Organisational conditions facilitating the emergence of mobbing.

APPLIED PSYCHOSOCIOLOGY

In the ‘90s the concept of mobbing (bullying) at work, understood as systematic exposure to negative acts (verbal abuse, offensive remarks, ridicule, slander, or social exclusion) from co-workers, supervisor, or subordinates, emerged as an important stressor key risk factor for employees and organizations.

This main aims of this study are threefold: firstly, to increase our understanding of the psychometric properties of the Val.Mob. Scale (Aiello, Deiting, Nardella, Bonafede, 2008), an Italian tool devoted to evaluate mobbing; secondly to pinpoint the presence of those organisational aspects foreshadowing the appearance of phenomena affecting workers’ health and thirdly to examine the exposure (presence or absence) to those actions perceived as mobbing in work environments.

The paper bears out the fact that the Val.Mob Scale is a reliable psychometric instrument predicting the mobbing phenomenon in organizations, also in the specific target context chosen, such as the strategic Healthcare sector.

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Introduction

The quality of the working environment has become an increasingly important aspect in people’s lives, since it has a considerable influence on their wellbeing and state of health.

Social relations developed within the working environment have a great influence on one’s self-image, sense of identity and group belonging. Feelings and emotions of all types (positive and negative) may arise among the members of any group or organisation, and a wide range of interpersonal factors can be related to those dynamics, such as social support or obstructionism (Favretto, 2005).

These feelings, if they remain within physiological limits, form part of the normal development of social relations, but if interpersonal relations deteriorate to a level where the environment starts to be perceived as hostile, then working life, as outlined by Dollard, Skinner, Tuckey and Bailey (2007), no longer has the role of helping social integration but becomes a risk factor for the workers’ wellbeing.

These psycho-social aspects, first brought to light in the ’70s
studies (Levi, 1971) show that social or physical isolation, interpersonal conflict and a lack of support may be a cause of stress leading to psychophysical disorders, just like other key factors causing stress: workload, work shifts, etc.

The seminal work by Cox and Griffiths (1995) proposed the concept of “psycho-social risks” defining it as those aspects relating to the planning, organisation and management of work and to the social and environmental context that have the potential to cause psychological or physical harm.

Referring to the study of complex worker-organisation relationships, Leyman (1996) highlighted the presence of a circular association between the phenomenon of work-related stress and mobbing (Italian translation for bullying), attributing to the latter a dual role: a consequence of organisational stress and a source of individual and social stress.

In the ’90s mobbing at work, i.e. systematic exposure to negative acts (verbal abuse, offensive remarks, ridicule, slander, or social exclusion) from co-workers, supervisor or subordinates (see: Einarsen, 2000), emerged as an important risk factor or stressor for many employees (Einarsen, Raknes, Matthiesen, 1994).

Mobbing and stress appear to be closely interrelated and mutually determined and influenced (Agervold, Mikkelsen, 2004). Other authors identified a logical and temporal continuity in which other organisational factors and processes, including states of conflict, are linked to the mobbing phenomenon (Zapf, Knorz, Kulla, 1996; Vartia, 2001).

The consequences of mobbing are many, and relate not only to the victim but to the whole organization. The organisation indeed may be affected by an increase, i.e., in absenteeism, greater staff turnover, drops in productivity and early retirement (Leymann, 1990; Einarsen, Raknes, 1997; Hoel, Salin, 2003). The Fourth European Survey of Working Conditions reports that 5% of European workers have been exposed to mobbing or harassment at work in the previous 12 months, whereas in Italy the figure was 2% (European Foundation, 2007).

Along similar lines, some recent studies have highlighted a significant association between mobbing and physical illness and injury (Bowling, Beehr, 2006), as well as decreased job satisfaction (De Pedro et al, 2008) and decreased organisational commitment (Hoel, Einarsen, Cooper, 2003).

A number of authors, moreover, have shown that a drop in self-esteem, sleeping disorders, anxiety, problems of concentration, chronic fatigue, anger, depression, DPTS and psychosomatic disorders are the possible psychophysical health consequences that may result from mobbing (Giorgi, 2008).

Finally, some studies focusing on the victims of mobbing show that certain personality factors might make people more prone to mobbing. Matthiesen and Einarsen (2001), through the MMPI2 personality inventory, identified a specific profile for “mobbed” victims: these persons appear to be hyper-sensitive, mistrusting and mostly depressed, with a tendency to convert psychological discomfort into a series of psychosomatic disorders.

These opinions are not fully recognized in the literature. Bjorkqvist et al. (1994) argued indeed that the empirical evidence gathered is not yet sufficient to draw up a typical victim profile.

On the whole, mobbing research can be broken down into three main areas of study: the first area emphasises the individual traits and personality traits of the aggressor -“mobber”- and the
“mobbed” victim (Randall, 1997; Matthiesen, Einarsen, 2001); the second area analyses worker-organisation interaction, and mutual influences (O'Leary-Kelly, Griffin and Glew, 1996); the third area, especially dealt with by Leymann (1992), outlines the organisational variables prior to the mobbing phenomenon, deeming these to be primary causes of mobbing rather than personality factors.

This paper has sought to take the latter line, focusing on organisational analysis in order to identify situations potentially "at risk of mobbing", focusing the analysis on a specific organisational sector like the Healthcare system. There is now well-established evidence that this work environment presents some crucial aspects related with the emerging of work-related stress pathologies (Rees, Cooper, 1992; Bennett et al., 2001; Escribà-Agüir, Pérez-Hoyos, 2007).

Objetivo

As previously mentioned, this study aims to ascertain the psychometric properties of the Val.Mob. Scale (Aiello, et al., 2008), an Italian tool used to evaluate mobbing, and indicate the presence of organisational aspects capable of predicting the phenomenon also in the public healthcare sector and, more generally, to examine exposure (presence or absence) to actions perceived as mobbing in the context examined.

Method and Procedure

Description of the Tool

The Val.Mob Scale is made up of three sections:

- a) Mobbing Scale, consisting of 48 items evaluated on a 7-point Likert scale, studying four factors: Relational, Intrusiveness/interference, Downgrading and Organizational commitment and affective/emotional climate.
- b) Symptom Scale, consisting of 23 items on a 5-point Likert scale, referring to main diagnosis categories in place in forensic medicine to investigate the mobbing phenomenon;
- c) Socio-Demographic data: consisting of 9 items for the recording of some personal and organisational characteristics (Gender, age, position at work, etc).

Participants

The tool was administered to all the employees of an Italian Hospital (N=1058). 51% of questionnaires were returned completed. This number, deemed valid for the survey, made up 45% of the total. The final amount of participants thus consisted of 474 subjects.

The age of respondents was between 20 and 64 years (average of 45), with a prevalence within the 41 - 50 (35.4%) and 31 - 40 (26.6%) age brackets.

Interviewees were largely women (63.9%), 32.7% were men. This could be attributed to a typical characteristic of the so-called help professions, in which women generally outnumber men. The level of education was average: 54.2% of the sample had studied up to secondary school level, while 32% of interviewees had a higher level of education (University Diploma and Degree). The most common profession was qualified nurse (48.1%) followed by managers (14.3%), auxiliaries (11.6%) and technicians (6.5%). Length of service was, on average, 10 years (sd = 9). There is a 36-hour working week in the sector. No data was obtained by part-time workers.
Results

For each sub-scale of the Mobbing Scale the item-total correlation and Cronbach’s alpha were used to determine internal consistency.

For the Relational dimension (no. items = 21) Cronbach’s alpha was 0.94; the average item-total correlation was 0.64; the average inter-correlation among items was 0.44. No item showed an item-total correlation below 0.30 (see Table 1).

Table 1 – Relational Scale: psychometric properties of items and item-total correlation.

<table>
<thead>
<tr>
<th>Ítem</th>
<th>Adjusted item-total correlation</th>
<th>Cronbach’s alpha if item is excluded</th>
</tr>
</thead>
<tbody>
<tr>
<td>m17</td>
<td>Impression of being rejected by gestures or unfriendly attitudes</td>
<td>0.777</td>
</tr>
<tr>
<td>m22</td>
<td>Hostile climate around me</td>
<td>0.768</td>
</tr>
<tr>
<td>m11</td>
<td>Pretexts sought to rebuke me</td>
<td>0.735</td>
</tr>
<tr>
<td>m16</td>
<td>Impression that I am being boycotted</td>
<td>0.728</td>
</tr>
<tr>
<td>m40</td>
<td>Impression of being a &quot;scapegoat&quot;</td>
<td>0.726</td>
</tr>
<tr>
<td>m42</td>
<td>Impression that others are looking at me</td>
<td>0.725</td>
</tr>
<tr>
<td>m12</td>
<td>Hostile relationship with co-workers</td>
<td>0.705</td>
</tr>
<tr>
<td>m33</td>
<td>Impression there are rumours about me</td>
<td>0.702</td>
</tr>
<tr>
<td>m35</td>
<td>Impression of being the target of disrespectful behaviour</td>
<td>0.691</td>
</tr>
<tr>
<td>m19</td>
<td>Impression of being the target of humiliating remarks</td>
<td>0.685</td>
</tr>
<tr>
<td>m7</td>
<td>Impression that others behave as if I don't exist</td>
<td>0.677</td>
</tr>
<tr>
<td>m10</td>
<td>Impression that others speak behind my back</td>
<td>0.665</td>
</tr>
<tr>
<td>m27</td>
<td>Impression of being monitored by my co-workers</td>
<td>0.650</td>
</tr>
<tr>
<td>m45</td>
<td>- Impression that no one listens to me</td>
<td>0.611</td>
</tr>
<tr>
<td>m6</td>
<td>- Exclusion from informal gatherings</td>
<td>0.609</td>
</tr>
</tbody>
</table>
Cronbach's alpha 0.942, Average item-total correlation 0.645, Average inter-correlation among items 0.442.

The Intrusiveness/Interferencedimension (no. items = 10) had a Cronbach's alpha of 0.87; the average item-total correlation was 0.61; the average inter-correlation among items was 0.43 (Tab. 2). No item showed an item-total correlation below 0.30.

**Table 2 – Intrusiveness/interference Scale: psychometric properties of items and item-total correlation.**

<table>
<thead>
<tr>
<th>Ítem</th>
<th>Adjusted item-total correlation</th>
<th>Cronbach's alpha if item is excluded</th>
</tr>
</thead>
<tbody>
<tr>
<td>m8 Impression that aggressive tones are used against me</td>
<td>0.580</td>
<td>0.940</td>
</tr>
<tr>
<td>m43 Solitude during breaks</td>
<td>0.557</td>
<td>0.940</td>
</tr>
<tr>
<td>m18 Received written threats</td>
<td>0.554</td>
<td>0.940</td>
</tr>
<tr>
<td>m23  I am too anxious about the work to be done</td>
<td>0.483</td>
<td>0.942</td>
</tr>
<tr>
<td>m46r Good relationship with co-workers (recodified)</td>
<td>0.476</td>
<td>0.941</td>
</tr>
<tr>
<td>m37r Happy with relationship with co-workers (recodified)</td>
<td>0.439</td>
<td>0.942</td>
</tr>
</tbody>
</table>

Cronbach's alpha 0.872, Average item-total correlation 0.612, Average inter-correlation among items 0.442.

Cronbach's alpha 0.942, Average item-total correlation 0.645, Average inter-correlation among items 0.442.
Average inter-correlation among items 0.435.

The Downgrading dimension (no. items = 10) had a Cronbach’s alpha of 0.85; the average item-total correlation was 0.55; the average inter-correlation among items was 0.36. No item showed an item-total correlation below 0.30. (Table 3).

<table>
<thead>
<tr>
<th>Item</th>
<th>Adjusted item-total correlation</th>
<th>Cronbach’s alpha if item is excluded</th>
</tr>
</thead>
<tbody>
<tr>
<td>m1</td>
<td>Assigned to tasks below level of competence</td>
<td>0.565</td>
</tr>
<tr>
<td>m2</td>
<td>Lack of information essential for performing the work</td>
<td>0.510</td>
</tr>
<tr>
<td>m3</td>
<td>Removal of essential work instruments without warning</td>
<td>0.508</td>
</tr>
<tr>
<td>m13</td>
<td>Assigned job duties which are not within my competence</td>
<td>0.571</td>
</tr>
<tr>
<td>m15</td>
<td>Assigned to job duties below the level of those for which I was hired</td>
<td>0.581</td>
</tr>
<tr>
<td>m25</td>
<td>I am asked to perform meaningless tasks</td>
<td>0.576</td>
</tr>
<tr>
<td>m32</td>
<td>I am excluded from meetings and official gatherings</td>
<td>0.492</td>
</tr>
<tr>
<td>m38</td>
<td>Management has prevented my career advancement</td>
<td>0.475</td>
</tr>
<tr>
<td>m39</td>
<td>Assigned to deskilled tasks</td>
<td>0.686</td>
</tr>
<tr>
<td>m47</td>
<td>Impression that my career is deliberately ampere by management</td>
<td>0.485</td>
</tr>
</tbody>
</table>

Cronbach’s alpha 0.846, Average item-total correlation 0.545, Average inter-correlation among items 0.356

Finally, the dimension Organizational commitment and affective/emotional climate (no. items = 7) had a Cronbach’s alpha of 0.79; the average item-total correlation was 0.52, and the average inter-correlation among items was 0.35 (Table 4). No item showed an item-total correlation below 0.30.

<table>
<thead>
<tr>
<th>Item</th>
<th>Adjusted item-total correlation</th>
<th>Cronbach’s alpha if item is excluded</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3 – Downgrading Scale: psychometric properties of items and item-total correlation.

Table 4 – Organizational commitment and affective/emotional climate Scale: psychometric properties of items and item-total correlation.
An exploratory factor analysis was also conducted on the 4 dimensions of the Val.Mob Scale. Firstly, a factor analysis was undertaken using the principal axis method with oblique rotation. The results of this analysis highlighted two dimensions with little inter-correlation. In light of these results, the analysis was repeated with the orthogonal rotation of factors.

This second analysis confirmed the presence of two factors which, taken together, account for 57% of the initial variability. The first factor consists of the dimensions Relational, Downgrading and Intrusiveness/interference. The second factor is the dimension Organizational commitment and affective/emotional climate (Table 5).

The results of the factor analysis enable us to assume that the Organizational commitment and affective/emotional climate dimension is in all likelihood an aspect not closely associated with the perception of mobbing.

