RESIDENTIAL SOLAR ENERGY POTENTIAL FOR PUBLIC DISSEMINATION: A CASE STUDY IN CONCEPCIÓN, CHILE

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ABSTRACT

This paper presents a method for estimating the solar capture capacity of dwellings using the central urban area of Concepción, Chile, as a case study in order to promote self-generation of energy by residents. The method takes into account the growing domestic energy demand and the possibility of meeting this demand through integrated solar energy collection into buildings using different systems. The methodology considers a study of the potential incoming solar radiation on buildings according to their geographical location and the surrounding buildings. The capacity for solar capture is then estimated for different dwelling types according to their morphology. Subsequently, the energy contribution provided by different technologies (solar thermal, photovoltaic and hybrid) is identified in relation to the main average energy demands for electricity, water and space heating. Finally, systems for each dwelling are recommended in an urban map available online. The development is based on climate information, cartography, aerial photographs, surveys, housing models, technical standards, standardised calculations and dynamic simulations, implemented according to building layouts from an online Geographic Information System (GIS). The housing types are categorised in an urban map that relates household demands and the contribution of different solar energy systems. According to the estimates calculated, the residential units in the study offer sufficient solar capacity to supply between 40 and 60% of their energy consumption, especially in detached houses using roof-mounted hybrid systems.

KEYWORDS

solar energy, urban area, housing, solar map, Concepción, Chile.

1. INTRODUCTION

Cities have a high energy consumption and 45% of energy generated on the planet is used in urban activities (The Aalborg Commitments 2004). This demand is constantly increasing due to urban population growth and rising levels of services and comfort (Pérez-Lombard, Ortiz, and Pout 2008) (A.L. Martins, Adolphe, and E.G. Bastos 2014). Meanwhile, urban buildings could produce energy from renewable sources, such as solar radiation, by integration of

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capture systems. However, local use of this energy requires the specific analysis of several technologies in different building types (M. Grauthoff, U. Janssen 2012).

Chile, like typical developing countries, is strongly dependent on imported fuel, with high levels of pollution, fluctuating energy prices and insecure supplies due to restricted resources and over-congested electricity systems (Comite Técnico de la Plataforma Escenarios Energéticos 2030 2013). Thus, new alternatives for energy generation become necessary to meet energy needs, especially at a local level (on-site). In Chile, domestic solar capture systems are starting to be regarded through subsidies for thermal systems in the construction of new housing. Moreover, new legislation is being implemented concerning household supply to the national electricity network to encourage PV-installations, but high initial costs, ignorance of the technologies and a scarcity of information for the general public have meant the application is still limited (Comisión Ciudadana-Técnico parlamentaria para la política y la Matriz Eléctrica 2011).

In some cities of developed countries, maps of energy consumption and the solar potential of buildings have been made in order to promote on-site installations. Examples can be found in the United States, Germany and Spain (Mapdwell LLC 2014)(Jakubiec and Reinhart 2013). These works usually involve plans of the cities with graphic values for each block, plot or building, according to annual consumption rates for the main energy services and/or estimated ranges of solar radiation by its surface amount and location. In some cases, assessments for installing roof-level solar capture systems are provided (Dean et al. 2009). These are based on climate information and cadastral data implemented in Geographic Information Systems (GIS), (Borfecchia 2014), (Papadopoulos, & Hegger, 2012) and in some cases generated with volumetric models from LIDAR scanning (Alexander et al. 2009) (Jakubiec and Reinhart 2013) (Redweik, Catita, and Brito 2013). These procedures need a high level of computer processing and local calibration, along with substantial financing and centralised information that smaller cities do not possess. Local authorities in developing countries rarely manage their own services and lack the capacity to gather detailed data on their buildings. Besides, these methodologies calculate the full potential of the roofs for photovoltaic technology. However, they are not related to household demands, and current energy prices in the country make thermal energy more profitable (as there is no district heating). Specific analysis with tools like DIVA for Rhino design software can give detailed results, but for existing construction and installations they require much work to collect and process information.

