Energy 48 (2012) 398–405

Contents lists available at SciVerse ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

# Long term energy demand projection and potential for energy savings of Croatian tourism–catering trade sector

Bojan Irsag, Tomislav Pukšec*, Neven Duić

*Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb, Ivana Lučića 5, 10000 Zagreb, Croatia*

ARTICLE INFO

*Article history:*
Received 16 December 2011
Received in revised form
23 June 2012
Accepted 26 June 2012
Available online 21 August 2012

*Keywords:*
Energy demand
Forecast
Tourism
Energy efficiency
Bottom-up modelling

ABSTRACT

Today, tourism represents one of the backbones of Croatian economy and one of the main factors of its growth. Combined with catering trade sector, tourism represents a significant energy consumer that has the tendencies of future growth. Since services sector, which tourism–catering trade sector is a part of, is not yet well described regarding future energy balances it would be very interesting to see how could possible future growth in tourism influence energy consumption of the services sector in Croatia. Through this paper long term energy demand projections of tourism–catering trade sector were studied with special emphasis on future growth of tourism in Croatia as well as different mechanisms that might lead to certain energy savings. Bottom-up approach was chosen as the most suitable one since it allows better quantification of different measures, technological or legal, that would influence future energy demand. Downside of this approach is extensive input data that is required to analyse and model future energy demand which is roughly divided into heating/cooling section and all other consumption. Results show that additional energy savings in the tourism–catering trade sector are possible if careful and rational demand side planning is in place.



## 1. Introduction

Tourism presents a highly intensive and economically propulsive sector in Croatia. At the same time energy consumption of tourism sector is constantly increasing and is expected to do so. That is why it would be very interesting to see how could future tourism expansion and growth influence energy consumption in Croatia [1,2]. Tourist activities are present in the entire country; however they are seasonally intense in the southern, Mediterranean part. During the tourist season population in the southern part of the country becomes immensely larger while the population in northern counties is lower during the middle months of summer. Such specific conditions of input parameters greatly influence energy consumption. Previous works have shown important influences on basic input parameters which depend on geographical location [3,4]. One of the questions raised based on this particularity is whether this need to attract tourists produces excess or unnecessary spending of energy and is this justified? What is certain, assessing energy demand for such a unique sector made of versatile objects is not simple. In order to present correlation between tourism expansion and energy consumption, long term energy demand model, that presents Croatian tourism–catering trade sector, was developed. This model is an attempt to explain, in detail, the total demand of the sector. It gives modelled demand for each of the twenty one Croatian counties including the monthly heating/cooling modes. Model was made so that, when calculating, each county is represented with an average value of specific factor for that county in a certain month of the year. Calculations for long term energy demand assessments are often complicated and require different approaches. Demand side modelling is essential for all future energy system analysis since it presents an input data [5,6], crucial as a starting point. Sohn et al. have pointed out many difficulties when making long term assessments, especially difficulties associated with analysing energy transformations [7]. Planning future energy demand considering all influential mechanisms can lead to more rational energy policies with lower energy consumption and $CO_2$ emission as a result [8,9].

There are many different approaches to model energy demand in a large scale entity, whether it is a unique sector or an entire country. Particular approach, presented in this paper, does not use complex calculations, however since input data is scarce there is a need for calculating most of the input parameters. Example is the need for modelling square footage of different objects as a necessary basic input parameter. Data was always obtained in a form that

* Corresponding author. Tel.: +385 1 6168 242; fax: +385 1 6156 940.
*E-mail addresses:* bojan.irsag@fsb.hr (B. Irsag), tomislav.puksec@fsb.hr (T. Pukšec), neven.duic@fsb.hr (N. Duić).

0360-5442/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.energy.2012.06.069

requires further interpreting, or calculations, to determine input parameters. Most of the necessary data were modelled in various ways as described in the following paragraphs. Such scarcity of data can easily lead to inaccuracies so the approach used to do the calculations must be chosen carefully. As this sector and difficulties that comes along when assessing energy demand are unique, the implemented model is "patched" by different approaches. Model is based on a bottom up approach that needs a lot of input information and based on some simple calculation it gives yearly energy demand data [10,11]. Bottom up analysis is checked with limited top to bottom approach. Koopmans et al. have analysed the gap between bottom up and top down approaches and they have shown how different types of data can be applied combining these two models [12].

Long term analysis or forecasting models can be conducted in various ways. For the purposes of this research, different approaches were observed and their benefits and shortcomings were tested, such as exponential smoothing method which has proven to be useful when predicting consumption [13] but not applicable in this case. Both linear and non linear forecasting models have been proven as efficient in modelling demand [14,15]. Such methods can sometimes be used with certain estimation of error which is difficult in this case.

As economics is closely connected with both consumption and tourism a cost benefit analysis was conducted. Calculations in the model are made with classical engineering equations as well as detail analysis of input data by using a statistical approach. Interpolation techniques can come quite useful, especially when it comes to calculating capacity factors [16]. Final results are based on summarizing all objects through all Croatian counties. In the following paragraphs detailed methodology will be presented.

## 2. Methodology

In the following analysis consumption is comprised of heat transferred through the outer walls of buildings (in following text – envelope) and "other" consumption which includes various machinery, water heating, lights etc. Overall consumption is the sum of final energy demand used for heating/cooling and "other" consumption. As "other" consumption was calculated in a way with no dependable monthly analysis possible, the character of monthly changes is determined solely by calculated final energy demand which adds inaccuracy in the model that is explained later.

Heat transferred through the envelope is heat necessary to maintain inner temperature at a set level. Apart from the temperature difference, solar heat flux is also included into the calculation. The solar flux contributes to lower need for heating in winter and is the biggest contributor to cooling needs in the summer. In the methodology section, first the process of calculating basic input parameters is explained which is then followed by explanation of parameters that effect the model, formulae that are the basis of this model, calculation of "other" consumption and the methodology for demand projection.