Table 5 – Rotated matrix of factor loading.

<table>
<thead>
<tr>
<th></th>
<th>Factor 1</th>
<th>Factor 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relations</td>
<td>0.952</td>
<td>0.102</td>
</tr>
<tr>
<td>Intrusiveness/interference</td>
<td>0.838</td>
<td>0.014</td>
</tr>
<tr>
<td>Downgrading</td>
<td>0.695</td>
<td>-0.234</td>
</tr>
<tr>
<td>Organizational commitment and affective/emotional climate</td>
<td>-0.010</td>
<td>0.337</td>
</tr>
</tbody>
</table>

Los resultados del análisis factorial nos permiten considerar que la dimensión compromiso organizativo y clima afectivo/emocional es con toda probabilidad un aspecto escasamente relacionado con la percepción de mobbing.

The stability of the factor structure was also studied using a cross-validation. Firstly, the factor analysis was repeated separately on men and women. Subsequently, the original
sample was randomly split into two and, in this case too, the factor analysis was repeated separately for the two halves. To establish the invariance of the factor structure the Tucker Phi index was also calculated.

Table 6 shows factor loadings for men and women. In the men's group the variance percentage obtained for the two dimensions was about 62%, while in the women's group it fell to about 52%. Tucker's Phi coefficient was 0.998 for the first factor and 0.882 for the second.

<table>
<thead>
<tr>
<th>Table 6. – Rotated Matrix of Factor loading for Men and Women.</th>
</tr>
</thead>
<tbody>
<tr>
<td>(H = 154) (M = 303)</td>
</tr>
<tr>
<td>Factor 1</td>
</tr>
<tr>
<td>Relations</td>
</tr>
<tr>
<td>0.975</td>
</tr>
<tr>
<td>Intrusiveness/interference</td>
</tr>
<tr>
<td>0.881</td>
</tr>
<tr>
<td>Downgrading</td>
</tr>
<tr>
<td>0.769</td>
</tr>
<tr>
<td>Organizational commitment and affective/emotional climate</td>
</tr>
<tr>
<td>-0.014</td>
</tr>
</tbody>
</table>

Table 7 illustrates results for the two halves of the samples. For both the first and second halves the variance percentage recorded for the factor solution was about 57%. Tucker's Phi coefficient was 0.997 for the first factor and -0.684 for the second. As the table shows, in the second half of the sample the Downgrading sub-scale had a significant saturation for the second factor too.

<table>
<thead>
<tr>
<th>Table 7. – Rotated matrix of factor loading for the two halves of the sample.</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1st half = 238) (2nd half = 235)</td>
</tr>
<tr>
<td>Factor 1</td>
</tr>
<tr>
<td>Relations</td>
</tr>
<tr>
<td>0.941</td>
</tr>
<tr>
<td>Intrusiveness/interference</td>
</tr>
<tr>
<td>0.829</td>
</tr>
<tr>
<td>Downgrading</td>
</tr>
<tr>
<td>0.736</td>
</tr>
<tr>
<td>Organizational commitment and affective/emotional climate</td>
</tr>
<tr>
<td>0.020</td>
</tr>
</tbody>
</table>

Following Tucker's indications, Phi values of below 0.95 indicate that the factor structure is not invariant. Accordingly, as the two cross-classification analyses show, the second dimension, relating to the Organizational commitment and affective/emotional climate dimension, did not appear to be invariant among the groups. In the factor solution calculated for the initial sample and in the cross-validation analyses this dimension showed a saturation a little above the necessary minimum of 0.30.

The results of these analyses confirm the satisfactory internal consistency of the sub-scales of the Val.Mob Scale, especially for
the dimensions Relations, Intrusiveness/interference and Downgrading. The Organizational commitment and affective/emotional climate dimension presented an alpha value below the others, but was generally acceptable.

The factor structure of the Val.Mob Scale appears to consist of two independent dimensions: the first, consisting of the one dimension Organizational commitment and affective/emotional climate, the second consisting of the other three dimensions. It would appear, therefore, that the perception of the mobbing phenomenon is identified more by these dimensions than by the Organizational commitment and affective/emotional climate dimension. Cross-classification analyses backed up the stability of the factor formed by the sub-scales Relations, Intrusiveness/interference and Downgrading, while the sub-scale Organizational commitment and affective/emotional climate appeared to be somewhat problematical.

With reference to company situations at risk of mobbing, to correctly interpret the company profile it should be stressed that this phenomenon can have varying degrees of intensity (low, quite low, quite high, high).

Scores are considered "high" if they are in the upper quartile of the distribution curve, "quite high" if they are in the third quartile, "quite low" in the second and "low" in the lower quartile (see Table 8).

**Table 8 - Val.Mob. Scores.**

<table>
<thead>
<tr>
<th>Mobbing</th>
<th>Low (L)</th>
<th>Quite low (QL)</th>
<th>Quite high (QH)</th>
<th>High (H)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relations</td>
<td>≤ 27</td>
<td>28-71</td>
<td>72-120</td>
<td>≥ 121</td>
</tr>
<tr>
<td>Intrusiveness/interference</td>
<td>≤ 10</td>
<td>11-12</td>
<td>13-26</td>
<td>≥ 27</td>
</tr>
<tr>
<td>Downgrading</td>
<td>≤ 20</td>
<td>21-42</td>
<td>43-57</td>
<td>≥ 58</td>
</tr>
</tbody>
</table>

The results confirm Interpersonal relations as being positive (see Figure 1), even though 12.8% of respondents complained about relational difficulties (10% had the impression of people talking behind their backs; 11% felt anxiety while travelling to work; 11.8% felt they were being controlled by colleagues; 11.4% felt they were not being listened to).

![Figure 1](image.png)

**Figure 1.** Graphical representation of "Relational aspects"

With reference to Intrusiveness/interference (see Figure 2), 44.5% of interviewees scored Quite High values and 12.4% High values, especially with reference to the feeling that their privacy was being violated.
In the Downgrading (see Figure 3) 1.5% posted a “High” score, and 11.2% Quite High, with special reference to: (e.g.) item 13 – I often find myself doing tasks outside my area of competence (27%); item 1 – I am often assigned tasks beneath my job level (13.7%); item 15 – I often find myself doing tasks below the level I was hired for (13.3%); Item 3 – Sometimes they have taken away the tools needed to do my job without telling me (11.8%); item 39 – I am often forced to downgrading tasks (8.9%).

Concluding remarks

This work has shown that the Val.Mob Scale is a reliable psychometric tool for predicting the mobbing phenomenon in organizations, and more specifically in a specific organizational context such as healthcare.

Results have indeed shown that among company staff there is a large group with a high perception of Intrusiveness/interference (56.9%), while a small group (12.7%) highlights the lack of recognition and appreciation for work performed. These conditions facilitate mobbing processes, and emphasize the fundamental role of organisational levels in this process. Further confirmation of this relationship comes from the presence of official complaints about mobbing presented by some employees in the period following the survey.

The Val.Mob Scale, furthermore, has been included in the Protocol for the appraisal of the mobbing phenomenon proposed by the “Italian National Network for the Prevention of Psychosocial Distress in the Workplace” promoted and organised by ISPESL, with the participation of public centres belonging to Italy’s National Health Service.

The scale has also been translated and validated for the Spanish-speaking countries, and is at the present day used by the Faculty.
of Psychology of the University of Buenos Aires, which has started up a specific "Mobbing programme", developed by the 1st Postgraduate Work Psychology Course. The scale is currently being cross validated to deepen its psychometric characteristics and offer a reliable measure of the mobbing phenomenon in the organisational context.

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Entrepreneurial interaction, health and safety and temporary employment agencies

LEGISLATION

This article, dealing with entrepreneurial liaison and interaction in occupational health and safety matters, is a continuation of the paper published in an earlier review. It analyses in detail the legal system pertaining to a special group of workers, i.e. those with a temporary employment relationship assigned to the workplace firm by a temporary employment agency. We will look at the EU legislation regulating the situation of this group of temporary workers and see how this has been transposed into Spain’s body of law, ascertaining which obligations are incumbent on the companies and in particular the temporary employment agencies, in terms of safeguarding the health and safety of these temporary workers.

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Article 28 of the Spanish Occupational Risks Prevention Act (Ley de Prevención de Riesgos Laborales: LPRL) deals in an individualised way with the risk prevention aspects of a given group of workers, i.e., temporary workers. It makes a distinction between, on the one hand, the direct hiring of temporary workers by the workplace firm, through a temporary work contract under one of the arrangements laid down in labour legislation, and, on the other, the indirect hiring of workers through temporary employment agencies. In other words it lays down one system for directly hired temporary workers and a different one for temporary workers hired through a temporary employment agency. These should not, however, be construed as two totally different and hermetic systems, for the same two principles underlie them both: firstly, ensuring that temporary workers are given the same level of health-and-safety protection as permanent staff and, secondly, ruling out any discrimination of temporary workers in comparison to permanent staff as far as their health-and-safety-at-work rights are concerned.

Furthermore, in the case of workers placed at the workplace firm’s disposal by a temporary employment agency another factor comes into play. It should be borne in mind here that the hiring of workers indirectly through temporary employment agencies involves two contracts, one between a worker and the temporary employment agency and the other between the temporary employment agency and the workplace or user firm, whereby the former places this worker at the disposal of the latter. This three-part arrangement calls for clarification of the set of health-and-safety-at-work obligations incumbent on the temporary employment agency and the user company to ensure...
that prevention procedures are efficiently applied.

It is worth pointing out here that the decision of where in the Act to deal with the legal health-and-safety situation of workers assigned by a temporary employment agency has been called into question by jurists. It has been claimed that this matter would have been better dealt with in article 24 LPRL, which deals with the liaison duties between different employers responsible for the occupational safety of the same workers. Nonetheless, without wishing to question the validity of this claim, this author believes that the liaison arrangements laid down in article 24 LPRL do not really make it clear whether they refer to the concurrence of employers or the concurrence of workers from different firms, so it is by no means a mistake to deal with the different temporary employment arrangements together in the same part of the Act. For legislation purposes the temporality of the employment relationship has tended to override the concurrence of workers and/or employers and the concomitant liaison duty, a task dealt with not only in article 28.5 LPRL but also the development regulations, passed into law in Royal Decree 216/1999.

The EU Framework

There is absolutely no doubt that effective preventive action with respect to temporary workers stood in need of specific health-and-safety-at-work legislation. Before being passed into Spain’s body of law, this need was recognised and laid down in Community law with the passing of Council Directive 89/391/EEC of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work, and also in Council Directive 91/383/EEC of 25 June 1991 supplementing the measures to encourage improvements in the safety and health at work of workers with a fixed-duration employment relationship or a temporary employment relationship. These directives have been partially transposed into Spanish law in article 28 of the LPRL and in the regulations developing same, specifically Royal Decree (Real Decreto) 216/1999.


First and foremost it lays down the principle that temporary workers are entitled to the same level of protection as other employees working on an indefinite term contract, and then also enshrines the concomitant principle that the length of the employment relationship can never be held up as justification of any difference in the treatment of permanent and temporary workers in health-and-safety matters. Article 2.1., therefore, lays it down that temporary workers shall be guaranteed the same level of protection as that of other workers in the user undertaking and/or establishment, without it being possible to invoke the existence of a temporary employment relationship as grounds for different treatment with respect to working conditions inasmuch as the protection of safety and health at work are involved, especially as regards access to personal protection equipment (article 2.2).

It then lays down a series of information-giving obligations. Article 3.1. establishes the obligation of the user undertaking and/or establishment, before going ahead with any activity, to inform temporary workers of the risks they will be exposed to therein. In article 3.2 it then specifies that this information shall cover, in particular, any special occupational qualifications or skills or special medical surveillance required, as defined in
national legislation. Article 7.1 then lays it down that the user undertaking is bound, again before any work goes ahead, to inform the temporary employment agency of the occupational qualifications required for the job and the specific features thereof. It leaves it up to each member state to decide whether the information to be given by the user undertaking to the temporary employment agency should be recorded in a contract. Article 7.2 establishes the obligation of the temporary employment agency to bring all these facts to the notice of the workers concerned.

Thirdly, as regards training, the directive is fairly terse and woolly, article 4 laying it down that Member States shall take the necessary measures to ensure that temporary workers receive sufficient training appropriate to the particular characteristics of the job, due account being taken of their qualifications and experience.

Fourthly, article 5.1 of the Directive entitles member states to prohibit the hiring of temporary workers for carrying out work deemed to be dangerous to their safety or health, leaving it up to the national body of law to define what should be understood by "dangerous to their safety or health". Article 5.2 goes on to say that if this prohibition possibility is not taken up, then the necessary measures shall be taken to ensure that temporary workers who are used for work which requires special medical surveillance, as defined in national legislation, are provided with appropriate special medical surveillance. Article 5.3 leaves it open to Member States to provide that this appropriate special medical surveillance shall extend beyond the end of the employment relationship of the worker concerned.

Fifthly, article 6 obliges Member States to take the necessary measures to ensure that prevention services or the persons fulfilling this remit are informed of the direct employment or indirect assignment of temporary workers, to the extent necessary for the designated workers, services or persons to be able to carry out adequately their protection and prevention activities for all the workers in the undertaking and/or establishment.

Sixthly, article 8 refers to the responsibility incumbent on temporary employment agencies, declaring that, without prejudice to the responsibility of the temporary employment agency as laid down in national legislation, the user undertaking and/or establishment is/are responsible for the conditions governing performance of the work. These conditions governing the performance of the work shall be limited to those connected with safety, hygiene and health at work.

Finally article 9 of Directive 91/383/EEC lays it down that the Directive shall be construed without prejudice to any existing or future national or Community provisions that are more favourable to the safety and health protection of workers with a temporary employment relationship, whereby the Directive cannot have derogatory effects with respect to any national legislations that may have or adopt a greater number of guarantees, obligations and rights in relation to the health-and-safety rights of temporary workers.

**Transposition of the Community Directives:**
article 28 LPRL and the principle of equal protection rights and non discriminatory treatment

Spain’s national law has transposed Directive 91/383/EEC into article 28 of the LPRL. Section 1 of this article establishes the temporary workers’ entitlement to the same level of protection in terms of health-and-safety-at-work as the workers on indefinite term contracts and rules out any possibility of the temporary nature of their working relationship being used as grounds to justify a different treatment.