Therefore, it is convenient to promote more comprehensive and effective methodologies for calculating dwelling solar potential and encourage household installation of solar systems through procedures to calculate radiation in different areas of the city using 3D topography and samples of building types. Then, using available information from GIS, statistics of services and classification of buildings, an estimate of electrical and thermal energy demand is calculated. With these values, solar systems are sized based on the requirements for electricity and heat, which is a particular feature of this methodology. Potential energy savings are then estimated for each household in the city depending on whether a thermal, photovoltaic or hybrid PVT solar capture system were to be installed on the roof and/or facade. Finally, an online interface with an urban map of buildings is generated, displaying results per unit that can be published for public dissemination.

2. MATERIALS AND METHODS

2.1 Methodology

The proposed process is based on general information and specific calculations developed over four stages (see Figure 1).

FIGURE 1: Schema of the Methodology.

The first stage estimates the incident solar radiation on the urban area based on meteorological data and general modelling of the topography. At this stage it is also necessary to calculate geographical obstructions as well as the percentage of shading on representative city squares with incident solar radiation, separated into buildings with a distribution of residential types according to available statistical information.

In the next stage, models of the different housing types are established according to build morphology, and they are distributed in a map of the urban area. In this way, the area of solar capture per residential unit can be estimated as well as annual energy consumption according to official data.

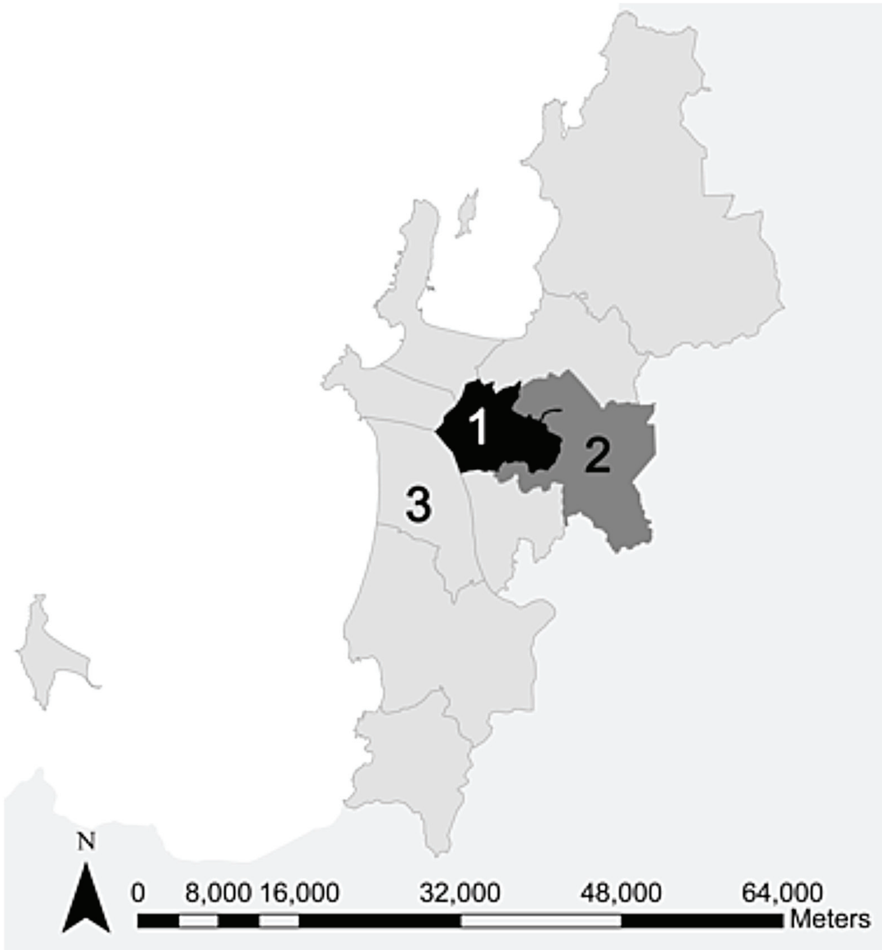
Subsequently, calculations are made to establish the energy generation capacities of the different solar capture technologies, and their eventual contribution in relation to the different domestic consumption amounts. This is determined in proportion to the size and performance of the different systems for the varying housing morphologies.

In the final stage, the process and information is inputted into an online information system by uploading records of city roof layouts onto the Internet, together with procedures to estimate installations and contributions based on location and size of the corresponding building polygons. A presentation interface is also developed with chromatic indications showing the different degrees of energy capture per building and an information frame listing values for each residential unit (houses or apartments).