Parallel to the analysis described in the following text another model of heat demand through the envelope was made using degree days instead of modelled appropriate factors in the transmission losses formula. This model was made as a method of error checking to verify if the numbers are closely comparable. Degree day model was not further used in this research since it turned out to be insufficiently detailed to catch all interesting parameters influencing energy consumption. All the calculations in this paper, except long term analysis, were conducted based on the data for the year 2008, which was set as a base year.

### 2.1. The envelope

In this paper "the envelope" is a name given to the surface of all outer walls of the building or buildings, in a certain Croatian county. First step of the envelope calculation is determining basic floor surface of all object types in the sector. Tourism–catering trade sector is comprised of tourism and catering parts. As available information on these parts was scarce, the floor surface, and later on volume and envelope were modelled by different methods for tourism and catering sections. When calculating the volume, height was always set to 2.4 m in accordance to the current building codes.

Floor surface in tourism sector is determined from the data on the number of different types of objects and their properties, regarding number and type of rooms and beds [17]. Number of housing units and beds, percentage of double, single and triple rooms, are important because the rooms have different floor surfaces. Number of rooms with certain number of beds in a county is determined by dividing the number of rooms in the county with the number of beds [17]. Floor surface is determined by multiplying the percentages of double, single and triple rooms with percentage share of different types of units, for instance hotels or apartments, with basic square units of surface and the number of units in the county. Example of this calculation principle for tourism sector floor surface is given through:

$$B/HU = 2.0723 \tag{1}$$

$$SQF = B_{Q2} \cdot HU \tag{2}$$

Dividing beds with housing units determine whether the county will be calculated as mostly one bed, two beds or three bed county. The basic data of square footage is available for one, two or three bed units. Table 1 shows how basic information on number of objects, rooms and beds was tabled. Objects with different number of stars are separately calculated since basic unit of square footage is different. Calculation differs when calculating different types of objects. The principle remains the same; however different types of objects require different approaches (Table 2).

Following example is given: as tourist settlement consists of different types of objects, B/HU ratio no longer directly defines the county as a one bed, two beds or three beds. It determines the AF factor which is used to determine the scenario by which the county will be calculated, as described in formula (3).

$$B/HU = 2.245 \tag{3}$$

$$SQF = (AF \cdot B_{Q3} \cdot HU)P_{SA} + (AF \cdot B_{Q2} \cdot HU)P_R + (AF \cdot B_{Q3} \cdot HU)P_A \tag{4}$$

Camps and marinas were not included in the estimation because it is too difficult to estimate their consumption. Basic floor surface for different types of housing units was obtained from regulations for minimal square units of surface and modified by using empirical data from the available sources to create a more realistic image. Floor surface of catering facilities was obtained by multiplying the number of different types of catering facilities with associated floor surfaces. Different types of catering facilities are divided according to the official categorization. Due to incomplete data and the similarity of some types of buildings, sometimes the same average surface

**Table 1**
Part of calculation principle for available surfaces of tourist sector – hotels.

| Example | Hotels 1* | | |
|---|---|---|---|
| Zagreb county | H | HU | B |
| | 10 | 866 | 1936 |

**Table 2**
Part of calculation principle for available surfaces of tourist sector – tourist settlements.

| Example | Tourist settlements 3* |
|---|---|
| Dubrovnik-Neretva county | SQF |

represents few different types of objects. Number of different types of objects is determined for each county. Objects which fall under catering or tourism sector are presented through Table 3.

After determining floor surfaces, volume is determined by multiplying this surface with height. This is followed by the determination of surface area of the entire sector. There are two formulae connecting the envelope with transmission loses (heat through walls). First formula was used in calculation and second one solely for verification:

$$A = \frac{\Phi_v * V_h}{U_m * \Delta T} \tag{5}$$

$$A = \frac{(\Phi_v - 7) * V_h}{14} \tag{6}$$

To determine the surface of the envelope, specific transmission heat loses are equalized with the nominal normative with regard to units and height of 2.4 m. Heated volume was determined by using the estimated percentages on the part of central and room heating in Croatia for 2010 and the percentage determining heated surface with regard to a certain type of heating [18].

$$V_h = 0,873 * 0,766 * V + 0,157 * 0,486 * V \tag{7}$$

The percentages of window area on the West-Southeast are set to 20%, Northeast-North-Northwest are 30% and skylights participate with 15% of the total area of these surfaces [19]. From this the overall percentage of 24% is selected, which is used in the calculation. This percentage is taken arbitrarily with regard to these three values. The factor representing windows is *fp*. Window surface is an important aspect of calculating the envelope and is represented with average heat transfer coefficient value for older and newer buildings. Table 4a presents different buildings distribution based on the year of completion.

### 2.2. Heat transfer coefficient, capacity factor and temperature

Heat transfer coefficient was modelled from basic data on coefficients for specific buildings in different counties. This base information was obtained from internal audits, various available national and international projects dealing with energy efficiency in Croatia and available manuals [18]. For a county with no available data, missing data was copied from the nearest similar county. Data based on which the county will be modelled depends whether it belongs to the southern or northern region of Croatia.