To this end it lays down the principle that workers on a fixed term or temporary employment contract or those made available by a temporary employment agency shall enjoy the same level of protection in health-and-safety matters as the other workers in the workplace firm. Furthermore, under no circumstances may a direct or indirect (through a temporary employment agency) temporary employment arrangement be held to justify different treatment in terms of any aspect of their working conditions or health-and-safety-at-work implications.

The enshrinement of these principles of same entitlement and same treatment in terms of the prevention of occupational risks of temporary workers under Spanish law is substantially the same as the corresponding principles of equality and non-discriminatory treatment laid down in the Directive. Having said that, it is worthy of note that the national legislation omits the specific reference made in the Directive to the temporary worker’s equal right to personal protection equipment. In my opinion this omission has no practical importance, insofar as access to personal protection equipment should be construed as included within the general formulation of non discrimination laid down in article 28.1 LPRL, insofar as this precept refers to working conditions.

The establishment of the principles of same entitlement and equal treatment has been dismissed as superfluous by some labour law theorists, on the grounds that article 17 of the Statute of Workers’ Rights (Estatuto de los Trabajadores: ET) lays down the general and across-the-board principle of non discrimination in labour relations. It should be remembered here that article 17.1 of the ET lays it down that «any legislation, clauses of collective bargaining agreements, individual agreements and unilateral decisions by the employer that contain discriminatory stipulations directly or indirectly unfavourable by reason of age or incapacity as the favourable or adverse in terms of employment conditions, remuneration, working hours and other working conditions, on the grounds of sex, origin (including racial or ethnic origin), marital status, social condition, religion or creed, political ideas, sexual orientation, membership or not of trade unions and their agreements, kinship with other company workers and language other than Spanish shall be deemed null and void». Quite on the contrary, therefore, the establishment of both principles in the field of the occupational health and safety of temporary workers strikes me personally as essential rather than reiterative. If we look at article 17 ET, we see that discrimination against temporary workers in the prevention of occupational risks cannot be neatly slotted into any of the examples of prohibited discrimination, i.e. age, invalidity, sex, origin, marital status, social condition, religion or creed, political ideas, sexual orientation, membership or not of trade unions, kinship and language other than Spanish, even though it may be invoked as an example of indirect discrimination when any of the examples of prohibited discrimination obtain in the group of temporary workers. This prompts me to side with another sector of labour law theorists who believe on the contrary that the principles of same entitlement and same treatment of temporary workers comes out reinforced and secured by virtue of the legal
The LPRL lays down the principle that temporary workers are entitled to the same health-and-safety-at-work protection as the permanent staff.

That said, the enshrinement of the principles of same entitlement and same treatment should rightfully be construed as a minimum level of protection of temporary workers, without this meaning that they forfeit their right to even more favourable treatment than permanent staff, either by means of collective bargaining, agreement with the employer or even unilateral decision of the latter. This more favourable treatment would be justified by the proven statistics showing that temporary workers record a higher accident rate than permanent staff. Any criticism of the Spanish legislation on the grounds that it went no further than establishing the same entitlement would not really hold water, however, for establishment of the legal principle of more favourable treatment for temporary workers may have hemmed in their rights and even had counterproductive effects if employers should obviate this more favourable treatment by sheer inertia. It would therefore seem more proper to leave it up to collective bargaining in its different forms to establish this more favourable framework in light of the sector or activity involved.

To clear up any lingering doubt, the last paragraph of article 28.1 LPRL reminds us that the entire health-and-safety-at-work legislation, i.e. the LPRL and its development regulations, will apply fully to temporary work relations. This is just a memory jogger, for article 3 LPRL, establishing the scope of application, refers in general to the labour relations regulated in the ET, which include direct temporary employment relations and the indirect temporary employment relationships through temporary employment agencies.

Health-and-safety-at-work duties of employers (information-giving, training and surveillance)

Like the Community Directive Spanish law lays down some information-giving duties. Firstly, article 28.2 of the LPRL stipulates that the employer shall take the necessary measures to ensure that the workers referred to in the previous section receive information on the risks they are going to be exposed to, especially in terms of the need for particular qualifications or skills, the requirement of special medical surveillance or the existence of specific risks in the job to be performed, as well as the prevention and protection measures against those risks. This information shall be passed on before the temporary workers go ahead with their tasks. Spain’s legislation adds nothing to the Directive here.

Article 28.4 of the LPRL places another important information-giving obligation on the employer. Whenever the firm takes on new temporary workers the employer is bound to communicate this to the workers with designated responsibilities for protection and prevention or, as the case may be, the prevention service in any of the inhousing or outsourcing arrangements provided for in article 31 LPRL, to ensure that the aforementioned prevention workers can carry out their duties properly with regard to the company’s whole staff.

If we look at both these information-giving duties we will see that they are directed at the employer, whose identification poses no problem whatsoever in cases of direct temporary hiring, i.e., the hiring arrangements made by whoever acts as employer through...
any of the temporary hiring arrangements allowed for in the ET. The problem in identifying the subject of these obligations does arise, however in the case of temporary labour hiring arrangements through temporary employment agencies, where the direct employer of the worker involved is not the person for whom said worker will work nor the provider of the workplace. Rather will it be the workplace employer for whom the temporary worker will actually work. A simple perusal of the information that needs to be passed on suggests that the obligation to do so is incumbent on the workplace employer rather than the temporary employment agency, above all because the information deals with aspects that only the workplace employer can know. This is the solution, moreover, adopted by article 28.5 of the LPRL, expressly attributing both information-giving obligations to the user or workplace firm.

Paragraph two of article 28.2 of the LPRL establishes the employer’s duty of training the temporary worker. This training has to be sufficient for the particular characteristics of the job in question, taking due account of the worker’s qualification and career experience and the risks he or she is to be exposed to. Spain’s national law goes further than the training obligation laid down in Directive 91/383/EEC, since the latter makes no reference to training on the risks of the job. This therefore represents a fleshing out of the information-giving obligation. Labour law theorists have indicated that the training, as well as sufficient, can and must be specific to the particular group of temporary workers existing in the companies.

The general legal stipulations on the training obligation does not specify exactly who this duty falls on. In the case of direct temporary hiring there is no doubt that this duty falls on the employer. In the case of indirect temporary hiring through temporary employment agencies, however, as we will see later, the training duty falls on the temporary employment agencies, never on the user firm, which is nonetheless bound to ensure that the latter is able to fulfil its training obligation in due form and time with the worker who is going to be made available to the user firm. In terms of the training on the job risks, for example, the user firm is bound to inform the temporary employment agency with sufficient notice of the risks actually posed by the job in question.

Little hard information is given on the training obligation in regard to temporary workers. Missing information includes the timing, who is to give the training, etc. We therefore have to fall back on the general provisions laid down in article 19 of the LPRL, meaning that the training can be either theoretical or practical depending, as I see it, on the job vacancy to be temporarily filled.

Furthermore, the training has to keep apace with changes in the risks as they crop up over time and there must also be regular top-ups as necessary to ensure efficient preventive action as regards the temporary worker (article 19.2 LPRL).

As regards the timing, the training has to be given at three moments: when the hiring arrangement is made, whenever there are any changes in the temporary worker’s duties or when any new technology is introduced or there are any changes in the working equipment (article 19.2 LPRL). Another interesting aspect is the decision on whether or not the training is to be given inside or outside the working hours. The act lays it down that it should be carried out whenever possible within working hours, and whenever this is not possible the worker should be given time off in lieu (art. 19.3 LPRL).
The Act is flexible in terms of who gives the training, laying it down that it might equally be given by inhouse methods or duly qualified outside services brought in for that purpose (article 19.3 LPRL). It establishes no criteria whatsoever for prioritising these two options. It is therefore up to the employer to decide freely between these two options allowed by the LPRL.

Finally it should be pointed out that this training obligation falls exclusively on the employer. None of the health-and-safety-at-work training costs may therefore be passed on to the worker, either in part or full.

The last general prevention obligation laid down vis-à-vis temporary workers has to do with their healthcare, employers being bound to make sure that the work does not impair their health in any way. Article 28.3 of the LPRL stipulates tersely that temporary workers are entitled to periodic health checks, without stipulating the scope of this obligation, referring back to the general health surveillance obligations laid down for all workers, permanent or temporary, in article 22 LPRL.

As regards health surveillance national legislation has not taken up all the possibilities allowed in the Directive, in general ignoring the prohibition of hiring temporary workers for certain especially dangerous jobs. Nonetheless, as we will see later, Spain’s legislation does debar workers hired through temporary employment agencies from carrying out a series of activities, albeit in the development regulation passed in Royal Decree 216/1999.

The health surveillance of temporary workers, as with the rest of the workers, will be carried out by suitably skilled, trained and accredited healthcare personnel (article 22.6 LPRL); it has to be periodical, normally yearly, and has to bear due relation to the risks inherent to the particular job in question (article 22.1 LPRL). The checks therefore have to be carried out from the principle of causing the least possible nuisance to the worker, and kept in due proportion to the risk involved. In many of the temporary hiring arrangements the duration will be no longer than one year, meaning that after the induction training there will be no time for any more periodical checks.

Health surveillance is obligatory for the employer, so he or she is bound to watch out for the health of the temporary workers, but it is voluntary for the workers, needing their consent to go ahead. That said, the checks do become obligatory for the workers when so stipulated in a legal provision pertaining to protection against specific risks and especially dangerous activities and when such checks are essential for ascertaining the effects of the working conditions on the workers’ health or verifying whether the state of the worker’s health might endanger the worker him/herself or the other workers or other persons related to the firm. Establishment of the obligatory nature of the temporary workers’ health checks by the employer calls for a prior report from the workers’ elected representatives. This report, a sine qua non of the whole procedure, will be made through the delegados de prevención (worker representatives delegated with risk prevention responsibilities) or, in default thereof, through the legal representation or trade union representation. In my opinion this is not binding.
The vetting and surveillance of the workers’ health has to respect their right to privacy and the personal dignity of the temporary worker, safeguarding the confidentiality of all health-related information obtained from the various tests carried out (article 22.2 of the LPRL). The confidentiality of the information means, on the one hand, that it will be communicated only to the temporary workers concerned (article 22.3 LPRL) and, on the other, that only medical personnel and the health authorities vetting the workers’ health will be entitled to access this information. The information may not be passed on to the employer or other persons without the express consent of the worker concerned (article 22.4 of the LPRL). Nonetheless, the employer and the persons or organisations with prevention responsibilities will be duly informed of the conclusions drawn from the medical checks in terms of the worker’s aptness for the job or the need to bring in or improve the protection and prevention measures, to ensure they can properly fulfil their preventive duties. But in no case may the information obtained be used for discriminatory or harmful purposes against the worker (article 22.4 of the LPRL).

Taking up the option given in article 5 of Directive 91/383/EEC, the Act lays it down that, where warranted by the nature of the inherent job risks, the workers’ right to periodic health checks shall extend beyond the end of their employment relationship, in such terms as may be laid down by regulations (article 22.5 LPRL). At the time of writing no such regulations have been forthcoming. This does not mean that extension of the health surveillance may not be required, since these regulations would only dictate how this post-contractual health surveillance would be carried out and the option itself depends solely on the nature of the job risks.

**Health-and-safety-at-work and temporary employment agencies**

1. Within the group of temporary workers, special mention must to the protection of the health-and-safety of workers hired under the legally permitted arrangement of workers assigned temporarily from temporary employment agencies. This arrangement involves a three-way relationship in which the temporary employment agency formalises an employment contract with a worker who is then assigned to a user firm under a contract for the provision of temporary workers formalised between the user firm and the temporary employment agency. The presence of two different employers makes it necessary to ring-fence the health-and-safety-at-work obligations to be taken on by each one (Montoya Melgar).

Article 28.5 of the LPRL spells out the legal health-and-safety-at-work responsibilities of the two employers, the workplace or user firm and the temporary employment agency. These responsibilities are further fleshed out by the provisions laid down in the Temporary Employment Agency Act (LETT in Spanish initials) 14/1994 of 1 June and Royal Decree 4/1995 of 13 January, developing the former law, as well as Royal Decree 216/1999.

What transpires from the above legislation is a fragmented legal framework establishing an obligation-based system with no shared responsibilities. Each of the two employers, the user firm and the temporary employment agency, is assigned a series of obligations, although, as legal theorists have pointed out, the duties imposed on the temporary employment agency are less onerous than those placed on the user firm. This is because it is the later that wields effective control over the working conditions and environment (Montoya Melgar). Another idiosyncrasy of this obligation framework is a breaking of the general rule whereby
the hiring employer is usually given responsibility for health-and-safety-at-work matters. In this case, however, article 28.5 of the LPRL and article 16.2 of LETT place this responsibility fairly and squarely on the user firm, which does not directly hire the worker, laying it down that the user firm will take on responsibility for the work performance conditions in all matters related to the protection of the health and safety of the workers assigned from temporary employment agencies.

2. We have already pointed out that Spain’s national law did not in general take up the option given in article 5 of Directive 91/383/EEC to prohibit temporary workers from carrying out certain jobs or activities that could be classified as dangerous. This prohibition possibility has been taken up, however, in terms of hiring through temporary employment agencies. Article 8 b) of the LETT prohibits the formalisation of contracts for the provision of temporary workers when the work to be carried out is especially dangerous for the health and safety of the worker to be temporarily assigned from the temporary employment agency under said contract.

Royal Decree 216/1999 prohibits the hiring of temporary workers through temporary employment agencies for a set of especially dangerous jobs or activities, grouped under nine headings

The LETT itself does not determine or qualify what is an especially dangerous activity or job for the purposes of excluding the possibility of temporary hiring through a temporary employment agency, leaving it up to development regulations to round out this concept. This has been duly done in article 8 of Royal Decree 216/1999, whereby the especially dangerous activities or jobs are deemed to be the following:

- **a.** Construction site work referred to in Annex II of Royal Decree 1627/1997 of 24 October, laying down minimum health-and-safety-at-work provisions on construction sites. This annex gives the following non-exhaustive list of jobs implying special risks for the health and safety of workers: 1) jobs involving especially grave risks of underground entrapment, subsidence or fall from height, due to the particular features of the activity carried out, the procedures applied or the job environment; 2) work in which exposure to chemical or biological agents implies an especially grave risk, or for which specific surveillance of the workers’ health is binding by law; 3) work involving exposure to ionising radiation for which the specific legislation lays down the necessity of marking off controlled or keep-out areas; 4) jobs in the vicinity of high voltage transmission power lines; 5) jobs involving risk of drowning; 6) tunnel excavation, well-digging and other work involving underground earth movements; 7) underwater work with underwater diving equipment; 8) work carried out with compressed air caissons; 9) work involving the use of explosives; and 10) work involving the assembly or disassembling of heavy duty prefabricated elements.