2.2 Study area

The sector analysed is the urban area of the commune of Concepción, the central municipality of the main metropolitan area in the centre-south of Chile (see Figure 2), located at 36º46'22"S latitude and 73º03'47"W longitude. The area lies at the foot of the coastal mountain range on the northern banks of the Biobío River on the Pacific coast, 12m above sea level. These conditions create an irregular geomorphology of hills, gorges and plains. The region has a temperate oceanic climate with Mediterranean influence and four marked seasons. It has a population of 229,684 (estimate from the 2012 Census), with an average income level of US$23,165 (GDP) and economic activity based on services and on industry located in the surrounding communes. The commune has a variety of single-family homes and apartment buildings for the different socio-economic groups, with a diversity equivalent to the country and similar developing nations.

FIGURE 2: Urban area of Concepción (1), commune area (2) and metropolitan area of Concepción (3).



3. ESTIMATE OF THE URBAN POTENTIAL

The solar capture potential of a building must take into account the urban morphology in a given geographical context. Since the process proposed could be applied to different locations, an estimate of general losses in annual incident radiation is initially necessary and can be figured from meteorological records. Therefore, urban potential refers to the amount of energy incident on built surfaces factoring an estimated reduction according to specific obstructions due to topography, surrounding buildings and relevant urban infrastructure.

The urban area is analysed in a Geographic Information System (Arcmap with SHP format) in order to relate the street plan with a digital terrain model and with geo-referenced aerial photographs. Obstruction of incident solar radiation from topography and from buildings was analysed separately, incorporating the likelihood of shading from cloud cover and urban infrastructure (trees, overhead cables, signposts, etc.). Both analyses distinguished three levels of reduction in total radiation (high, medium and low) in predetermined urban sectors. Overlaying these two analyses results in nine distinct zones (see Table 2), each with a corresponding total value for incident radiation for the residential units located therein.