**Table 3**
Overview of all establishments covered by the model.

| | | |
|---|---|---|
| **Catering sector** | | |
| Guest houses | Eating houses | Grill houses |
| Motels | Retreats | Bistros |
| Inn houses | Ship cabins | Fast food objects |
| Rest stops | Sleeping carts | Coffee shops |
| Hostels | Restaurants | Night clubs |
| Mountain houses | Pubs | All other catering units |
| Hunting lodges | Dining rooms | |
| **Tourism sector** | | |
| Hotels | Tourist settlements | Apartments |
| Apart-hotels | | |

**Table 4a**
Buildings distribution by the year of completion.

| Year of completion | –1950 | 1950–1970 | 1971–1980 | 1981–1987 | 1988–1994 | 1994–2010 |
|---|---|---|---|---|---|---|
| Zagreb county | 19.1% | 13.2% | 25.0% | 14.7% | 11.8% | 16.2% |
| Vukovar-Srijem county | 16.2% | 16.2% | 28.4% | 10.8% | 8.1% | 18.9% |
| Virovitica-Podravina county | 21.1% | 15.5% | 16.9% | 14.1% | 12.7% | 19.7% |
| Varaždin county | 9.4% | 20.3% | 14.1% | 17.2% | 9.4% | 14.1% |
| Sisak-Moslavina county | 21.7% | 21.7% | 23.3% | 10.0% | 10.0% | 10.0% |
| Požega-slavonija county | 21.7% | 21.7% | 23.3% | 10.0% | 10.0% | 10.0% |
| Osjek-Baranja county | 16.4% | 16.4% | 28.8% | 11.0% | 8.2% | 17.8% |
| Međimurje county | 12.7% | 21.1% | 14.1% | 16.9% | 5.6% | 29.6% |
| Krapina-Zagorje county | 18.6% | 12.9% | 24.3% | 14.3% | 12.9% | 17.1% |
| Koprivnica-Križevci county | 22.4% | 17.1% | 14.5% | 13.2% | 11.8% | 21.1% |
| Karlovac county | 22.1% | 20.8% | 10.4% | 11.7% | 9.1% | 26.0% |
| Zagreb City | 18.8% | 11.6% | 26.1% | 14.5% | 11.6% | 17.4% |
| Brod-Posavina county | 21.7% | 21.7% | 23.3% | 10.0% | 10.0% | 13.3% |
| Bjelovar-Bilogora county | 21.1% | 15.5% | 16.9% | 14.1% | 12.7% | 19.7% |
| Dubrovnik-Neretva county | 13.0% | 27.5% | 20.3% | 8.7% | 1.4% | 29.0% |
| Split-Dalmacija county | 13.0% | 27.5% | 20.3% | 8.7% | 1.4% | 29.0% |
| Šibenik-Knin county | 21.7% | 21.7% | 23.3% | 10.0% | 10.0% | 10.0% |
| Zadar county | 11.4% | 20.3% | 21.5% | 10.1% | 6.3% | 30.4% |
| Lika-Senj county | 24.6% | 14.5% | 18.8% | 10.1% | 8.7% | 23.2% |
| Primorje-Gorski kotar county | 24.6% | 14.5% | 18.8% | 10.1% | 8.7% | 23.2% |
| Istra county | 28.4% | 13.4% | 22.4% | 10.4% | 9.0% | 16.4% |

Number of people in the county at a certain moment is described by the capacity factor presented in Fig. 1. To determine this factor occupancy data from the Ministry of Tourism was very important. This data speaks on hotel occupancy in each of the counties. Unfortunately this was the only way to determine the change in the occupancy. Direct reading from the data could not determine the changes on a monthly basis; this was modelled in a table where the number of nights was divided by the number of available beds containing the resulting occupancy per month. Since we cannot determine the entire accommodation in tourism–catering trade sector, the goal was to set the value of the total load for the whole of Croatia. Then a table was made using simple interpolation in which data was obtained so that every county in the year has an average occupancy value. This was important since these values give an average of the before mentioned target and the data can be exchanged in the proportions in which the figures are calculated in the beginning. This is done by dividing the number of nights with the accommodation capacity of hotels in each county [17]. Resulting table contains occupancy values for every county in every month and for the entire year.

Air temperatures in each county are represented by the nearest city for which temperature data could be read. Temperature data was extracted from the Croatian Meteorological and Hydrological service for larger cities [20]. Whether the result of temperature difference is positive or negative is determined by the temperatures. In summer when the outside temperature is greater than the inner, the difference will be negative and with it the heat flow. This means that cooling is necessary and the heat must be taken away. Working with average monthly temperatures is in accordance with the standard [21], but not particularly realistic to calculate the cooling energy of an entire sector, because of the low temperature difference. This shortcoming is compensated by the solar flux.

**Table 4b**
Energy consumption for different segments of objects [24].

| Consumption of certain segment | | |
|---|---|---|
| Kitchen | 21.2625 | KWh/m$^2$ |
| Lighting | 17.975 | KWh/m$^2$ |
| Hot water | 57.78825 | KWh/m$^2$ |
| Equipment | 27.05225 | KWh/m$^2$ |

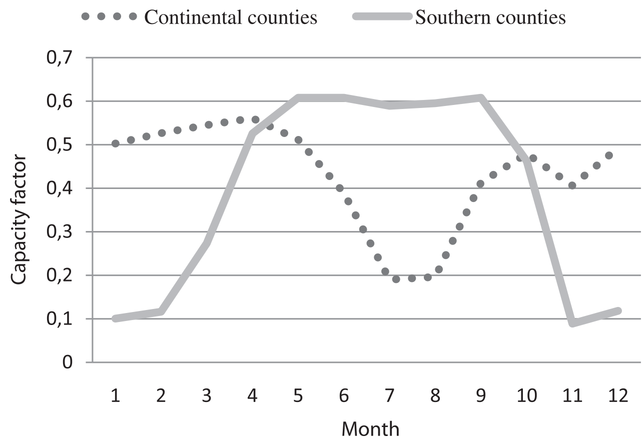


**Fig. 1.** Values of modelled capacity factors for Continental and Mediterranean counties.

### 2.3. The heat flux

The heat flux formula according to the regulations [22] is as follows:

$$\Phi = 0,9(\Phi t + \Phi l) - (\Phi i + \Phi s) \quad (8)$$

As the size of the losses due to ventilation and internal gains are difficult to calculate, and are both small considering the size of other values in brackets, they are ignored. The value 0.9 is a factor that diminishes the value of first bracket because of disruption of heating. The formula is now:

$$\Phi = 0.9(\Phi t \pm \Phi s) \quad (9)$$

Will the solar flux be added or subtracted depends on the season of heating or cooling. Cooling season lasts from fourth to ninth month in the northern counties and from third to tenth in the southern counties. Heating season runs from ninth to sixth month. In the northern counties the overlap is in fourth to sixth month and in the southern from third to sixth and in the tenth month. Calculating heating and cooling demand and its overlap is very difficult with this approach so it was made by a separate calculation. The formula for the transmission losses is as follows:

$$\Phi t = \left\{[U_e \cdot A \cdot (1 - fp)] + \left[U_e \cdot A \cdot f_p\right]\right\} \cdot h \cdot \Delta T \cdot cf \quad (10)$$

