporated sensors, wireless connections, user interfaces and autonomous controllers.

These systems will be designed with standardized and open communication protocols, in order to increase unit durability, which means that in the event of technological evolution and/or material replacement they will be replaced individually, without having to forcefully change the whole unit or used software. These systems could be, according to the data obtained by the sensor, proportionally regulated or all-none regulated.
Sensors

On the application field of these integrated management systems, we can emphasize:

**Air quality sensors**, which will **measure quality conditions**, both of the **outer and inner air** of the dwellings, and which will renew building air according to established parameters on the installed software. These sensors will control and operate basically on the **air volume, temperature variations, relative humidity**, etc., and this way will be able to increase comfort and therefore, **life quality of the users**.
Luminosity sensors, that will control and operate on the lighting systems both communal and private, according to established parameters and obtained data from taken measurements. They will be able to send signals and modify from window blinds and curtains, to electronic ballasts of the installed lighting, thus modifying unused areas or improving the lighting in the currently used area and controlling glare.

Wind sensors, modifying openings for ventilation and window positioning, housing conditioning and air quality, thus improving the users’ comfort.
Rain sensors, operating over watering and/or windows.

Sensors in windows, operating over housing conditioning. (electrochromic windows)

Movement detectors, interacting with lighting, movement and conditioning.
Electrical signals with alarm control, so that in case of need or emergency, it is possible to operate automatically over electric, hydraulic and/or alarm circuits.

Different building monitoring will be permanently interacting and will be achieved through wireless networks, which will be designed to be controlled from a single checkpoint, either in situ or remote, by an energy manager or by the developer where appropriate.
Multiparameter metres, installed in the dwellings and/or communal areas, so that every user may know in real time his consumptions and may interact with his energetic spending, water, air, etc.
In order to achieve all the improvements on life quality, energy savings, and greenhouse gas emissions (mainly CO₂), it is necessary to obtain the participation of all the stakeholders: researchers, manufacturers, architects and engineers, suppliers... and most of all, the final users. We consider that creating awareness and promoting education with respect to these subjects are two basic tools to be used. The EMVS has been contributing for several years with its “The City in the Eyes of Youth” programme, along with the local Agenda 21, to the growing awareness of the need to reduce energy and water consumption. The EMVS also advises the users of its housing developments how to use their dwellings in the most efficient way.
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