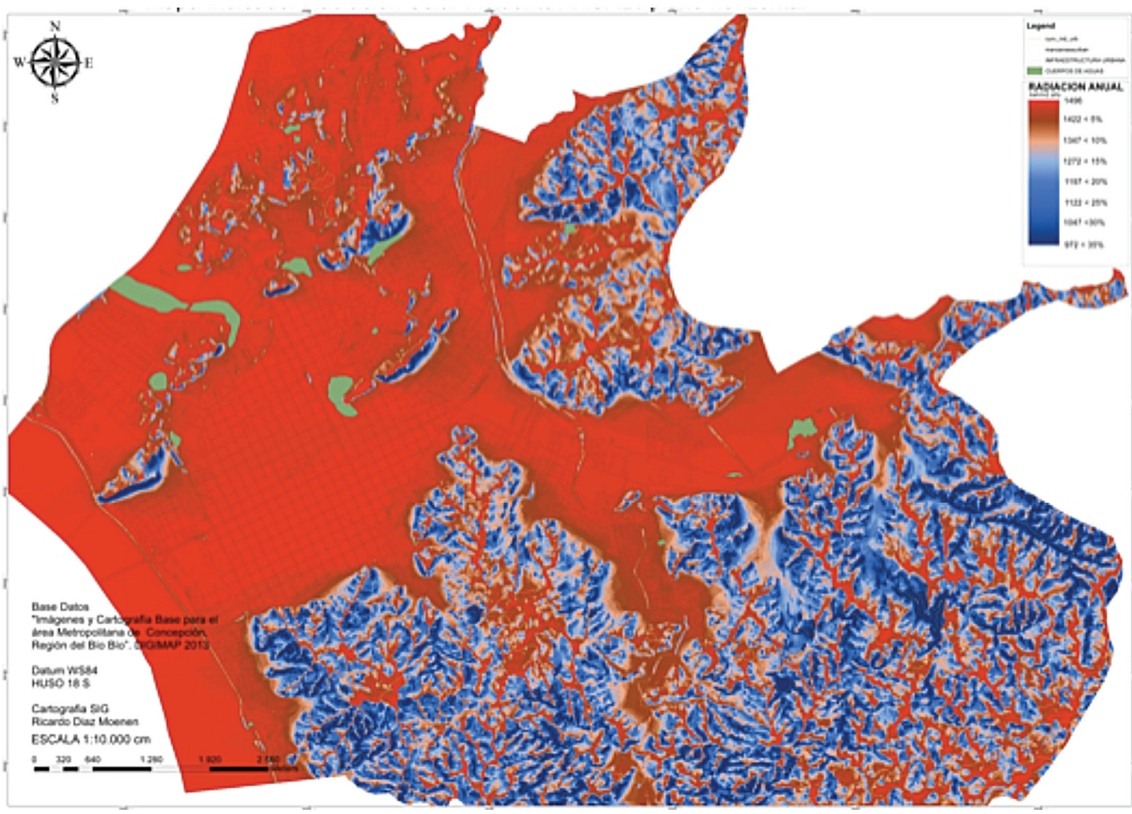
3.1 Average annual horizontal radiation

The average amount of radiation obtained in one year was calculated through the URBES simulation code (Merino 2013), which factors in climatic phenomena, sky models and digital techniques, incorporating calculations for direct, indirect and diffuse radiation. This gave an average value of 1,675KWh/m^2/year on an uncovered horizontal surface in the area of Concepción, with a range of proportional values according to tilt and orientation and further broken down for every day of the year.

3.2 Solar obstruction by topography

Topography is one of the main factors in determining the amount of incident solar energy on any geographical place (Dubayah and Rich 1995). CERCASOL software was used to calculate the topographical obstructions on the urban area by determining the amount of solar energy for different surface slopes and orientations. These were calibrated with the values from the URBES code, developing a procedure to georeference a Digital Terrain Model of 5x5m pixels in ARCVIEW 10.0. This procedure regards direct, indirect and diffuse radiation, but not reflection of ground and building surface that usually is scarce. Applied to the urban area of Concepción, the study shows that, between 20m and 50m above sea level, the solar energy potential falls between 1% and 40% (Díaz 2013). Thus, it can be seen that most of the urban area maintains adequate radiation levels for solar capture, with variable reductions in perimeter sectors and three radiation levels established for classifying different zones (see Error! Reference source not found.).

FIGURE 3: Plan of incident solar radiation on the topography of the commune of Concepción.

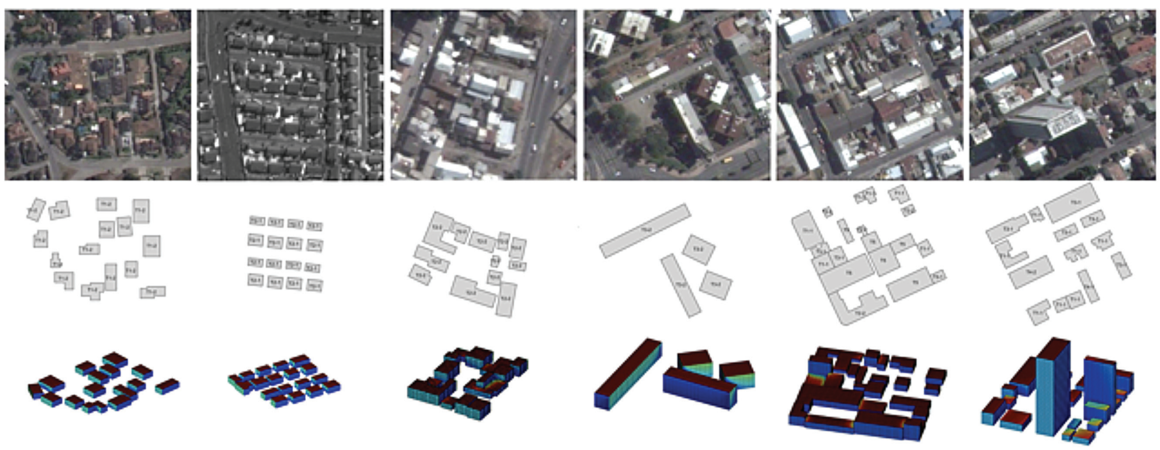


3.3 Solar obstruction by buildings

Calculations of solar energy loss due to neighbouring buildings or urban infrastructure refer to the analysis of radiation reaching the different built surfaces within a specific environment, which is unlike other studies based on complete volumetric models of the city by LIDAR flights; it studies radiation levels on city squares with groupings of similar buildings.