The solar flux is contained in a table with regard to different month and county and is calculated according to the standard ISO 13790 [21].

$$\Phi s = Fsh\,ob \cdot I \cdot As - Fr \cdot \Phi r \quad (11)$$

$$\Phi r = R \cdot U \cdot As \cdot hr \cdot \Delta\theta e \quad (12)$$

$$hr = 4 \cdot \varepsilon \cdot \sigma \cdot (\theta r + 273)^3 \quad (13)$$

Insulation values are taken from certifying regulation [23] for Continental and Mediterranean region of Croatia. In order to find out the consumption of the tourism and catering trade parts of the sector individually, the calculation of heat flux and the solar flux was made with only catering surfaces.

### 2.4. "Other" consumption

This is the second part of energy consumption of tourism–catering trade sector. Here the different objects in a tourism–catering trade sector are divided according to the official classification. These objects are then multiplied by the total surface in each county belonging to a particular type of object. Information on segments of objects is available with their consumption in kWh/m$^2$ [24] (Table 4b). Objects are multiplied with the consumption of segments depending on how many different segments particular object consists of. Consumption of segments is simplified and refers to values without air conditioning.

Fuel consumption is derived from total final energy demand in GWh. Percentages show the proportion of fuels in the southern Croatian counties [24] and in the north [25]. Fuel types are divided into electricity, gas, liquid fuels, and other. This division is thus simplified because detailed data on the percentage of shares was not available.

Gas refers to natural gas while liquid fuels are various petroleum products. Because the conversion factors, taken from Croatian energy balance [25], have various values for different petroleum products, in this work, conversion factor for liquid fuel is calculated with modelled value that consists of seventy percent of the conversion factor for fuel oil and thirty percent of conversion factors for other oil derivates. In the southern part of the country both thermal energy and natural gas are not available.

Cost in HRK (Croatian national currency) is calculated by multiplying fuel consumption with corresponding prices [25] per unit of measure. In addition, conversion was required only for liquid fuels because they are calculated per kilogramme, while the price is in HRK/l.

## 3. Energy demand projection

Total final energy demand of an entire sector is calculated by summarizing final energy demands for heating and cooling and "other" consumption. Throughout the consumption projection different scenarios are used. The first scenario is "Business as usual" and the other is "rational". When determining heat flux through the envelope in both scenarios, the annual share of new and demolished buildings in the fund is 0.5% for new buildings and 1% for demolished ones. The main difference in scenarios is the percentage of renovated surfaces while the savings came from reduced consumption. Renovations are represented with 1% in no change and 3% in "rational" version. Factors influencing the consumption are the annual increase in the number of buildings, renovated buildings annually, annually demolished buildings and modernization of equipment. The "rational" version has higher proportion of large renovations which includes solar panels, facade renovation, carpentry restoration etc. Under minor renovations we can include modernized lighting, LED lighting, reactive power compensator etc.

Apart from rational scenario two more scenarios are introduced for the purpose of comparing the differences between scenarios in regard with changes to the percentage of renovated buildings every year. All scenarios are summarized in Table 5.

Changes in these factors are linear, except for an increase of the season occupancy, which works so that each year the addition adds to the capacity factor, which multiplies the rest of the linear formula. The rest is linear with every year having the same amount of savings due to the renovation or cost of new buildings. These amounts are aggregated into the overall formula:

$$P_a = P_{a-1} + P_n - P_d - P_r + P_i \quad (14)$$

Consumption in an each year is equal to the consumption of last year, plus an annual increase in consumption of new buildings and extension of the season all subtracted with the reduction of consumption because of demolished buildings and the savings in renovation. It is important to note that in both versions after 2020,

**Table 5**
Values of different parameters that effect different scenarios.

| Scenario | Business as usual | Rational | Rational 2 | Rational 3 |
|---|---|---|---|---|
| New buildings | 0.50% | 0.50% | 0.50% | 0.50% |
| Destroyed buildings | 1.00% | 1.00% | 1.00% | 1.00% |
| Percent of renovations | 1.00% | 3.00% | 2.50% | 4.00% |
| Increase of capacity factor (2008–2050) | 0.001–0.017 | 0.001–0.017 | 0.001–0.017 | 0.001–0.017 |

following legislation, all new buildings and renovations are carried out as a passive construction.

Modelling renovations in the "other" consumption is made with the help from two tables, one containing mayor and minor savings for first and for second scenario. In all scenarios an increase of 2% of total demand per year is assumed ($P_{im}$). The formula for calculating the "other" consumption is as follows:

$$P_{am} = P_{am-1} - P_{rm} + P_{im} \tag{15}$$

$$P_{rm} = R \cdot P_{amB} \cdot S \tag{16}$$

Consumption in every year is the sum of final energy demand consumed through building envelope and modelled "other" consumption. Every scenario consists of these two areas of demand and in every scenario the same increase in season occupancy, percentage of new and destroyed buildings and an increase in total demand are assumed. The changes in renovations between scenarios imply reduction in demand for space cooling and heating in the first area of demand and a reduction in demand due to more energy efficient devices in modelled "other" consumption area. Percentage of renovations which changes in every scenario determines the square footage in the sector, for which either renovations of envelope or higher energy efficiency imply. Reduction of consumption from measures of higher energy efficiency is described in Table 6. From this data percentage "S" is derived. S is different for business as usual and rational scenario.