- **b.** Open-cast mining work and enclosed mining work involving any of the following activities: underground or surface ore extraction, including by dredging; prospecting work with such extraction in mind; preparation for sale of the extracted material, excluding the activities of processing said substances; drilling or excavation of underground tunnels or galleries, whatever their purpose may be, without prejudice to the legislation laying down the
minimum health and safety conditions in construction work (article 2 of Royal Decree 1389/1997 of 5 September approving the minimum provisions for protecting the health and safety of mining workers).

- **c.** Work involving the extraction of core samples on land and sea, such as test holes, soil pits, trial pits, reconnoitres of old mine workings or other prospecting work laid down in article 109 of the General Regulation on Basic Mining Safety Rules (*Reglamento General de Normas Básicas de Seguridad Minera*).

- **d.** Work on oil rigs.

- **e.** Work directly involved with the manufacture, handling and use of explosives included in fireworks or other objects or instruments containing explosives, regulated by the Explosives Regulation (*Reglamento de Explosivos*), approved by Royal Decree 230/1998 of 16 February.

- **f.** Work involving exposure to ionising radiation in keep-out areas, according to Royal Decree 53/1992 of 24 January on health protection against ionising radiation.

- **g.** Work involving exposure to carcinogenic, mutagenic or toxic-to-reproduction agents, of first and second category, according to Royal Decree 363/1995 of 10 March, approving the Regulation on the notification of new substances and the classification, packaging and tagging of hazardous substances and Royal Decree 1078/1993 of 2 July on the classification, packaging and tagging of hazardous substances and their respective development regulations and regulations bringing them into line with technical progress.

- **h.** Work involving exposure to biological agents of groups 3 and 4, according to Royal Decree 664/1997 of 12 May on the protection of workers from risks related to the exposure to biological agents during their work, and also the regulations of amendment, development and adaptation to technical progress.

- **i.** Work involving high voltage electricity risk.

Should the temporary employment agency or the user firm draw up a worker assignment contract that breaches this prohibition, this is categorised as a very grave infraction in article 18.3 b) – for the temporary employment agency – and 19.3 b) – for the user firm – of Royal Decree Law 5/2000 of 4 August approving the revised text of the Act on Infractions and Penalties in the Social Order (*Ley Sobre Infracciones y Sanciones en el Orden Social*).

3. From the formal point of view, both the temporary employment agency and the user firm are bound to record a set of information and data not only in the contract for the provision of temporary workers formalised between them but also in the employment contract taken out between the temporary employment agency and the worker to be temporarily assigned to the user firm.

The contract for the provision of temporary workers has to make mention of the occupational risks involved in the job, as laid down in article 14 e) of Royal Decree 4/1995. This general obligation has then been fleshed out in article 2 of Royal Decree 216/1999, whereby the contract for the provision of temporary workers has to specify the inherent characteristics of the job and the tasks to be carried out, the occupational risks involved and the professional qualifications, skills and aptitudes called for, all from the point of view of protecting the health and safety of the worker to be hired and of the user company’s other workers. Furthermore, given that the formalisation of a contract for the provision of temporary workers will be possible only for filling a
job for which the compulsory assessment of occupational risks has been carried out, this information must include the results of the risk assessment of the post to be filled, with due specification of the following information: a) occupational risks of a general character existing in the workplace and which might affect the worker and also the particular risks of the post to be filled; b) prevention measures to be adopted in relation to the general and particular risks that might affect the worker, including a reference to the personal protection equipment to be used and made available; c) training in the prevention of occupational risks that the worker must have already had and d) health surveillance measures to be adopted in relation to the job to be performed, specifying whether, pursuant to applicable legislation, such measures are compulsory or voluntary for the worker and the frequency with which they must be taken.

The employment contract between the temporary employment agency and the temporary worker has to mention the occupational risks of the job to which this worker is to be assigned (article 15.2 b of Royal Decree 4/1995), doing so in the terms mentioned above when dealing with the formal aspects of the contract for the provision of temporary workers. This means that the health-and-safety information contained in the contract for the provision of temporary workers shall also be recorded in the employment contract (article 3.2 of Royal Decree 216/1999).

Furthermore, the temporary employment agency is bound to furnish the user firm with documents proving that the worker made available to said firm has received the due information on the risks and preventive measures, has been given the necessary training and enjoys a general state of health that is compatible with the job to be carried out. This documentation shall also be passed on to the delegados de prevención or, in default thereof, to the legal representatives of the workers in the temporary employment agency and to the agency’s persons or organisations with the remit for preventive matters (article 3.5 of Royal Decree 216/1999).

The documentation on the information and data referred to in this Royal Decree will be recorded and kept both by the temporary employment agency and the user firm, in the terms and for the purposes laid down in article 23 of the LPRL (article 7.1 of Royal Decree 216/1999).

4. The obligations of the temporary employment agency, besides the formal obligations already mentioned in terms of drawing up the employment contract, also take in information-giving and training obligations plus worker health surveillance obligations.

It is the temporary employment agency that is bound to inform the workers of all the information that has been passed on to the user firm and laid down in the contract for the provision of temporary workers (article 3.2 of Royal Decree 216/1999). Correct compliance of this information-giving duty calls for previous liaison of the user firm with the temporary employment agency.

Responsibility for ensuring that the training given is suitable for the worker’s job falls on the temporary employment agency (article 28.5 of the LPRL and article 12.3 of the LETT). To fulfil this responsibility it will have to liaise with the user firm, which has to inform it of the characteristics of the job and the qualifications it calls for, to ensure that the training fulfils its true preventive purpose and does not turn into a formality to be gone through perfunctorily by the temporary employment agency.

That said, although the temporary employment agency is responsible for the preventive training of the worker temporarily assigned to the user firm, the regulation waters this duty down
somewhat, laying it down that the temporary employment agency is bound to ensure that the worker, before being assigned to the user firm, has the necessary practical and theoretical preventive training for the job to be performed. To do so it will religiously check that the worker’s training is apt for the job, up to date and adapted to the ongoing trend in working methods and equipment and the progress of technical knowledge. If not, the temporary employment agency shall previously provide the worker with this training, directly or indirectly, for the necessary time. This training time will form part of the term of the contract for the provision of temporary workers but must precede the actual rendering of the services in question (article 3.3 of Royal Decree 216/219).

Al margen de las obligaciones formales a la hora de elaborar contratos de trabajo, la ETT tiene una serie de obligaciones informativas, formativas y de vigilancia de la salud de los trabajadores

Legal theorists have quite rightly criticised the regulation’s watering down of the training obligation, reducing it from actually giving the training to merely checking that the worker has the necessary training for the job concerned. This introduces a more favourable legal situation than that obtaining for permanent workers, which is hard to justify. If to this we add the fact that temporary hiring arrangements of this type have shown that on many occasions the urgency of filling the post makes it very difficult to observe this obligation, small wonder that compliance often becomes formal rather than real. This difficulty, as pointed out by legal theorists, can never be invoked as grounds for breaching this training obligation incumbent on temporary employment agencies.

To wind up this account of the scope of the training obligation to be taken on by the temporary employment agency, it should be pointed out that this training has to be given, whether directly or indirectly, before going ahead with the work, the training time then counting as part of the term of the contract for the provision of temporary workers (article 12.3 LETT). The regulation returns to this obligation later, adding that, if special preventive training should prove to be necessary for the job in question, this part of the training can be given by the temporary employment agency in the user firm itself before going ahead with the work. It may even be given by the user firm itself with the temporary employment agency picking up the bill, by prior arrangement between both companies (article 3.3 of Royal Decree 216/219). Finally, it is pointed out that any contractual clause attempting to pass on all or part of the training cost onto the worker will be considered null and void (article 12.4 of the LETT).

Another of the obligations to be taken on by the temporary employment agency is the periodical health surveillance of the workers assigned to the user firm in the terms laid down in article 22 LPRL and in article 37.3 of the Prevention Services Regulation (Reglamento de los Servicios de Prevención), bearing in mind the characteristics of the job to be performed, the results of the risk assessment conducted by the user firm and any complementary information that may be required by the responsible medical staff. The collaboration of the user firm is essential for the temporary employment agency to be able to fulfil this obligation, the former being bound to inform the latter of the result of all assessments of the risks to which said workers are exposed, doing so with the required frequency. This information shall include in all cases a determination of the nature, degree and duration of worker exposure to agents, procedures or working conditions that might impinge negatively on their health or might
be pertinent in terms of future temporary employment of the worker by the same user firm or a different one (article 5.3 of Royal Decree 216/1999).

The temporary employment agency is bound to inform the labour authority of any harm caused to the health of the assigned temporary workers, recording in all cases the name or tradename of the user firm, its activity sector and the address of the workplace where the harm occurred (article 7.3 of Royal Decree 216/1999).

5. It is the user firm that takes on most of the obligations with respect to the temporary workers assigned by the temporary employment agency, since, in the final analysis, it is the user firm that is held liable from the prevention-of-occupational-risks point of view for the working conditions of all these temporary workers. It is also responsible for guaranteeing them the same level of protection as the other workers of the firm (article 28.5 LPRL, article 6.2 LETT and article 5.1 of Royal Decree 216/1999).

A question that raises no little controversy among legal theorists is the responsibility for paying the work-accident additional social-security entitlement laid down in article 123 of the Spanish Social Security Act. Indeed, article 16.2 of the LETT identifies the user firm as the party liable for the additional social-security entitlement due to lack of health-and-safety-at-work measures, as the party responsible for this breach. The moot point, however, is whether the liability for the additional social-security entitlement can also be regarded as severally shared by the temporary employment agency. Some legal findings have ruled against this on the grounds that the additional payment is imposed only on the defaulting employer and in the regulation of the assignment of workers through temporary employment agencies the user firm is held accountable for the working conditions of the workers temporarily assigned to it. User firms are even expressly held to be liable for payment of the extra entitlement in article 16.2 LETT. Nonetheless, some recent findings have upheld the possibility of extending the liability for payment of the extra benefit to the temporary employment agency, severally with the user firm, when the agency has breached its health-and-safety-at-work obligations. This is so, they claim, because the legal attribution of the responsibility for paying the extra benefit to the user firm does not rule out the possibility of attributing responsibility for the extra payment to the temporary employment agency, but merely stresses that the user firm, as the party responsible for the safety of the workers assigned to it, is liable for this extra payment. This caveat is made because the user firm is not the employer of said workers but only the party responsible for safeguarding their safety.

The user firm, besides being the party responsible for safeguarding the health and safety of the workers made available to it, is bound to observe a series of information-giving duties.

Before the work goes ahead, for example, it will inform the worker of the existing risks to his or her health and safety, both in general terms throughout the whole firm and also those pertaining to the worker’s particular job within the firm. It will also inform the worker of the tasks to be carried out, the requirement for special medical checks and the corresponding prevention and protection activities and measures, especially in relation to possible emergency situations (article 28.5 LPRL and article 4.1 of Royal Decree 216/1999).

The temporary employment agencies are bound to organise their resources for carrying out the occupational risk prevention activities for all their workers, including those hired to be assigned temporarily to user firms.
Again before any work goes ahead, the user firm shall make sure that the assigned worker is fit for the job. It will therefore ask the temporary employment agency for the necessary information on the following aspects: a) the fitness of the temporary worker, verified by means of the suitable health check, for proper performance of the work under the conditions laid down for its execution; b) possession of the necessary qualifications and skills for carrying out the tasks to be taken on in the proper conditions and possession also of the necessary training, all in relation to the prevention of risks to which the worker might be exposed, in the terms laid down in article 19 LPRL and its development regulations, and c) the worker has received all necessary information on the job characteristics and the tasks to be carried out therein, the qualifications and aptitudes required and the results of the risk assessment (art. 4.1 of Royal Decree 216/1999). The user firm will not be permitted to allow the temporary worker to begin working until such time as it has verified compliance with the abovementioned aspects (article 4.2 of Royal Decree 216/1999). Furthermore, as we have already pointed out when dealing with the obligations of the temporary employment agency, the user firm will inform the temporary employment agency of the results of all assessments of the risks said workers will be exposed to, to enable the agency to fulfil its health-surveillance obligation (article 5.3 of Royal Decree 216/1999).

Another of the information-giving obligations is aimed at the worker representatives. The user firm is bound to inform them of the hiring of any workers made available by the temporary employment agency (article 28.5 LPRL). The regulation then fills out this obligation in terms of both the persons involved and the content. The persons to which this information is to be sent are the delegados de prevención and, in default thereof, the worker’s general legal representatives, omitting any reference to the trade union representatives. In terms of content the information to be furnished shall specify the job to be carried out, its risks and planned preventive measures and the information and training received by the worker. This information will also be passed on by the user firm to its risk-prevention service or, as the case may be, the workers designated for carrying out preventive activities (art. 4.3 of Royal Decree 216/1999).

The user firm will be bound to inform the temporary employment agency in writing of any harm to the worker’s health caused by said worker’s job, so that the latter may then inform the labour authority in due form and time. In the event of any breach by the user firm of this information-giving obligation, said firm will be held liable for any effect that may derive from the temporary employment agency’s knock-on breach of its own notification obligation (article 7.2 of Royal Decree 216/1999).

Rather redundantly, a reminder is given that in the cases of coordination and liaison of entrepreneurial activities as referred to in article 24 of the LPRL, due consideration should be given to the incorporation in any of the concurrent firms of workers made available by a temporary employment agency (article 5.2 LPRL).

The assigned temporary workers will be entitled to apply to the user firm’s representatives – delegados de prevención or, in default thereof, legal representatives – to enforce their health-and-safety-at-work rights as recognised in the legislation (article 28.5 LPRL and article 4.3 of Royal Decree 216/1999). They may also apply to the user firm’s risk-prevention service, whether an inhouse or outsourced arrangement (article 6.3 of Royal Decree 216/1999).

6. The designated workers or, as the case may be, the risk-prevention services of the temporary employment agency and user firm shall liaise to guarantee proper protection of the health
and safety of the temporarily assigned workers. In particular they shall pass on any relevant information for the protection of the health and safety of these workers, while duly respecting the confidentiality of the personal medical information as laid down in article 22 of the LPRL.