Six zones with clearly differentiated morphologies are identified, according to building size, density and urban pattern. One representative block is selected from each zone and analysed with the URBES simulation code (See Figure 4). The first blocks identified are from homogenous sectors. In the city of Concepción, this corresponds to approximately 40% of the urban surface, mainly on the periphery. These buildings are more recent and they have different construction types (defined as blocks A, B, C and D). The remaining zones, corresponding to 60% of the urban surface, possess a more heterogeneous conformation with a variety of housing types as well as service areas. These can be differentiated into two separate patterns (blocks E and F), mainly located in the city centre.

FIGURE 4: Representative blocks (photographs and models) analysed in the URBES simulation code.



Then, the average radiation is calculated for each representative block considering both the horizontal and vertical plane for each building. The block with the highest radiation is identified and the rest are calculated considering a decreased radiation caused by shadows of surrounding buildings. The effect of such surroundings is usually a significant reduction in incident radiation on the lower sections of a building's vertical surfaces, so solar potential of elevations below 7m (two storeys) is excluded from calculations. Table 1 shows that blocks with homogeneous building types (A, B, C) have a low percentage of horizontal radiation reduction, or, in other words, high solar potential on roofing. This stands in contrast to blocks of heterogeneous types (E and F), where three ranges of incident radiation (high, medium and low) are also established by zone. Roof tilt is factored later in the analysis according to building type and suggested solar technology.

Urban sectors

Lastly, the zones are combined according to topography and building obstructions, resulting in nine areas with different ranges of reduction, again categorised into three levels (Table

TABLE 1. Percentages and values used for each representative block.

Representative block	Housing types	Horizontal radiation [KWh/m^2/year]	Percentage of radiation
A	T1-2	1638	100%
B	T2-1	1638	100%
C	T2-2	1574	96%
D	T3-2	1637	100%
E	T1-1 T2-2 T3-1	1587	97%
F	T4-1 T4-2 T3-1 T1-1	1451	89%

2). Sectors with high radiation levels, i.e. ranges almost equal to unshaded horizontal plane capacity are found mainly in the intermediate zone of the city (flat areas with low-rise buildings). Intermediate sectors with an estimated 10% reduction in total incident radiation correspond to central zones with heterogeneous buildings or peripheral zones on sloping land. Sectors with low solar potential appear where building roofs receive approximately 80% of the radiation levels of unshaded surfaces and are located in peripheral zones with sloping land and heterogeneous building patterns.

TABLE 2. Reductions in radiation from topography and buildings.

Overlaid radiation level	Percentage obstruction from topography [%]	Percentage obstruction from buildings [%]	Overall radiation percentage [%]	Overall radiation level
high-high	1%	1%	98%	high
high -medium	1%	2%	97%	high
high -low	1%	10%	89%	medium
medium- high	5%	1%	94%	high
medium-medium	5%	2%	93%	high
medium-low	5%	10%	85%	low
low-high	10%	1%	89%	medium
low-medium	10%	2%	88%	medium
low-low	10%	10%	80%	low

4. ESTIMATE OF THE RESIDENTIAL POTENTIAL

The residential potential refers, in this methodology, to an estimate of the capacity for residential buildings to capture solar energy according to the typological shape. This depends on the amount of external surface area per residential unit, while also taking into account the potential percentage for use of such a surface (part available for installing equipment). Besides, all roofs are regarded as horizontal surfaces, as if it were a flat roof, similar to other research (Bayod-Rújula, Ortego-Bielsa, and Martínez-Gracia 2011)(Izquierdo et al. 2011), with average tilts included later when the performance of solar capture equipment is calculated. Previous studies in this zone examined geometric characteristics such as building orientation and roof tilt (Araya-Muñoz et al. 2014) (Bergamasco and Asinari 2011). Then, representative typologies are defined according to the existing variety (Theodoridou et al. 2012). Energy consumptions are also included in calculations, since these patterns vary according to the building types and their physical characteristics.

4.1 Building types

First, construction records from the Municipal Department of Public Works are used to identify building types. These records have a total of 90,000 properties recorded with 110,000 building classified into 47,000 urban polygons. This information is stored in spreadsheets linked with GIS system mapping and is constantly being updated. The database includes block location, property registration number, the year when the authorisation was issued, amount of separate constructions, amount of storeys, total and floor-by-floor surface areas, building structure, date, registration number when the building was completed, legislation applied, observations, building use and an identification number for each plot of land. Aerial photographs and on-site visits are also used to verify information.