Total yearly demand equals:

$$P = P_a + P_{am} \tag{17}$$

The following part is the cost and benefit analysis. Methodology for fuel consumption and prices is identical in both versions of the projection. The cost of renovation is calculated by multiplying the renovated surface with the cost of certain renovations per square meter. The data on this cost was derived from several energy audits, but also from a previous work [26]. Major and minor renovations are listed in Table 7. The annual price changes are included in the projection while cost and benefit analysis was conducted between the two scenarios. What is compared, are the potential gains from renovations, expressed as the difference in costs of energy sources in two versions and the difference in costs, extra expenditure, in savings scenario.

**Table 6**
Major and minor renovations.

| Major renovations | Reduction of consumption | Minor renovations | Reduction of consumption |
|---|---|---|---|
| Modernization of boiler room | 25.00% | Replacement with thermostatic valves | 10.00% |
| Solar collectors | 40.00% | Reactive power compensator | 10.00% |
| Replacement of windows and doors | 35.00% | Lightning modernization | 15.00% |
| | | LED lights | 17.00% |

**Table 7**
Cost of renovations.

| Cost | HRK/m$^2$ |
|---|---|
| Lightning modernization | 5.74 |
| LED lights | 2.37 |
| Solar collectors | 80.80 |
| Reactive power compensator | 7.64 |
| Envelope renovation | 280.00 |
| Replacement of windows and doors | 171.44 |
| Replacement with thermostatic valves | 23.08 |
| Modernization of boiler room | 44.16 |

Comparison with the scenarios S1 and S2 from the National Energy Strategy [27] was made. Scenario S1 includes classic technologies without active government measures. Scenario S2 includes new technologies and active measures. Since there is no exact data for tourism–catering trade sector in National Energy Strategy, but only for the total services sector, values in the Strategy are multiplied with a factor bringing the demand to tourism–catering trade level.

## 4. Results and discussion

On Fig. 2 consumption including envelope and "other consumption" together is presented. It contains data for twenty Croatian counties and City of Zagreb and the data is expressed in GWh. Expectably larger and cooler counties have a larger heat demand. Specific counties stand out either due to their size in population or large temperature differences. Most puzzling is the Lika-Senj county as it has both Mediterranean and mountain parts. This may justify the large heat demand; however it requires verification with further detailed modelling.

On Figs. 3 and 4 a monthly final energy demand used for cooling and heating can be seen. The data follows the expectations, showing peaks for cooling in summer and for heating in winter. It is difficult to conduct error checking for these results as there is no other data on this subject that is known or available to the author.

Cooling energy presents a significant part of energy consumption in tourist–catering trade sector. On Fig. 5 percentage of cooling energy for every county in Croatia for the base year is presented. This percentage presents final energy demand for space cooling. Expectably southern counties have a much larger demand for cooling. Lika-Senj and Primorje Gorski-Kotar counties have both the coast and cold mountain areas so it is hard to make exact expectations from results. Based on the Figs. 3 and 4 the highest cooling demand is in the sixth month not the seventh or eighth, as expected. This is because the majority of this sector belongs to the catering side and quantitatively there is much more catering facilities in the north of the country where climate is in monthly

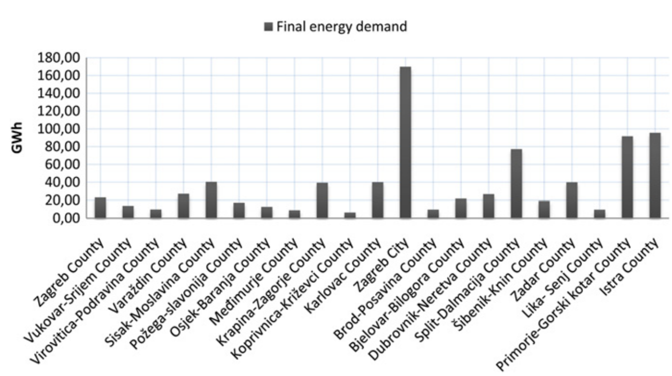


**Fig. 2.** Final energy demand for every county.

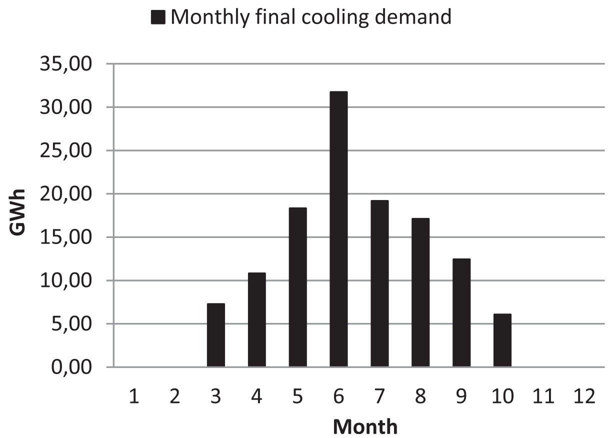


**Fig. 3.** Monthly final energy demand used for cooling.

average temperature colder than the south. Same effect can be seen when observing final energy demand for heating.

Fig. 6 shows the percentages of catering and tourist parts of the tourist–catering sector. These are the percentages of final energy demand. Majority of tourist objects are on the south, Mediterranean part of the country, while catering object are distributed more evenly from geographical perspective. Which objects belong to which sector is presented through Table 3.

### 4.1. Overall consumption projection

One of the focuses of this paper was also to present future energy demand projections of Croatian tourist–catering trade sector. One of the intentions was to compare different scenarios based on different mechanisms that would lead to energy saving in the future regarding this sector. Compared with Business as usual scenario there is a 21.32 percent increase in demand in Rational 1 scenario, 27.73 percent decrease in the Rational scenario and a 40.54 percent decrease in the Rational 2 in the year 2050. During forty years, demand has increased 50 percent in Business as usual scenario, 19.1 percent in Rational 1 scenario, 9,6 percent in Rational scenario and decreased for 10 percent in Rational 2 scenario.