7. The temporary employment agencies are bound to organise their resources for carrying out the occupational risk prevention activities for all their workers, including those hired to be assigned temporarily to user firms, pursuant to the provisions laid down in chapter III of Royal Decree 39/1997 of 17 January approving the Prevention Services Regulation (Reglamento de los Servicios de Prevención). For the purposes of determining the organisation arrangement to be used and the necessary wherewithal for said activity, the workers hired temporarily to be assigned to user firms will be counted as the monthly mean of social-security registered workers during the preceding twelve months.

The user firms will calculate the monthly mean of workers made available to them by temporary employment agencies in the preceding twelve months to ascertain the resources and organisation arrangements of the risk-prevention activities, pursuant to the provisions laid down in chapter III of the Prevention Services Regulation (article 6.2 of Royal Decree 216/1999).
Experimental measurement of the contribution of green roofs and green façades to energy saving in buildings in Spain

ENVIROMENT

This article looks at the possibility of using vegetation as an integral part of the building process to save energy. Vegetation can be planted on the roofs of the buildings (green roofs, the traditional practice) or the walls (green façades, not yet as widespread). An in-depth study has therefore been made of the characteristics and performance of both systems. In general green roofs are catching on more quickly while green façades are still in the initial development phase, with a scattered range of systems.

Different trials have been carried out to find out more about how these systems work, such as the use of double-skin green façades or green curtains and the planting of a simple green roof (gravel, growing substrate and vegetation) in an experimental cubicle.

By GABRIEL PEREZ, ANNA VILA, ALBERT CASTELL y LUISA F. CABEZA.

The increasingly pressing problem of efficient energy use is on everyone’s lips nowadays. The main factors behind the current energy problem are the high energy demand of developed countries and the growing demand from developing countries, together with the limited energy sources and the environmental burden involved in using them. Any enhancement in the efficiency of energy use, therefore, any progress down the road of energy saving or conservation, is not only highly desirable for the global environment but will also be beneficial to the economies of the developed and developing countries. Witness the fact that the international agreements of the Kyoto (1997) and Bonn (October 1999) Summits put forward rational energy use as the prime tactic in reducing the planet’s greenhouse effect. Following ratification by the Russian Federation, the Kyoto Treaty finally came into force on 15 February 2005.

The energy dependency of the developed countries is especially heavy in terms of oil and gas. In Spain’s case imports of both commodities in 1998 accounted for over 99% of total demand. In view of the political and economic upheavals and uncertainties to which the supply countries have been subject in recent decades, any reduction of this dependence and increase in the use of renewable energy sources would redound greatly to the benefit of Spain and Europe as a whole. It is estimated that, if the current trend continues, Europe’s import dependency will have risen from the current figure of 50% to 70% by 2020. For this reason many
countries, Spain included, are mooting the use of renewable energy sources such as hydroelectric, wind and solar energy (both thermal energy and photovoltaic), biomass and geothermal energy, among others, which are all nationally based and sustainable energy forms.

Given the above situation, there is a growing trend in Spain, and above all in the countries of northern Europe, towards bioclimatic architecture, which aims to adapt energy solutions to suit the particular site and seeks sources of renewable energy. Architecture of this type can be broken down into three main factors: eco-friendly design (natural lighting, water cycle, etc.), materials (use of natural materials, etc.) and energy source (which in the Mediterranean area boils down mainly to harnessing the sun and wind).

Article 15 of the recently published Spanish Technical Building Code (Código técnico de la edificación), dealing with «Basic Energy Saving Requirements » stresses that the objective of the basic «energy saving » requisite is to achieve a rational use of the energy necessary for building use, bringing consumption down to sustainable levels and also tapping into alternative energy sources as far as possible during the processes of design, construction, use and maintenance.

A trawl of the bibliography shows no systematic comparative studies of the behaviour of different insulation systems in real buildings. Most of the studies are conducted with theoretical calculations or simulations based on theoretical calculations. Furthermore, most of the simulations are difficult to verify, since heat loss and gain in real buildings depend on so many factors that it is almost impossible to ascertain which percentage of these changes is due solely to the insulation system.

Our aim in this project, therefore, is to carry out experiments on building prototypes to cancel out the other variables and isolate the importance of using green roofs and façades.

Ecological or even green architecture is a strand that has built up within the concept of bioclimatic architecture or construction, tending towards a concept of sustainable architecture. One of the more recent developments in this trend is the idea of integrating plant life into buildings, which has come to be called “arquitectura vegetada” in Spain (“vegetated” or “living architecture”), including the covering of building roofs and walls with vegetation.

Traditionally these systems have been used for mainly aesthetic reasons, but nowadays their use could be justified for functional and diverse economic reasons, including energy saving, the durability of the surface materials, the improvement of the urban environment and encouragement of biodiversity, etc. [1].

One of the problems in implementing these ideas in Spain is the fact that they have been directly imported from northern European countries and grafted onto Spain’s buildings without adapting them to Spain’s buildings and construction systems [2].

One of the prime benefits of the use of vegetation in buildings, and particular green façades, is its contribution towards the heat regulation of buildings [3].

In general the use of vegetation, in a well-designed and -managed way, could be a useful form of building heat regulation with the concomitant energy saving [4]. According to previous studies this heat regulation effect arises from four, often interrelated factors: the vegetation acts as insulation, gives added shade, has an evaporative cooling effect and changes the wind behaviour on the building.
The salient factors in the case of green façades are the following:

- **Insulation.** Density of the foliage, wind barrier effect, modification of the characteristics of the intermediate gap and, in some cases (e.g. living walls), the characteristics of the growing substrate [3,5].
- **Interaction with solar radiation (shade).** Density of the foliage (the number of layers) [3,6-8].
- **Evaporative cooling.** Type of plant, exposure, climate (dry/wet) and wind speed [3,6-9].
- **Variation of the wind effect on the building.** Density and penetrability of the foliage and the orientation of the façade [5].

Three different experiments were carried out to study and verify these functions, using double-skin green façades or green curtains and for different plant species in the local climate, i.e., a Continental Mediterranean climate.

Firstly, in the town of Puigverd de Lleida (Lleida) four different species of climbers were planted. The main aim of this experiment was to study and compare their capacity of blocking off solar radiation (shading effect) in a Continental Mediterranean climate.

Secondly a double skin green façade (or green curtain), with Chinese Wisteria (*Wisteria sinensis*) growing on a modular mesh climbing frame, was monitored for one year in the town of Golmés, near Lleida, to obtain hard facts about how this type of façade works in a Continental Mediterranean climate.

Finally, to study and measure the contribution of green roofs to the reduction of buildings’ energy demand, a green roof was set up in an experimental cubicle in Puigverd, comparing its energy demand with another identical control cubicle with no green roof.

**Materials and Methodology**

**Study of the possibility of using a green façade as a ventilated façade**

*Experiment in Puigverd de Lleida*

Four modular mesh climbing frames were designed and built to conduct this experiment. Each one was made of a square steel profile 40 x 40 x 2 mm forming a mesh of 200 x 200 x 4 mm with a handrail of 40 x 4 mm (figure 1). The structure has an L-shaped base to hold a 100 x 40 x 40 mm container. The growing substrate used was a mixture of potting soil for gardeners and top soil. The plant species were chosen from a list of climbers suitable for a Mediterranean climate [10]. The selection criteria were their capacity of adaptation to the Continental Mediterranean climate, their hardiness, the height they could grow to, the type of support they needed, nursery availability and their ornamental character.

In view of the above criteria two evergreens were chosen and two deciduous plants, to compare also their performance. The species selected were Ivy (*Hereda helix*), Japanese Honeysuckle (*Lonicera japonica*), Clematis (*Clematis sp. «Miss Bateman»,

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Vegetated or living architecture is used for various reasons, such as energy saving, durability of the surface materials and improvement of the urban climate.
«The President») and Virginia Creeper (*Parthenocissus quinquefolia*).

**Figure 1.** Modular climbing frames and containers with watering system

A four-module south-facing green façade was set up to simulate the southern wall of a building for data taking purposes (figure 2). An automatic watering system was set up using a simple timer and polyethylene tube fitted with drippers giving a flow of 3.2 l/h to each one of the containers. The watering frequency was weekly during the winter (10 minutes watering) and daily in the hottest months (15 minutes watering).

In the first growth months the plants in each container were treated against slug and snail attack and given bedding compost to encourage plant growth.

To determine the radiation blocking capacity of each species, the amount of light was measured (using a luxmeter) behind and in front of the green curtain (for each plant species). On 28 July 2009 two light readings were taken every hour, from 9 am. to 9 pm. After 5 pm. the figures were no longer counted since the sun had slipped round to the side of the façade or behind it. These figures enabled a rough calculation to be made of the shading capacity of each species (quotient between the average light values behind and in front of the screen).

**Experiment in Golmés**

The town of Golmés stands at a height of 276 m above sea level in the district of Pla d’Urgell, about 25 kilometres from Lleida. The old *Casal Parroquial* (currently a theatre called *Teatro Lo Casal*) is a building from the fifties (figure 3); in 2007 it was reformed and a green façade was set up on its walls.

**Figure 3.** Outside views of the *Teatro Lo Casal* of Golmés.

The building’s main front faces northwest and the back faces southeast. The side walls face southwest and northeast. The green façade involved covering with plants the main front
(northwest), the back wall (southeast) and the southwest facing side wall.

Eleven measuring points were set up to monitor the situation, ten in the gap between the building façades and the green façade (two in the main northwest facing façade, five in the southwest facing side wall and three in the southeast facing back wall and another outside in front of the southwest façade. Weekly readings were taken (always at about 2 pm.) of illuminance, temperature and relative humidity in the intermediate gap and outside, surface temperature of the building façades and estimation of the wind speed outside on the Beaufort scale.

Measurement of the contribution of green roofs in the energy demand in the experimental cubicles of Puigverd de Lleida

Lleida University runs an experimental site in the town of Puigverd de Lleida for assessing the energy efficiency of different construction systems. This site comprises different cubicles with inner dimensions of 2.4 x 2.4 x 2.4 metres. A green roof was set up in one of these cubicles to analyse its thermal behaviour, comparing it with other control cubicles of identical characteristics but without the green roof.

The type of roof constructed was an extensive type, and in this case it was implemented under minimum conditions and in a Continental Mediterranean climate, observing not only its effect as a passive energy saving system but also the behaviour of the plants under such extreme conditions (figure 4).

Figure 4. View of the cubicle during the setting up of the green roof.

The vegetated roof is made up by the following layers and materials:

- **Vegetation.** Sedum sp.
- **Growing substrate.** Light potting soil, 4 cm layer.
- **Drainage layer.** Volcanic gravel, 5 cm layer.
- **Waterproofing membrane.** Soprema waterproofing membrane comprising a framework of polyester fibre and elastomeric bitumen. The bitumen mass has anti-root agents stopping roots from penetrating the waterproofing complex. The lower layer is covered by a hot melt film and the upper face is protected by mineral wool.

No automatic watering system was fitted, opting instead for weekly hose watering. Watering was omitted in weeks with rainfall.

To analyse the thermal behaviour of the cubicles with and without a green roof the following readings were taken: wall temperature (east, west, north, south inside, south outside, roof and floor), inside ambient temperature (at a height of 1.5 metres), humidity of the inside air, heat flow on the southern wall (inside and outside), solar radiation, outside ambient temperature, humidity
of outside air and wind speed.

All the wall temperatures were measured with Pt-100 DIN B temperature sensors calibrated with a maximum error of ± 0.3 °C.

The ambient humidity and temperature sensors used were Elektronik EE21FT6AA21, with a precision of ± 2 %. The heat flow sensors were Huksflux HFP01, with a precision of ± 5 %. Solar radiation readings were taken with Middleton Solar SK08 pyranometers. There was also a weather station for measuring the temperature and ambient humidity, as well as wind speed. Finally all the data was recorded with a computer-connected STEP DL01-CPU data logger.

## Results and Discussion

### Study of the possibility of using a green façade with a ventilated façade as a new construction solution

**Experiment in Puigverd de Lleida**

The first variable assessed was plant growth. Seedling growth was fairly stunted, though this was not expected. The most likely reasons are:

- The location of the experiment, in an open field, means that the plants suffered the harshness of the Continental Mediterranean climate in its full force, especially the cold winds of winter. In a more sheltered position, lying parallel to a building façade, they would probably have grown more.
- The fact that they were planted in containers rather than directly into the soil makes them more vulnerable.
- The admixture of the growing substrate with topsoil of a high clay content, making this substrate too compact for quick plant growth.

The plants that grew highest were the two evergreens (ivy and honeysuckle) albeit leaving gaps with a lower foliage density [10]. The Virginia Creeper gave the best foliage density, although it had difficulties in growing high on the modular climbing frame.

Finally, the plant that grew least was the Clematis. This was largely to be expected bearing in mind the exposure conditions and the fact that it is the least hardy of the four plant species in the Continental Mediterranean climate [10]. In spring it in fact recorded the quickest growth rate but as soon as the really hot days of summer arrived it suffered and shed many leaves. At this moment the growth stopped.

The readings taken to measure the radiation blocking capacity, on 28 July 2009, are summed up in figure 5. This shows that three of the species, the Virginia Creeper (deciduous) the Honeysuckle (evergreen) and the Ivy (evergreen), at no moment of the day exceed a shading factor of 0.3. This figure is comparable with the best values obtained for south façades using façade shading devices like the ones laid down in the Technical Building Code[10].
Figure 5. Shading factor of the various climbing species in a Continental Mediterranean Climate. Puigverd de Lleida. Julio 2009

The slower growing Clematis records less favourable figures than the rest of the species, giving shading factor readings at the brightest part of the day of between 0.35 and 0.65. The Virginia Creeper is the species affording the best foliage density, hence recording a lower shading factor than the other plants. The average daily readings of the shading factor calculated for each of the species are shown in table 1.

Table 1. Mean shading factors in the experiment

<table>
<thead>
<tr>
<th>Species</th>
<th>Mean daily shading factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Virginia Creeper</td>
<td>0.15</td>
</tr>
<tr>
<td>Honeysuckle</td>
<td>0.18</td>
</tr>
<tr>
<td>Clematis</td>
<td>0.41</td>
</tr>
<tr>
<td>Ivy</td>
<td>0.20</td>
</tr>
</tbody>
</table>

Experiment in Golmés

Figure 6 shows the monthly mean illuminance trend in the gap between the green curtain and the building façade (intermediate gap) for the three orientations and the reading outside. It also shows the value trend for the whole vegetated façade, which figure takes into account the three orientations that are in contact with the air in the building.
The readings show a different dynamic on the three façades. The southwestern façade is the most representative of the shading effect caused by the green curtain. This is a result of the time when the readings were taken, at 2 in the afternoon.