Secondly, to establish the housing morphologies, the data from the municipal records are filtered to select only buildings used for residential purposes. Later, these are subdivided by building height into houses (with one or two storeys), small apartment blocks (with 3 to 5 storeys) and high-rise towers (with six or more storeys); and assigned an initial nomenclature for each one. Apartment blocks and towers are collective housing that usually accommodate several families. This classification by building use and height is simple enough to be determined directly in other cities where public records do not linked to maps as those in Concepción. Then, each of these basic categories is subdivided in two, according to conditions affecting their energy performance and floor area. Subsequently, each building type is classified according to whether it showed a high, intermediate or low capacity for solar energy capture based on its geometric features.

The single-family homes are divided into two main types, according size and adjacency; one sub-type with larger surface and detached shape (T1), and the other sub-type with less area and semi-detached or terraced shape (T2), which have also different housing densities. Later, smaller single-family homes (T2) are subdivided according to the year they were built: newer constructions built after 2006 that have thermal regulations (T2-1), and older buildings built before 2006 (T2-2). Mid-rise multi-family residences (T3) are also classified according to whether they were grouped (T3-1) or independent (T3-2). High-rise apartment buildings (T4) are separated according to number of storeys, between 6 and 10 (T4-1), and over 10 (T4-2). This morphological variety reflects the diversity of housing in the city, similar to other developing urban centres (with different sizes and material conditions). Differences are related to building size, which in turn depends on the different socio-economic levels and energy consumption patterns as well as the urban distribution, giving a total of 24 categories.

The average characteristics of each housing type are based on the municipal records. These include range of storeys, amount of units per storey and amount of units per building. The percentages of useful roof surface and facades are also estimated for each type and verified through aerial photographs and site visits (Table 3). While all the roofs are considered flat, the calculation of the energy for the different systems considers a tilt similar to the latitude of the city because dwellings have roofs close to this angle or horizontal coverings that can accommodate panels with this inclination.

TABLE 3. Housing types and useful surface area calculations .

Building type	Name	Range of storeys	Average number of storeys	Units per storey	Units per building	useful roof area [%]	useful wall area [%]
Housing	T1 y T2	1 o 2	2	1	1	25%	0
Multi-family residences	T3	3 a 5	4	6	24	30%	20%
Apartment buildings	T4	>6	15	10	150	50%	20%

The sub-types are then characterised and quantified (Table 4), indicating the floor area per unit and total floor area for each building. This allows estimating the number of people inhabiting each building type in the urban area of the commune.

TABLE 4. Record of housing types and sub-types in the urban area of Concepción.

Types	Characteristic	Sub-types	Average floor area per unit [m^2]	Amount of Residential units	Total floor area [m^2]	Number of people
Type 1 larger single-family homes	higher density	T1-1	210	4,223	205,800	13,720
	lower density	T1-2	200	979	844,605	56,307
Type 2 semi-detached and terraced houses	constructed > year 2006	T2-1	86	5,155	443,436	29,562
	constructed < year 2006	T2-2	75	20,246	1,557,839	103,855
Type 3 mid-rise dwellings	group of buildings	T3-1	60	10,139	572,259	38,150
	isolated buildings	T3-2	95	2,525	217,549	14,503
Type 4 towers	6 - 10 floors	T4-1	75	4,139	355,161	23,677
	> 10 floors	T4-2	60	15,903	786,385	52,425

The distribution of the different housing types in the city (See Figure 5) shows a homogeneous mix of single-family homes in the periphery, while in the downtown a wider range of types becomes evident when representative urban blocks are analysed.

4.2 Identification of roofs area

The digital map of the area studied shows the polygon of each residential building (a shape file (shp), which is georeferenced with the urban terrain and associated data, and it can be regarded as equivalent to the horizontal roof projection (Bergamasco and Asinari 2011). Each layout is manually verified from aerial photographs, showing some inaccuracies, which are then verified using street photographs or visits. Each housing unit is then located within the

FIGURE 5: Distribution of housing types in the urban area of Concepción.