Fig. 7 presents a long term energy demand projection; forty year projection of overall consumption of Croatian tourist–catering trade sector. Different curves present different scenarios as mentioned in methodology section. When observing differences in Rational 2 and Business as usual scenarios it is interesting to note increasing potential for savings with three percent increase in renovations. The change in the year 2020 is because of legislation which will require all new buildings to be passive.

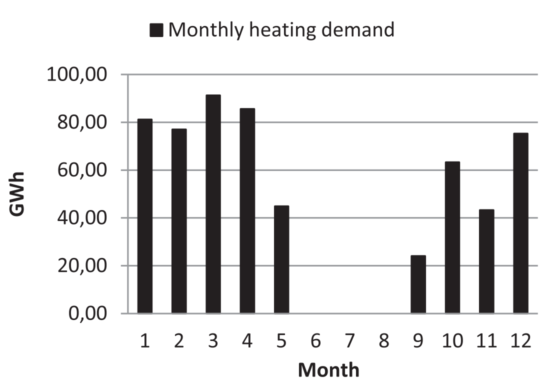


**Fig. 4.** Monthly final energy demand used for heating.

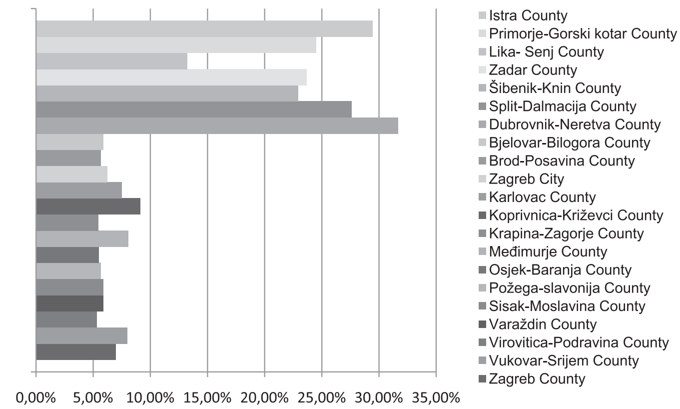


**Fig. 5.** Percentage of cooling energy of every county.

### 4.2. Cost and benefit analysis

Renovations and an increase in energy efficiency investments would lead to reduction of energy used in tourism–catering trade sector. This would also mean that the increase in investment cost would be necessary in order to follow this renovation paste. Energy efficiency scenarios would open the way for new jobs and play a part in the country's economic recovery. This could be seen as an opportunity for the construction sector to recover from the current economic crisis. Starting an investing cycle through massive buildings renovation would mean industry production boost together with possible export initiative. In this process it is important to track the ratio between energy savings and financial load necessary to achieve those savings.

In the Fig. 8 the rising grey lines represent profit from savings in different scenario each year and the black flat lines represents expenditure which is constant because each year the same amount of money is spent on renovations. Savings and expenditure are explained in methodology section. This figure shows the year in which investments in renovations become feasible. Observing this figure it would be safe to assume that significant increase in renovations investment does not significantly increase the feasibility. However, the scenario with the largest investment in renovations, the Rational 2 scenario, does have the quickest payoff and in the year 2050. The profit is 32.37 percent larger than scenario Rational and 48.56 percent larger than the Rational 1 scenario.

Fig. 9 shows the comparison between modelled scenarios and the National Energy Strategy scenarios. Modelled scenarios show a significantly lower energy demand suggesting bottom up modelling can lead to better quantification of all influencing factors. There is no data for the period between year 2030 and 2050 regarding national energy demand but assuming the same suggested trend line we can expect excessive overestimation of energy demand. The year 2010 is represented by data modelled in this paper for all scenarios.

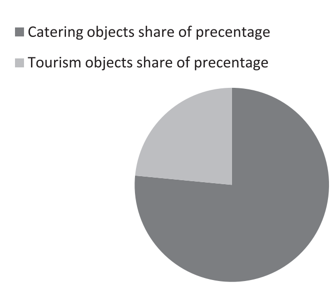


**Fig. 6.** Shares of catering and tourism parts of the sector.

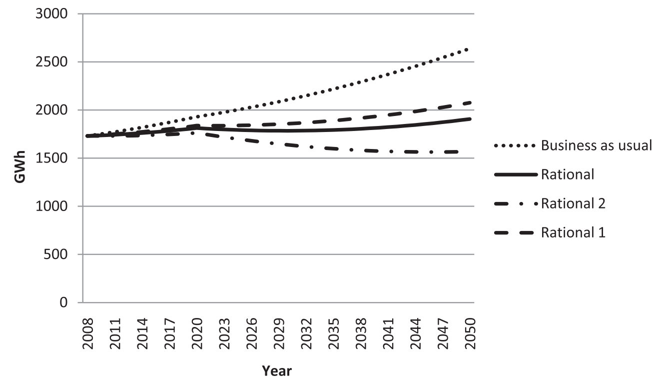


**Fig. 7.** Energy demand scenarios comparison.

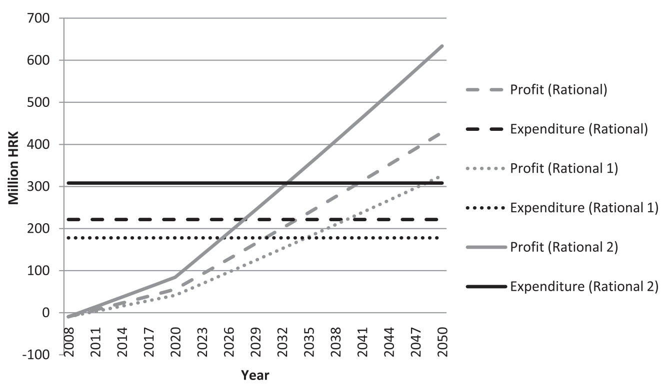


**Fig. 8.** Cost and benefit analysis.

Energy planning and especially energy demand projections were usually made by following trend-line assumptions which is the easiest way to go. Considering all new regulation regarding energy efficiency and renewable energy sources, future energy demand planning requires rational and careful approach in order to quantify all those elements. Through our results is it obvious that any kind of legal or financial mechanisms that would influence reconstruction paste could have a significant role in lowering future energy demand in the tourism–catering trade sector in Croatia. This assumption can be applied for all building sector in general, since envelope reconstruction presents a base for energy efficiency for buildings. This can of course have a long term consequence, since lowering energy consumption means lower energy dependence on foreign fossil fuel which should be a long term national interest.