The southeast façade even shows an increase in illuminance when the green curtain is in leaf. This is a result of the direct entrance of sunlight in the upper part due to the very vertical position of the sun and the greater separation of the metal structure from the wall than in the other two façades. This brings out the importance of the gap between the green curtain and the wall and also the design of the curtain to avoid entrance of sunlight when the sun is very high in summer.

The northwest façade receives low light intensity around midday, so the readings are low all year round, but the shading effect is also notable when the foliage is thicker.

Figure 7 shows the light transmission or shading effect, calculated as the quotient between the luminance in the intermediate gap and the outside illuminance, for the different orientations and for the whole façade.

This figure shows that for the whole façade the readings when the curtain was in leaf vary from 0.05 in July to 0.30 in April. In the leafless period the readings range from 0.26 in November to 0.54 in February.
It should be borne firmly in mind here that, due to the position of the sun at the time the readings were taken, it is the southwest façade that shows the most realistic sun-blocking possibilities of a green curtain, recording readings of between 0.03 in July and 0.37 in April, when the curtain is fully in leaf, and between 0.38 and 0.88 in the leafless period.

These readings are comparable to the values recorded by the artificial façade shading devices proposed in the Technical Building Code for shading building openings. The extreme values laid down there for southeast and southwest façades are from 0.16 to 0.98 for overhangs, 0.23 to 0.83 for setbacks, 0.39 to 0.61 for opaque awnings and 0.42 to 0.81 for translucent awnings. In the case of slats, the values range from 0.26 to 0.54 for horizontal slats and 0.30 to 0.56 for vertical slats [11].

The experiment of Puigverd de Lleida involved the constructed of modular climbing frames for various types of climbing plants well adapted to the Mediterranean climate.

Figure 8 shows the ambient relative humidity trend. In general, for all façades, the relative humidity of the intermediate gap between the green curtain and the building wall is seen to be higher than the outside relative humidity during the months with leaves.

Figure 8. Relative humidity by orientations. Teatro Lo Casal de Golmés. 2009.

This difference increased as the foliage grew and thickened, recording particularly high differences of up to 7% on the southwest façade during July.

In the leafless period the relative humidity in the intermediate gap was lower in all orientations; again it was the southwest façade that recorded the biggest inside-outside difference, peaking in December at about 8%.

Figure 9 shows the ambient temperature readings. In general it bears out the fact that, during the leafless period, the temperature in the intermediate gap was higher than the outside temperature readings, while in the period with leaves the intermediate temperature was lower than the outside temperature.
Figure 9. Ambient temperature by orientations. *Teatro Lo Casal de Golmés*, 2009.

Broken down by orientations, this effect is especially notable on the southwest façade. This façade recorded a temperature difference of -1.36 °C in July with respect to the outside ambient temperature. The effect is also notable in winter with temperatures up to 3.8 °C higher in the intermediate gap than on the outside.

This effect, taken together with the humidity readings, confirms that the air of the intermediate gap is modified, setting up a microclimate where the temperature is higher and the relative humidity lower in winter (leafless period) and the temperature is lower and humidity higher in summer (period with leaves).

Figure 10 shows the surface temperature readings on the building façade for the various orientations and on an outside point of the southwest façade not shaded by the green curtain. Although readings are not available for all the months, the figures to hand show that, in general, the surface temperature in an unshaded zone was on average 5.55 °C higher than in the areas partially covered by vegetation.

Figure 10. Surface temperature by orientations. *Teatro Lo Casal de Golmés*, 2009.

In August the surface temperature of the southwest façade recorded temperature differences of up to 12.64 °C between the sunny part and the shaded part.

In the leafless period, and as a result of the time when the readings were taken, with the sun shining on the southwest façade, it was this façade that registered the highest surface...
temperature, followed by the southeast façade, which received sunshine in the morning. The northwest, more shaded and receiving sunshine in the afternoon, recorded the lowest surface temperature.

In the period with leaves the vegetation produces a particularly notable shading effect. As the vegetation became thicker it even ended up bringing the southwest façade’s readings into parity with the northwest façade’s.

On the southeast façade, on the contrary, the readings rose with respect to the other two façades, due to the sun’s position and consequent entry of direct sunlight through the upper part, falling directly on the building wall.

The growth and also the annual cycle of the plants are key factors in guaranteeing the sound operation of the vegetated façades. Despite the intrinsic variability involved in working with living things, they always keep to a fairly stable pattern, both in terms of general growth and their seasonal and annual growth rates. These patterns, however, vary from species to species and also vary in terms of the climate where they are planted. It is therefore vital to glean information beforehand on the plant’s behaviour to forestall any problems and improve results.

In the Golmés trial a building was covered with a vegetated façade with 11 reading points to measure factors such as illuminance, temperature (inside and outside) and humidity

There are three aspects that will affect the operation of the vegetated façade and all three have to be borne firmly in mind: the occupied façade surface, the foliage growth model and its seasonality, i.e., the annual cycle of leaf fall and growth.

The analysis of the occupied surface on the southwest façade of Lo Casal de Golmés shows that during the first three years the Chinese Wisteria, in a Continental Mediterranean climate, covers the surface at the rate shown in table 2.

<table>
<thead>
<tr>
<th>Date</th>
<th>Approximate Occupied Surface</th>
</tr>
</thead>
<tbody>
<tr>
<td>September 2007</td>
<td>19%</td>
</tr>
<tr>
<td>September 2008</td>
<td>48%</td>
</tr>
<tr>
<td>June 2009</td>
<td>62%</td>
</tr>
</tbody>
</table>

The wisteria grew vertically very quickly as the main trunk thrust upwards, with secondary growth fanning out from the base; this growth form left gaps on the upper and lower parts of the façade.

Measurement of the contribution of green roofs to energy demand in the experimental cubicles in Puigverd de Lleida

In June, July and August 2009 the plants stood up fairly well to
the harsh conditions they were subjected to.

There was some dieback, however, though it is unlikely that all of it can be attributed directly to lack of water and the high temperatures the plants had to contend with. Both factors slowed down their growth rate and they took on a yellowish withered look. Under these conditions they were very vulnerable to other factors such as wind or bird attack.

A spontaneous appearance of some herbaceous weed species was also observed, particularly the species Portulaca oleracea spreading from the nearby fruit orchards.

Figure 11 shows the readings of solar radiation, outside humidity and temperature in one of the weeks studied in August 2009.

![Figure 11](image1)

**Figure 11.** Weather readings in one week of August: solar radiation, outside humidity and temperature.

Figures 12, 13 and 14 show the temperature and humidity inside the cubicles under study in one week of August 2009. The cubicle with a vegetated roof recorded a higher inside humidity (60-65%) and a lower temperature (26-27 ºC). The temperature inside the control cubicle showed the highest day-night difference, about 3 ºC.

![Figure 12](image2)

**Figure 12.** One week of August: inside humidity and temperature.
Conclusions

This article involves a study of vegetated or living architecture as a passive method of reducing buildings’ energy demand. A study was made of green façades in ventilated façade format and green roofs.

As regards the study of plant growth, the best performing species during this first year were the evergreens, Honeysuckle and Ivy, especially in terms of the height they reach. The Virginia Creeper (deciduous) performed best in terms of foliage density but found it difficult to gain height on the modular climbing frame unless helped by stakes. The worst performing plant was the Clematis, withering in the heat.

The analysis of light transmission through the different species shows a shading factor performance comparable to the values specified using façade shading devices in the Spanish Technical Building Code (Código técnico de la edificación) for south-facing façades. The light transmission readings taken during one day in late July ranged from 0.04 to 0.29 for the Virginia Creeper (deciduous), the Honeysuckle (evergreen) and the Ivy (evergreen). The light transmission values obtained for the Clematis (deciduous) ranged from 0.07 to 0.66.

The monitoring of the vegetated façade of the Teatro Lo Casal in Golmés showed that a façade with 60% surface coverage recorded an illuminance difference between the intermediate space and the outside of about 10,000 to 30,000 lux in the
months without leaves (attributable to the climbing frame and woody parts of the plant). When the foliage began to grow this difference increased, peaking at over 80,000 lux in July and August with total leaf growth.

The light transmission values obtained in Golmés, calculated as the quotient between the illuminance in the intermediate gap and the outside illuminance, are comparable to the shading factor values proposed in the Spanish Technical Building Code for façade shading devices, with the purpose of blocking off solar radiation from windows.

The relative ambient humidity in the intermediate gap was higher than outside during the leaf-growth period, peaking at a difference of 7% in July, and lower in the leafless period, the difference peaking at about 8% in December.

The experiment of Puigverd de Lleida shows that the inclusion of a green roof on an isolated cubicle improves the inside cubicle conditions in comparison to the control cubicle.

The ambient temperature in the intermediate gap was lower in the leaf-growth period (1.36 ºC on the southwest façade in July), and higher in the leafless period (3.8 ºC on the southwest façade in February).

The surface temperature recorded on the façade wall was on average 5.5 ºC higher in the unshaded areas in comparison to the areas shaded by the vegetated curtain. In September the southwest-facing façade recorded a maximum difference of +15.8 º.

As regards the surface covered by the Wisteria, it covered 19% of the façade surface in the first year of growth, 48% the second year and 62% the third year. As for the growth pattern, it grew upwards very quickly as the main trunk rose, with secondary growth fanning out from the base. This growth pattern left gaps in the upper and lower parts of the façade.

Finally, the experiment with green roofs conducted in Puigverd de Lleida showed that the inclusion of a green roof on an isolated cubicle improves the environmental conditions inside the cubicle in comparison to the control cubicles, recording lower inside temperatures and higher relative humidity.

This experiment showed that the chosen plants (Sedum sp) stood up well to the extreme summer temperatures, with only minimum watering. Some weeds sprang up, particularly Portulaca oleracea, spreading in from the nearby fruit orchards.

**Acknowledgements**

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**TO FIND OUT MORE:**


Harnessing groundwater as a water supply and energy resource
ENVIRONMENT

This study looks at the possibilities of harnessing the workings of the Central Asturian Coal-Bearing Basin (Cuenca Carbonífera Central Asturiana) as underground reservoirs to be used both as a water supply and energy resource, mainly by means of heat pumps and mini hydroelectric power stations. To do so an “underground reservoir” was chosen, made up by the connecting mine workings of the Barredo and Figaredo pits, and a detailed study was made of its climatic, hydrological, hydro-geological, hydro-chemical and thermal-conductivity properties to assess and quantify possible uses. The aim is to contribute towards the improvement of the economic and social conditions of a traditionally mining area in steady decline due to the phasing out of this activity.

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Asturias’ long-standing mining tradition has brought about a thoroughgoing change in the potentiometric levels and natural flows of the pre-existing aquifers in the affected areas. The workings can be considered to have given rise to a triple porosity aquifer1; whereas beforehand there were small aquifers in sandstone within a smallish multi-layer system. Now mining galleries have been generated together with fractured zones that function much like karst aquifers 2. In fact the set of cavities caused by coalmining in the Central Asturian Basin (Cuenca Central Asturiana) works like a large underground reservoir.

Harnessing the mine water as a resource, hitherto an overlooked possibility, could help to revive the economy of the mining areas and enable mining to be phased out sustainably in the area.

The pumping out of seepage water represents a heavy cost for the mining companies. This being so, the first option studied for optimising the use of the economic resources was to cease pumping in the closed pits, thereby flooding the mining cavity. This solution is not always feasible, however, due to the singular nature of the workings and the interconnections created after hundreds of years of mining. Other options for harnessing this water are now being studied with increasing interest due to several favourable factors: the proximity of the pits to built-up areas of the Cuenca Carbonífera Central, the physicochemical properties of the water and the soaring costs of conventional heating and cooling arrangements. It would therefore seem feasible to tap into this water in two ways: as a water supply for
certain uses and for energy production by way of heat pumps.

**Location and characterisation of the study area**

The study area lies in the centre of Asturias, within the Cuenca Carbonífera Central, on the eastern side of the River Caudal, between the valleys of the River San Juan to the north of the sector and the Turón river.

The extension of this zone has been defined in terms of the area influenced by the old mines, both of the valley and the mountain. These present connections in this area and might affect or be affected by the flooding of the pits Barredo and Figaredo (connected up to each other), San José and Santa Bárbara (also connected). The area takes in the south of the municipal district of Mieres, the northwestern sector of the municipal district of Aller and a small part of the northeastern sector of the municipal district of Lena. The total land area involved adds up to about 140 km² (Fig. 1).

From the hydrographical point of view the study zone takes in, firstly, the catchment area of the River Turón, which runs east-west from its birth near Uribés and then runs into the River Caudal beside Figaredo, and, secondly, the alluvial plain of the River Caudal, which, as it runs through Mieres, takes in the hinterland of the Barredo pit.

![Figure 1. Location of the mining pits of the Valley of the River Turón and the main connections between them (in red). Division into sub-catchment areas for the hydrological study and discharge gauging points: (1) La Granxa, (2) La Veguina, (3) Peñufe](image)

The seepage recharging the reservoir made up by the mineworkings of the Barredo and Figaredo pits is 20-23% of the useful rainfall, with a constant input from the runoff (river) seeping through the fractured zones.

Geologically, the rocks making up the subsoil – barring the thin quaternary surface formations – date from the Westphalian (Carboniferous) age, having formed immediately before or simultaneously with the development of the Hercynian orogeny (i.e., they are preorogenic and synorogenic sequences). The simultaneous occurrence of tectonic and sedimentation activity makes the carboniferous successions more complex than the former ones, with a pronounced lateral and vertical variability of facies and frequent changes of thickness. In general the carboniferous successions are formed by siliciclastic sediment, although carbonate sediments are highly developed in some particular spots, laid down in environments ranging from deep
sea to shallow sea and finally coasts and continental environments with coal beds. These deposits are organised in large scale somerisation sequences ranging from hundreds to thousands of metres thick.

As regards the orogenic activity, the carboniferous sedimentary record of the Cantabrian Zone can be broken down into three great groups, although this study involves only the intermediate (Namurian-Upper Westphalian D). This set can in turn be broken down into two intervals: one lower, predominantly calcareous (Barcaliente, Olleros and Valdeteja Fms.) and without influence in the study zone, and another upper, of clearly synorogenic characteristics, and which is described in a little more detail, as it is known in the Aller-Nalón sector.