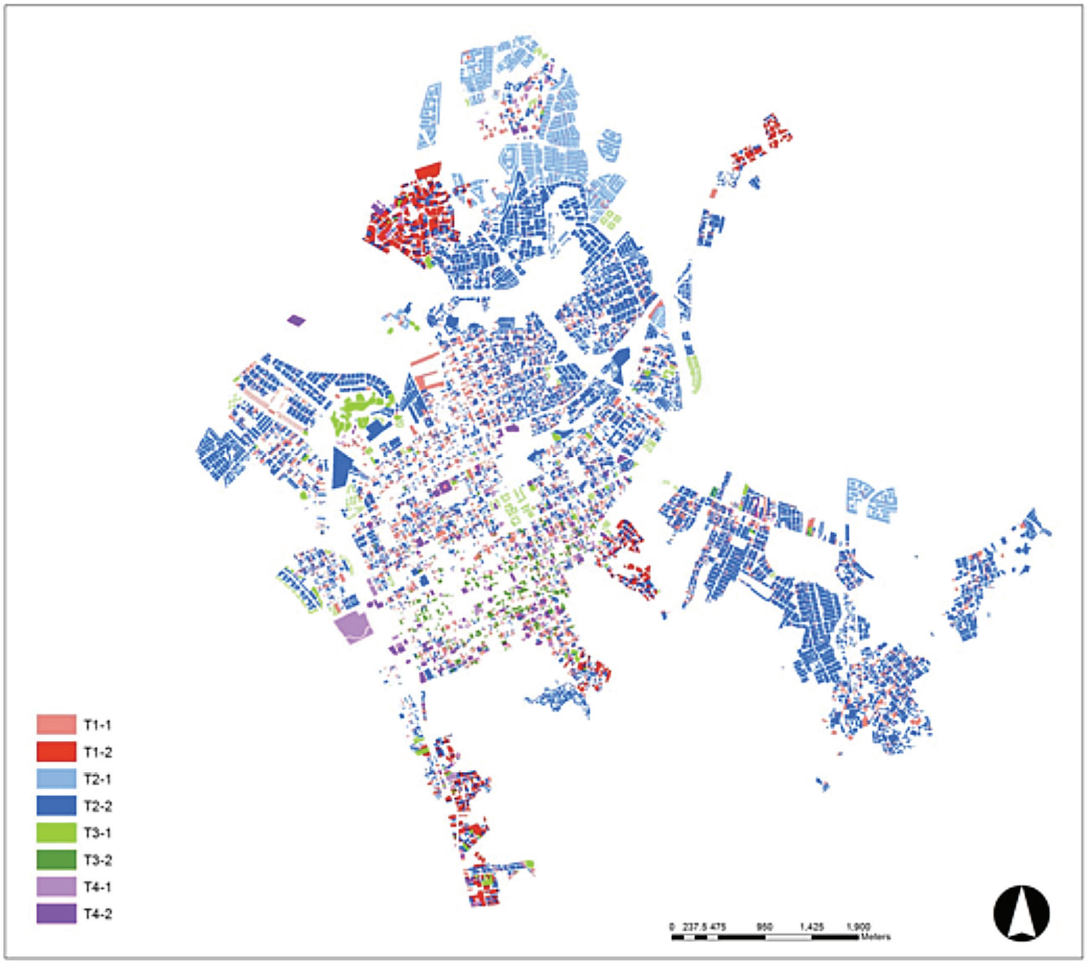


FIGURE 6: Roof polygons (fragment).

map, according to its type, block and obstruction sector, and the analysis area is calculated (differentiated by unit in the case of multi-family buildings).

4.3 Area of solar capture

A fraction of the total surface of each building envelope is estimated for installing solar energy systems, and then calculated with the annual radiation received in the corresponding surface. This is called 'useful area'. This percentage varies depending on the type. In roofs for houses it is regarded as 25% of the useful area (assuming they have a sloping roof); in blocks, a 30% useful area; and in high-rise towers, a 50% useful area (usually with flat or only slightly tilted roofs, but with servicing equipment installed). Calculations are thus made according to the following relationships:

Useful roof area ($A_{useful\ roof}$)) is equal to roof area (A_{roof}) multiplied by the useful roof area factor ($F_{usefulroof}$).