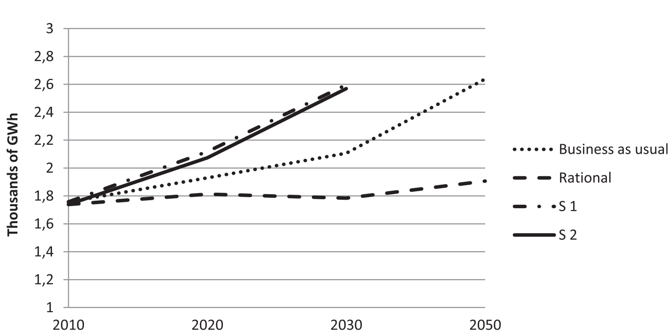


**Fig. 9.** Two scenarios compared with scenarios from National Energy Strategy scenarios S1 and S2.

## 5. Conclusion

In the first part of this work a model of consumption is explained for the Croatian tourism–catering trade sector. Following traditional thermodynamic calculation procedure, when it comes to heating and cooling demand, can lead to certain difficulties. One of the main reason is taking calculation procedures created for individual buildings and adopting them to be applicable for the entire sector. Using a base year as a correction factor, in order to test and certify all unavailable input data, has proven to be crucial for the observed sector. When comparing the developed model of total consumption, with the data available [28,29] on total consumption of tourism–catering trade sector, the difference between two mentioned values is less than 5%. This represented a good starting point for energy demand predictions which followed after the base year modelling. In the demand curve the most noticeable thing is a slight peak and then decline in consumption in the year 2020. After this, consumption, due to the increase of the season and general spending, increases. One of the key elements when observing final energy demand of the tourism–catering trade sector is decrease in energy consumption because of all measures regarding energy efficiency from one side, and an increase in energy demand because of increased tourist season and higher capacity factors from the other. Both of them are in lined with the higher efficiency for Croatian tourism and catering sector. The model of base year is satisfactory when using the annual data; however monthly data could be checked if such a source would be available. Simplicity of this model leaves room for an upgrade and while modelling of “other” consumption is the most simplified part of calculation; no detailed approach was attempted due to low amounts of available data. When using a bottom up model, input data presents a very important part of the modelling process. In this case quality input data was often unavailable which made things more difficult, especially when it came to assessing input data coming from different sources. Cost and benefit analysis shows that beyond year 2040 the savings compensate for the energy cost of all renovations. Higher increase in renovated surface does not imply faster payoff of investment. In comparison with other scenarios, it is important to note how the modelled curves differ from the scenarios presented on National Energy Strategy. National Energy Strategy predicts much higher consumption than what was modelled in this research. One of the reason probably lies in the fact that bottom up modelling usually predicts lower energy demand since it can describe and predict different mechanisms more precise than traditional top-down models.

## Nomenclature

| | |
|---|---|
| $B$ | beds, |
| $B_{Q2}$ | basic square footage for two bed rooms, $m^2$ |
| $B_{Q3}$ | basic square footage for three bed rooms, $m^2$ |
| $AF$ | added factor, |
| $H$ | number of hotels, |
| $AF$ | determines the scenario by which the county will be calculated depending on $B/HU$ ratio |
| $HU$ | housing units, |
| $SQF$ | floor surface, $m^2$ |
| $P_{SA}$ | percentage of studio apartments |
| $P_R$ | percentage of rooms |
| $P_A$ | percentage of apartments |
| $U_m$ | envelope heat transfer coefficient, $W/m^2K$ |
| $A$ | envelope surface, $m^2$ |
| $fp$ | prec. of windows in envelope |
| $h$ | hours in year, h |
| $\Delta T$ | inner and outer temperature difference, °C |

| | |
|---|---|
| $cf$ | capacity factor |
| $Fw$ | reduction factor for non perpendicular surfaces |
| $Fc$ | shades reduction factor |
| $\Phi_v$ | specific transmission heating loses, W |
| $V_h$ | heated volume, $m^3$ |
| $V$ | volume of building |
| $\Phi_r$ | additional heat flux for radiation into the cloud surfaces and sky, W |
| $R$ | thermal resistance of element, W/mK |
| $As$ | envelope surface according to the standard, $m^2$ |
| $\Delta\theta e$ | average outer temperature and sky temperature difference, °C |
| $I$ | insulation, Wh/$m^2$ |
| $Fr$ | form factor |
| $\Theta r$ | temperature and sky temperature difference, °C |
| $hr$ | outer heat transfer coefficient |
| $\varepsilon$ | envelope emission factor, W/$m^2$K |
| $\sigma$ | Stefan–Boltzmann constant, W/$m^2K^4$ |
| $Fsh\ ob$ | reduction factor for radiation on non perpendicular surfaces |
| $\Theta e, mj, min$ | minimal monthly outer temperature, °C |
| $\Theta i$ | outer temperature, °C |
| $\phi$ | heat flux, GWh |
| $\phi t$ | outer wall transmission loses, GWh |
| $\phi l$ | infiltration loses, GWh |
| $\phi s$ | solar gains or solar load, GWh |
| $\phi i$ | internal gains, GWh |
| $R$ | percentage of renovations |
| $S$ | percentage of reduced consumption |
| $P_a$ | annual consumption through envelope, GWh |
| $P_{a\text{-}1}$ | Past year consumption, GWh |
| $P_n$ | consumption due to increase in building fund, GWh |
| $P_d$ | consumption of destroyed buildings which is reduced, GWh |
| $P_r$ | consumption of renovated buildings, GWh |
| $P_i$ | consumption increase due to season increase, GWh |
| $P_{amB}$ | annual consumption of machinery in the base year, GWh |
| $P_{am}$ | annual consumption of machinery, water heating etc., GWh |
| $P_{am\text{-}1}$ | past year consumption of machinery, water heating etc., GWh |
| $P_{rm}$ | consumption of renovations in machinery consumption (reduced consumption), water heating etc., GWh |
| $P_{im}$ | increase in consumption for assumed annual consumption increase, GWh |
| $P$ | total yearly demand, GWh |