The succession in the Aller-Nalón Sector is divided into the Lena and Sama groups, whose limit lies in Westphalian D. Both groups are subdivided into units or “packets” of mining origin\(^{(3)}\) which correspond to the distribution of the coal beds.

The Lena Group (~3.350 m) consists mainly of sea deposits formed by alternations of lutites and sandstone with thin layers of coal and calcareous levels of different thickness and patchy distribution. The Sama Group (~2.200 m) is made up mainly by coastal deposits with some relatively important intervals of an alluvial character. These deposits are alternations of slate (lutite, limolite) and sandstone with abundant layers of coal and few calcareous levels. The group also presents several levels of conglomerates, siliceous and carbonated clasts. Mention must also be made of the division into “packets” of the Sama Group, from geological wall to ceiling: “Generalas”, “San Antonio”, “María Luisa”, “Sotón”, “Entrerregueras”, “Sorriego” and “Modesta-Oscura”. In the pits under study here, it was mainly the lower packets that were mined.

In terms of climate this area is characterised by an oceanic microclimate with abundant rainfall, averaging out at about 1080 l/m\(^2\) a year. Rainfall peaks in the winter and falls away significantly in summer. During winter peaks the soil becomes saturated, facilitating runoff. Despite the rainy climate and mild temperatures, there may occasionally be arid periods in the summer months due to high evapotranspiration and a fall in rainfall levels. The mean annual temperature is about 13.5 °C.

From the hydro-geological point of view, the study area comprises mainly material of low permeability, making up a multi-layer aquifer of very low porosity and permeability, where the sandstone acts as limited reservoirs and the slate, lutite and coal beds as confining levels. Due to this configuration the groundwater runs mainly through the open fractures and associated decompression zones, whereby the hydraulic behaviour of the formation is more closely bound up with the fracturing than the lithology. This is why the mineworkings of the area play such an important role in the management of the water resource, not only acting as circulation routes but also making up artificial aquifers that could be likened to pseudo-karst aquifers.

**Materials and Methodology**

A description is now given of the materials used and methodologies followed in each one of the various types of study that had to be conducted:

- **Climate Study.** This was carried out in view of the records from the 31 rainfall stations for which readings are available (covering an area of 1170 km\(^2\), centred in the study zone). Since the recording intervals do not coincide in all of them, the due corrections were made and the series completed by...
the double mass method, to fill in the missing data by comparison with a base station (4). For this purpose the base stations were taken to be Oviedo (El Cristo) and Santa Cruz de Mieres, since they have both been up and running a long time with trustworthy records. This method has provided us with stable maps of isohyets (for an average year, a dry year and wet year), isotherms, actual and potential evapotranspiration and isohyets of useful rainfall. Finally, a detailed study was carried out of the study zone (Valley of the River Turón).

- **Hydrological study of the catchment area of the River Turón.** The first stage in calculating spate discharges was a rainfall study to find out the all-time peak, using readings from the most representative temperature-and-rainfall station (Santa Cruz de Mieres). The classic Gumbel distribution method was used to ascertain the likelihood of extreme rainfall, in terms of its average intensity and for a given duration. Finally, the spate discharges were calculated for several return periods, using diverse methods. The discharge of the River Caudal was gauged by two methods; current-meter gauging (mainly) and dilution (chemical) gauging. A direct monthly reading was taken in three gauging points, upriver and downriver of the main mineworkings (Fig. 1) and an indirect daily reading by means of limnimetric scales set up on the gauging points, with an additional in-situ determination of the following parameters: pH, salinity, electrical conductivity, dissolved oxygen, turbidity, temperature and Eh, using a TURO multiparameter gauge.

- **Measurement of mining cavity volumes.** A determination was made of the tons of coal taken from each level in the Barredo and Figaredo pits by checking 59 mineworking plans kept in the Historical Archive of Oviedo (1970-1980) and the archive of the Mining and Energy Board (Dirección General de Minería y Energía) (1981 to date), plus other available information furnished by the Historical Archive of HUNOSA and the Official Mining Chamber of Asturias (the figures before 1970 had been destroyed). Depending on the type of mining (cut-and-fill or caving), criteria for calculating various residual cavities have also been considered (5,6) (Celada, 2009; Toraño, 2009, verbal communication). These findings were then crosschecked against the calculation of the seepage volume during the flooding period; the post-mining cavity was then taken to be 20% of the original cavity mined by cut-and-fill and 30% of the cavity mined by caving, plus the volume of other cavities (galleries, mine shaft, haulage tracks, etc.).

- **The mining reservoir and the rebound of the piezometric level.** A calculation was made of the time lag of the mean seepage in the pits under study by comparison of the rainfall records with the pumping data, availability permitting. The conceptual model was based on a mainly vertical flow defined by fracturing. A detailed analysis was also made of the pit flooding process, correlating the recovery of the piezometric level with seepage and estimated cavity volume.

- **Mine water hydrochemistry.** Complete spot analyses were made of the water nearest the surface of the Santa Bárbara, San José, Figaredo and Barredo pits and also the in-depth profiles of pH, temperature and electrical conductivity in the Barredo pit.

- **Thermal Model.** To find out the factors affecting the
thermal conductivity of the rocks of the successions of Barredo-Figaredo, a determination was made of the mineralogy, texture and porosity thereof by thin film polarising light microscopy; their thermal conductivity was calculated by means of the geometric mean model.

- **Conceptual hydro-geological model.** The water balance was established by analysing each term of the general equation of the water balance (inflows=outflows), with the particular feature that part of the surface runoff becomes underground runoff by seepage through the most heavily mined areas.

- **Techno-economic analysis of the water and energy harnessing possibilities.** Three options were considered: (1) For water supply: the Barredo and Figaredo pits, now closed, make up the aforementioned "mining reservoir", which could be exploited for supplying not only energy but also water for human and industrial use. Both pits are very close to built-up areas so the incorporation of these flows to the general water supply systems could turn out to be economically and technically feasible. (2) Energy generation by heat pump, since the energy used is less than the heat energy supplied; at current prices this spells a significant saving; (3) Setting up a mini hydroelectric power station, injecting the return water in the upper part of the reservoir and using it to run a turbine in the lower part, producing energy in peak hours and pumping in off-peak hours.

Calculation of the residual cavities of the Barredo-Figaredo mineworking, crosschecked against the seepage during the flooding process, gives an estimate of 6.2 Hm3 as the volume of the underground reservoir at the current flooding level.

**Results**

The results are summarised below, broken down into the same sections as in the above discussion.

- **Climate Study.** Figure 2 shows the maps of isohyets and annual mean isotherms for the whole study zone. In particular, for the study zone (Valley of the River Turón), the precipitation of an average hydrological year is about 1080 mm, of which nearly 60% is lost in evapotranspiration, leaving annual useful-rainfall figures of 440 mm. Moreover a month-by-month balance shows that the soil reserve is full 7 months a year (taking a value of 100 mm of useful reserve), while there will be a deficit in the months of July, August and September (the only months in which actual evapotranspiration is lower than the potential evapotranspiration) and a surplus (excess that will generate runoff) in the period running from November to May. Furthermore the useful rainfall is non-existent in the summer months. These results are shown graphically in figure 3.

Figure 3. Variation in rainfall, temperature and actual evapotranspiration in a mean hydrological year in the study zone

- Hydrological study of the catchment area of the River
the spate discharge of the catchment area of the River Turón has been calculated by various methods, throwing up estimates of 50, 150 and 250 m$^3$/s for return periods of 2, 50 and 500 years, respectively. Nonetheless the recent channelling work on the final run of the river, broadening the bed by over 12 m, means that the river is now very unlikely to burst its banks after storms, which have been proven to last no longer than two hours.

The discharges of the River Turón were gauged monthly with a current meter and daily by means of limnimetric heights, in three different sections (La Granxa, at the headwater, La Veguina in the middle run and Peñule near the end of the river). It is noteworthy that the discharge in Peñule (downriver of the most heavily mined area of Figaredo) is in general less than at La Veguina (upriver from Figaredo). This difference is masked during storms, which generate discharge peaks, but in general corresponds to an average of 61 l/s, i.e., about 5300 m$^3$ a day which seeps into this third sub-catchment area affected by the Barredo-Figaredo pits, more heavily mined and hence more fractured, although it comes from the runoff from the sub-catchment areas upriver. The hydrographs obtained from this station are displayed together in Fig. 4, showing that the discharge peaks coincide with high values of useful rainfall.

As for the surface water quality the study found that gauging point 1 (La Granxa) differs clearly from the other two in terms of the parameters analysed, especially after pumping was recently renewed in the San José pit, whereafter the river downstream received a heavy input of mine water. The parameters showing the biggest difference are temperature, electrical conductivity and turbidity, which vary within a small interval in La Granxa, but increase markedly in Peñule and especially in La Veguina, near to the pumping-in point. The conductivity of the River Turón may change from values of about 0.5 mS/cm upriver of this point to figures 5 times greater after receiving the input of mine water. Nonetheless, no significant variation has been observed in pH (which holds steady in all cases at circumneutral values) or in the rest of the measured parameters. The mine water pumped into the river significantly increases its discharge and also affects its quality, increasing its temperature and solids content, not only dissolved solids (tied in with electrical conductivity and salinity) but also suspended solids (tied in with turbidity). At the moment of writing, the discharge has not yet been gauged over a whole hydrological year, so it is not yet possible to ascertain in any precise manner the environmental flow. Nonetheless, the complete data series taken from a nearby river (River Aller), regularly gauged by the Cantabrian Water Board (Confederación Hidrográfica del Cantábrico), together with a calculation of the catchment area’s water balance, suggests that its mean discharge is about 700 l/s, giving an environmental flow of about 70 l/s.
**Measurement of mining cavity volumes.** A check of the mineworking plans of the Barredo and Figaredo pits has shown the coal tonnage taken out by cut-and-fill and caving for each mining level of both pits. The useful cavity will be the result of multiplying the volume mined by coefficients representing the percentage reduction of the chamber initially opened (0.2 for cut-and-fill mining and 0.3 for caving mining). From these figures of tons removed (average coal density, 1.6 t/m³), we can then calculate the volume left by the mined tons, to which must be added the volume of galleries (mean section of 8 m², taking convergence into account), which is multiplied by the kilometres of galleries at each mining level. Finally, the cavity left by the pit shafts is calculated by multiplying their length by a useful section of 25 m². The cavity left by the main haulage track zones is then estimated in terms of a useful section of 20 m² and a total length of 300 m per track. This estimation of cavities is imprecise (underestimated) in the upper levels of both pits, since the old mineworking plans were not available and could not therefore be factored into the equation.

To cross check these values and correct them in the upper levels, a calculation was made of the cavities on the basis of the volume occupied by the seepage water. This was calculated from the daily rainfall during the flooding period minus the actual evapotranspiration calculated for the same period. The seepage time-lag is known to be 19 days, so the seepage on each day was taken to correspond to the useful rainfall fallen 19 days earlier; this was calculated according to the equation relating seepage with useful rainfall (see following section). Once the daily seepage had been obtained, this gave the daily volume filling the reservoir. A calculation of the day-to-day accumulation of this volume, weighed against the known time trend of the flood level, gave us a trustworthy estimate of the cavity volumes at each level. This volume is then compared with the cumulative volume of estimated cavities for both pits, on the basis of the information obtained from the mineworking plans. This is shown in the graph of Fig. 5.

As might be expected, both curves fit well at the intermediate levels (with more information on the mining activity), bearing out the method, and differ greatly (1.2 Hm³) in the upper levels, part of whose production has not been completely factored in to the estimates. The volume of cavities has therefore been increased in the upper levels of both pits to improve the fit of both curves, and the volume of cavities resulting from the Barredo-Figaredo system,
both by linear metre and cumulative, is shown in Fig. 6. It is estimated that the total reservoir volume at the annual flood level (+150 m.a.s.l., 70 m below the collar of the Barredo pit) is 6.2 Hm$^3$.

This same figure shows the recovery curves corresponding to both pits against the cavity volume at each level. Logically the speed of ascent depends on the seepage volume (and hence on rainfall), but in general it is higher between the mining levels and falls upon reaching the sections of the greatest mining cavity. This fall in the slope of the curves is especially notable in those sections where the mining levels of both pits practically coincide.

An attempt has been made to model the flooding by means of the GRAM (Groundwater Rebound in Abandoned Mineworkings) model developed by the University of Newcastle upon Tyne (England) to enhance our knowledge of abandoned mineworkings by evaluating different conceptual alternatives, given the general paucity of known data (7). A critical dependence has been observed on such factors as the volume of water entering the system, the runoff percentage and the storage coefficient. Assigning a value of 0.08 to the latter gives satisfactory results, the levels chiming in with those observed in practice (Fig. 7).

This gives us a better understanding of the flooding process, since the modelling results can be applied to other similar cases pre-flooding for forecasting purposes.

![Figure 5. Variation over time of the cavity filling volume during the flooding and water seepage into the cavities](image-url)
Figure 6. Volume of the cavities of the Barredo-Figaredo mining reservoir per linear metre, compared with the piezometric level recovery levels during the flooding of both pits. Cumulative volume of cavities in the same reservoir, embalse.

Figure 7. Comparison between the piezometric level rebound process measured in the Barredo-Figaredo reservoir and the simulation using the GRAM model.

By regulating the Barredo-Figaredo mine reservoir, the water demand of a town of 68,000 inhabitants could be met, after suitable treatment of the water, or double this amount by taking a...
The mining reservoir and the rebound of the piezometric level. In earlier studies (8,9) the annual mean drainage of the Barredo-Figaredo system has been calculated to be 4.1 Hm³ a year. Two comparisons were made to determine the seepage time lag: firstly, the maximum drainage days (recorded in the mineworking plans) with the useful-rainfall peaks recorded on previous days (Figaredo pit), and, secondly, the few available daily pumping figures with the corresponding useful rainfall (Barredo pit). This gives a seepage time lag in the Barredo-Figaredo system of 19±5 days; this tallies with the findings of earlier studies for pits of Asturias’s Cuenca Carbonífera Central (10).

It should also be pointed out here that some pumping is maintained in the dry periods, indicating that there is a “constant” seepage input as well as rainfall input (seepage of water from the River Turón in the most fractured zone). Working from the figures on pumped flows (i.e., seepage inflow) and useful rainfall, an attempt was made to establish the relation between them. Considering the catchment area of the Barredo and Figaredo pits (18.59 km²), the monthly seepage is found to represent about 20-23% of the monthly useful rainfall (in m³, and assuming a 19-day time-lag), to which must be added a constant sum (150,000 m³ a month) not depending on rainfall input. This extra input does not involve inputs from connected aquifers due to low rock permeability. This independent term corresponds to the input of river water which seeps underground while running through the catchment area of both pits and is the reason why some pumping is kept up even during rainless periods, as already mentioned, and also explains why the water level rises so quickly during the flooding period. The following equation gives the most accurate reflection of the relation between daily useful rainfall and seepage into the interior of the Barredo-Figaredo mining reservoir:

\[
\text{SEEPAGE (m}³\text{ a day)} = 0.23 \times \text{USEFUL RAINFALL (m}³\text{ a day)} + 5300 (\text{m}³\text{ a day})
\]

Mine water hydrochemistry. Monthly in-situ readings were taken of pH, temperature and electrical conductivity in the pits under study. Hydrochemical studies were also carried out to assess the possibility of harnessing the water for municipal supply. The pH readings for the Figaredo pit vary between 6.7 and 8 with a mean value of 7.3. pH readings in the Barredo pit range between 6.9 and 8.1, with a mean value of 7.5. The electricity conductivity readings for the water of Figaredo pit vary from 1474 to 5773 µS/cm, with a mean value of 3134. The electrical conductivity readings for the water of the Barredo pit range from 1271 to 2070 µS/cm, with a mean value of 1531. In general the electrical conductivity for the Barredo pit holds fairly steady between 1000 and 2000 µS/cm, whereas much higher and more fickle conductivities were registered in Figaredo pit. A fall in these conductivities has also been observed since 2008, perhaps due to admixture with the water from the Barredo pit, of lower conductivity, during the flooding of both pits.

The iron, sulphate and manganese concentrations of both pits often exceed acceptable limits, especially in Figaredo. This pit shows a high content of suspended and dissolved solids, with particularly high levels of sodium, copper, aluminium and, in some samples, oils and fats. The Barredo
pit, for its part, has high concentrations of lead and arsenic in some samples. Turning to a consideration of the treatment for the raw water of these pits, we find on the basis of this analysis, and duly applying the stipulations of Directive 75/440/EEC, currently in force, that intensive physical treatment would be needed if the water were to be used for human supply, due to the high iron and manganese contents in both pits. The water quality study carried out by the firm HUNOSA has shown the water in question to be sodium bicarbonate in nature, never dropping below pH 7 and causing no rust problems in pipework. The main problem affecting this water is its excessive hardness, sometimes rising above 100ºf, debarring mine water from direct use as a cold source of the heat pump. Intermediate heat exchangers can be fitted to get round this problem (11).

The temperature readings of the samples taken (of the water nearest to the surface in the mine shaft) tended to fall slightly as the water level rose. In the Figaredo pit the minimum and maximum temperature readings were 14.7 and 23 ºC, respectively, with a mean reading of 18.5 ºC. The temperature of the flooding water of the Barredo pit varied from 14.2 to 26.1 ºC with a mean value of 17.6 ºC. The temperature and salinity profiles throughout the shaft of the Barredo pit show changes as the various mine levels are crossed, in general increasing in direct relationship to increasing depth until reaching the 3rd mining level (level +20), where they level off (Fig. 8). On average the temperature increases from about 17 ºC in contact with the air to 22ºC from 200 m downwards.

Harnessing the energy of the Barredo pit water by heat pump for the heating and air conditioning of two university buildings will reduced energy consumption by 74% as compared with a conventional system and CO₂ emissions by 40%.

![Temperature profile](image)

**Figure 8.** Profiles of various parameters recorded along the Barredo pit shaft

- **Thermal Model.** A determination has been made of the thermal conductivity of the material delimiting the Barredo-Figaredo mining reservoir, on the geometric mean method, which considers the rock’s thermal conductivity to be a function of its porosity: \( k = k_m (1-\phi) \cdot k_f \phi \) (km and kf, conductivity of the bedrock and fluid, respectively; \( \Phi \),...
To find out the mineralogical composition of the bedrock and its porosity, 2 representative rock samples were taken from the stratigraphic column of the Barredo pit, then subjected to thin film analysis. In order of abundance they were litharenites (phyllarenites), lithic greywacke, lutites and quartzarenites. The main petrographic component is quartz. The density and porosity were determined by using the procedures of UNE-103-301-94 and UNE-103-300-93. Tabulated values of thermal conductivities of the minerals present were used (12,13). The abovementioned equation was then applied to these values to obtain a representative thermal conductivity value of each individualisable rock level. This model is shown in summary form in Fig. 9

Figure 9. NW-SE section of the Barredo pit, showing the thermal conductivity calculations for the various geological materials

- **Conceptual hydro-geological model.** From all the abovementioned relations, together with climate records and discharge readings, it is then possible to draw up a conceptual hydro-geological model simplified for an average year in the catchment area of the River Turón, before and after the cessation of pumping (Fig. 10).
Figure 10. Simplified conceptual model of the water balance in the study zone (catchment area of the River Turon) for an annual period, before and after the interruption of pumping.

- Techno-economic analysis of the water and energy harnessing possibilities:
  Three water-harnessing options are considered in this section:
  
  o For water supply: Assuming seepage into the Barredo-Figaredo mining reservoir to be the sum of the pumped flows in both pits in 2005 and assuming a constant consumption of 172 l per inhabitant per day (average of Asturias), then the maximum consumption that could be satisfied is 0.35 Hm$^3$ a month, i.e., 4.2 Hm$^3$ a year (theoretically sufficient for supplying 67,800 people after previous treatment of the water). Given the existing inputs, the consumption could not increase much more even when the reservoir volume is higher. A possible way of increasing the water supply possibility would be to recharge the underground reservoir with river water when it is running high; this would give us a bigger control reservoir and therefore enable us to satisfy a higher water demand. For example, it would suffice to “import” a 130 l/s discharge of water from the River Aller during the six months of deficit (2nd half of year). This would be perfectly feasible, for the river’s average discharge is 6.7 m$^3$/s and its environmental flow is 700 l/s). This would allow us to recharge the reservoir and meet double the demand, i.e., 0.7 Hm$^3$ a month (theoretical supply of 135,600 people), minimising the overspill, which would be only 0.13 Hm$^3$, between the months of May and June.

  o Energy generation by heat pump: The stable temperature of the water of the mine of the Cuenca Central Asturiana, and also the high available discharge have proven the promising geothermal potential of this water, which could be harnessed by way of a heat pump. The first project using this hitherto unexploited geothermal flow for heating and air-conditioning two buildings of the University Campus of Mieres is expected to avoid 74% of the...
energy that would otherwise be consumed by conventional gas-burning heating systems and air conditioning systems. This is tantamount to a CO\textsubscript{2} emission reduction of over 40%.

To evaluate the thermal potential of HUNOSA’s mines in the Cuenca Central, the working assumption is a mean drainage temperature of 20 \degree C and an annual discharge of 30 Hm\textsuperscript{3}. Taking into account the temperature increment that optimises the energy yield of a heat pump system (8), we get: \( P_f \approx 19.91 \text{ MW}_t \) (thermal potential of the cold source) and \( P_c \approx 24.4 \text{ MW}_t \) (thermal potential of the hot source).

Taking habitual heat-pump COP values for the temperature increments considered (12-17 \degree C, to produce hot water at 45\degree C), it is estimated that the input needed in the form of electricity to work the heat-pump compressor will be 4.53 MW: in other words a consumption of 4.5 MW\textsubscript{e} would generate a heating thermal potential of 24.4 MW\textsubscript{t}. The pump would be available 24 hours a day, so this would entail annual thermal energy available for heating of \( 24.4 \times 24 \times 365 = 214,097 \text{ MWht a year} \), consuming only \( 4.5 \times 24 \times 365 = 39,683 \text{ MWhe} \).

- Setting up a mini hydroelectric power station. As applied to the Barredo pit, considering a net fall of 72.5 m and a mean return discharge to the pit of 0.6 m\textsuperscript{3}/s, the instant potential would be: \( P = 8.34 \cdot Q \cdot H_n = 362.8 \text{ kW} \) (\( Q \), discharge in m\textsuperscript{3}/h, \( H_n \), net height in m). As a first educated guess, therefore, taking into account the current energy prices and assuming a constant discharge, which may not always correspond to reality, the energy that could be obtained by harnessing the pit water this way is approximately 3,178,128 kW\cdot h a year. Assuming that the water is delivered to the turbines in peak hours (16 hours a day) and pumped in off-peak hours (8 hours a day), and according to the provisions laid down in Royal Decree 661/2007 (regulation of electricity generation activities), this would add up to an annual income of €218,731, without considering the cost of pumping the turbined discharge (€28,987) since this would already be included in the economic balance of the heat pump itself and would still obtain even if no mini hydroelectric power station was set up.

The return water from the above heat-pump system could be harnessed by injection into the upper part of the Barredo pit and then turning a turbine in the lower part, producing energy in peak hours and pumping in off-peak hours.

**Conclusions**

The following conclusions and general recommendations can be drawn from the work carried out in this research project:

- The zone studied, set in Asturias’s Cuenca Carbonífera Central, takes in an unusually large number of
mineworkings, either closed or in process of closure. These mineworkings make up between them an extraordinary “underground reservoir” that could be harnessed as a water and/or energy resource in various ways.

- This zone is characterised by an oceanic climate with abundant rainfall, averaging out at about 1080 l/m² a year, persistent cloud cover and a mean annual temperature of 13.5 ºC. The annual mean actual evapotranspiration is 642 mm and the useful rainfall is estimated to be about 444 mm.

- Geologically, the study zone is characterised by the presence of material from the Carboniferous age (Westphalian D strata), folded by past tectonic activity into very complex structures. In terms of sedimentology, the zone is made up by a series of coastal parasquences formed by a cyclical succession of sandstone, lutite and coal beds.

- In view of the above, the study area can be said to be characterised by the presence of predominantly impermeable or low-permeability material, making up multi-layer aquifers of very low porosity and permeability, where the sandstone acts as a limited reservoir and the slate, lutite and coal beds as confining levels. Due to the above set-up, the groundwater runs mainly through open fractures and associated decompression zones. This means that the hydraulic behaviour of the formation is more closely bound up with the fracturing than the lithology, with a triple porosity similar to that of a karst carbonate aquifer system.

- Discharge readings in three stations of the River Turón show that discharge in the headwaters sampling point varies from 50 to 600 l/s and in the middle point from 143 to 1775 l/s and from 121 to 1734 l/s in the end run. In the station of Peñule, moreover (just before it runs into the River Caudal) a lower discharge is in general recorded than in the La Veguina station (upriver from the former). This shows that there is significant seepage between said points, estimated at 61 l/s, due to the fracturing caused by the nearby mining. The mean discharge of the River Turón is estimated to be about 700 l/s and its environmental flow about 70 l/s. The spate discharge of the catchment area of the River Turón has also been calculated using various methods, giving estimates of 50, 150 and 250 m³/s for return periods, respectively, of 2, 50 and 500 years.

- Throughout the river the water pH varies from 7.02 to 9.27; the temperature from 8.46 to 20.66 ºC; the electrical conductivity from 0.335 to 2.517 mS/cm and the oxidation potential from 31 to 709 mV, always being positive. These values are very variable in the three sections and are clear indicators of the presence of mine water in the river from the pit pumping processes (which above all raises its temperature and electrical conductivity).

- The seepage that recharges the reservoir comprised by the Barredo and Figaredo mineworkings comes out at between 20 and 23% of the useful rainfall, together with a constant runoff input (river), which seeps in through the fractured zones. In the Barredo-Figaredo sub-catchment area the following relation holds true: SEEPAGE (m³ a day) = 0.23 x USEFUL RAINFALL (m³ a day) + 5300 (m³ a day). The average seepage time lag is 19±5 days.

- According to the conceptual water inflow and outflow model established for the Turón catchment area, of 59 km², more than 55% of the rainfall is lost by evapotranspiration in an average year, the useful rainfall being estimated at 510 mm, of which over 70% generates runoff and the rest seeps into the ground.
• Working from the figures on tons of coal extracted (applying residual cavity reduction coefficients according to the mining method used) and the estimated figures of galleries and other cavities, the total cavity volume of the Barredo-Figaredo system has been estimated; this figure has then been cross-checked against the seepage input during the flooding thereof, adding up to an underground reservoir volume of 6.2 Hm$^3$ at the current flood level (+150 m.a.s.l.).

• On average the water temperature of the Barredo pit increases from about 17 ºC in contact with the air to about 22 ºC from 200 m downwards.

• The thermal-conductivity values of the rocks crossed by the mineworkings vary from 1.4 W/m·K (lutite) to 4.7 W/m·K (quartzarenite).

• Three potential uses are proposed and analysed for the water stored in the Barredo-Figaredo underground reservoir:
  
  o Mine water could satisfy the demand of a town of about 68,000 inhabitants (0.35 Hm$^3$ a month), building up water in the surplus months (1st half of the year) to be used in the deficit months. This water supply could be doubled merely by taking a 130 l/s discharge from the River Aller; this would be environmentally feasible for said river, for its mean discharge is 6.7 m$^3$/s and its environmental flow is estimated to be 700 l/s. For human use the water content of Fe and Mn has to be monitored, since they lie above the drinking water thresholds laid down in Royal Decree 140/2003.

  o The discharge and temperature readings of the water stored in mining cavities indicate a geothermal potential that could be harnessed by means of heat pump equipment. This represents an energy resource that has hitherto been overlooked, and harnessing thereof would help to revive the economy of the mining areas and enable mining to be phased out sustainably. In particular, the future heating and air-conditioning of the two university buildings by this system will reduce energy consumption by 74% and CO$_2$ emissions by 40% in comparison with a conventional system.

  o The water could be used to run a mini hydroelectric power station, injecting the return water (once used for the abovementioned heat-pump purposes) in the upper part of the Barredo pit and using it to run a turbine in the lower part, taking advantage of the cost difference between producing the energy in peak hours and pumping it in off-peak hours. Working from the water drop and discharge, estimates were then made of the installed output and mean production as well as the economic balance, coming out as a saving figure of over €200,000.

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**PARA SABER MÁS**