## References


[1] Schiff A, Becken S. Demand elasticity estimates for New Zealand tourism. Tourism Management 2011;32:564–75.

[2] Michalena E, Hills J, Amat JP. Developing sustainable tourism, using a multicriteria analysis on renewable energy in Mediterranean Islands. Energy for Sustainable Development 2009;13:129–36.

[3] Lai TM, To WM, Lo WC, Choy YS. Modeling of electricity consumption in the Asian gaming and tourism center—Macao SAR, People's Republic of China. Energy 2008;33:679–88.

[4] Psiloglou BE, Giannakopoulos C, Majithia S, Petrakis M. Factors affecting electricity demand in Athens, Greece and London, UK: a comparative assessment. Energy 2009;34:1855–63.

[5] Lund H, Duić N, Krajačić G, Graça Da, Carvalho M. Two energy system analysis models: a comparison of methodologies and results. Energy 2007;32:948–54.

[6] Krajačić G, Duić N, Zmijarević Z, Vad Mathiesen B, Anić Vučinić A, da Graca Carvalho M. Planning for a 100% independent energy system based on smart energy storage for integration of renewables and $CO_2$ emissions reduction. Applied Thermal Engineering 2011;31:2073–83.

[7] Sohn I, Binaghi C, Gungor P. Long-term energy projections: what lessons have we learned? Energy Policy 2007;35:4574–84.

[8] Duić N, Juretić F, Zeljko M, Bogdan Ž. Croatia energy planning and kyoto protocol. Energy Policy 2005;33:1003–10.

[9] Schneider DR, Duić N, Bogdan Ž. Mapping the potential for decentralized energy generation based on renewable energy sources in the Republic of Croatia. Energy 2007;32:1731–44.

[10] Pukšec T, Mathiesen BV, Duić N. Potentials for energy savings and long term energy demand of Croatian households sector. Applied Energy 2012. http://dx.doi.org/10.1016/j.apenergy.2012.04.023.

[11] Tommerup H, Svendsen S. Energy savings in Danish residential building stock. Energy and Buildings 2006;38:618–26.

[12] Koopmans CC, Te Velde DW. Bridging the energy efficiency gap: using bottom-up information in a top-down energy demand model. Energy Economics 2001;23:57–75.

[13] Bianco V, Manca O, Nardini S, Minea AA. Analysis and forecasting of nonresidential electricity consumption in Romania. Applied Energy 2010;87:3584–90.

[14] Bianco V, Manca O, Nardini S. Electricity consumption forecasting in Italy using linear regression models. Energy 2009;34:1413–21.

[15] Pao HT. Forecasting energy consumption in Taiwan using hybrid nonlinear models. Energy 2009;34:1438–46.

[16] Tso GKF, Yau KKW. Predicting electricity energy consumption: a comparison of regression analysis, decision tree and neural networks. Energy 2007;32:1761–8.

[17] Croatian Ministry of tourism, http://www.mint.hr/default.aspx?id=371; 2011 [accessed 01.12.11].

[18] Kolega V, Simetin V, Bertol Vrcek J, Gajic Capka M, Cvitan L, Kritovac F, et al. KUEN house-energy efficiency programme in buildings, previous results and further activities. Zagreb: Energy Institute "Hrvoje Požar"; 1998.

[19] Veršić Z. Prozori-Zahtjevi zvuk toplina. Internal script; 2007. Varaždin.

[20] Meteorological and Hydrological Institute of Croatia, www.meteo.hr, [accessed 27.10.2011].

[21] Group of authors. Energy performance of buildings-calculation of energy use for space heating and cooling ISO 13790. 2nd ed.; 2008-03-01.

[22] Croatian technical regulation on heat energy savings in buildings http://narodne-novine.nn.hr/clanci/sluzbeni/289083.html, Appendix C, [accessed 01.09.11].

[23] Croatian technical regulation energy certification of buildings, http://narodne-novine.nn.hr/clanci/sluzbeni/342062.html [accessed 09.09.11].

[24] Zanki V. Energy use and environmental impact from hotels on the Adriatic coast in Croatia-current status and future possibilities for HVAC systems, Stockholm, Sweden; 2006.

[25] Vuk B, Vukman S, Karan M, Fabek R, Zivkovic S, Maricevic M, et al. Annual energy report – energy in Croatia. Zagreb, Croatia: Ministry of Economy, Labour and entrepreneurship; 2009.

[26] Nekić I. Energy audit and analysis of recommended savings for the police academy, Graduate thesis. 2010, Zagreb.

[27] Group of authors. Adaptation and upgrade of Croatian energy strategy – green book. Zagreb: Ministry of Economy, Labour and entrepreneurship; 2008.

[28] Group of authors. Energy efficiency policies and measures in Croatia. Zagreb: Energy Institute Hrvoje Požar; 2009.

[29] Odyssee energy indicators database, http://www.odyssee-indicators.org/; 2011 [accessed 22.09.11].