$$A_{usefulroof} = F_{usefulroof} \cdot A_{roof} \tag{1}$$

For dwelling facades the useful wall area ($A_{useful\ wall,h}$) is equal to zero. For apartment blocks and towers, the useful wall area ($A_{useful\ wall,a}$) is equal to the square root of the roof surface ($\sqrt{A_{roof}}$) multiplied by the number of storeys (N_S), the height of each storey (h_S) and the useful wall factor ($f_{useful\ wall}$). In multi-family buildings, an estimated 20% of the wall areas above the height of neighbouring buildings and vegetation can be used for solar installations.

$$A_{useful\ wall,h} = 0 \tag{2}$$

$$A_{useful\ wall,a}) = \sqrt{A_{roof}} \cdot N_n \cdot h_s \cdot f_{useful\ wall} \tag{3}$$

4.4 Estimate of energy consumption

The energy consumption of any home largely depends on the number of inhabitants and its size. These two factors are generally related but for a more accurate estimation each should be considered separately. Firstly, the number of inhabitants is calculated based on the floor area according to statistics collected. Consumption levels are then calculated per person and per unit of floor area as shown in Table 5. Daily hot water demands are fixed at 72 l/per person.

TABLE 5. Average consumption levels per person and per unit floor area in kWh/year.

	Per person	Per unit floor area
Hot water	1068	20
Electricity	728	25
Space heating	1595	133

To obtain the total energy use per home, the unit consumption levels are multiplied by the number of inhabitants or floor area accordingly and each of these results is duly weighted depending on relevance as shown in Table 6.

TABLE 6. Factor weighting for total consumption figures.

	Number of people	Floor area
Hot water	0.7	0.3
Electricity	0.5	0.5
Space heating	0.5	0.5

4.5 Calculation of residential potential by type

Finally, the residential potential for solar capture is calculated as the product of the incident radiation (per unit area) and the useful roof area. The incident radiation (G) depends on the angle of the solar panel (measured from the horizontal plane to the optimal capture angle or to the vertical plane in the case of wall installations).

$$G_{useful} = G \cdot A_{useful\ roof} \quad (4)$$

Then, useful radiation (G_{useful}) is equal to radiation (G) multiplied by the useful roof area ($A_{useful\ roof}$).

5. ESTIMATE OF SOLAR INSTALLATIONS

5.1 Values used

Three kinds of solar energy capture systems are considered to supply hot water or electricity: flat thermal panels, photovoltaic panels and hybrid photovoltaic-thermal panels (PV-T). The values for averaged data and the use of standard panels for building integration are shown in Table 7.

TABLE 7. Values used for solar capture systems.

Installation type	Capture area [m^2]	Efficiency
Solar thermal collector	2.2	50%
Photovoltaic panel	1.5	16%
Hybrid panel	1.6	Electrical: 7% (*) Thermal: 40%

(*) includes systems' internal consumption

5.2 Calculation of the energy generating capacity

Calculations for the systems are made per residential unit, giving priority to thermal energy production for hot water. If there is sufficient space remaining, photovoltaic panels can be added for electricity generation. Then, based on the solar potential, the useful building area and the efficiency values, the energy supplied and contribution to demand is calculated for each residential unit. The procedure provides data for the energy available from solar radiation, percentage of contribution to demand, and a graphic analogy to show the services supplied, such as the number of hot showers for thermal energy and light bulb consumption for electricity.

The energy available is calculated based on the useful roof area by type, and in the case of apartment buildings, also the useful surface area on the facade. In these cases, radiation is calculated on a vertical north-facing wall and the facade area is estimated assuming 20% usefulness.

Then, the area to supply up to 65% of DHW (Domestic Hot Water), based on the available roof area, is calculated according to equation 5. For the photovoltaic system, calculations are based on the available surface area, and then, the number of panels used to supply the home's electricity needs according to equation 6.

$$U_{p,i} = \min \left(\frac{C_{ACS,t} \cdot 65\%}{G_{uuseful} \cdot \eta_{th,i} \cdot A_{p,i}}, \frac{A_{useful,roof}}{A_{p,i}}\right) \tag{5}$$

$$U_{p,PV} = \min \left(\frac{A_{useful,roof} - U_{p,th} \cdot A_{p,th}}{A_{p,PV}} ; \frac{C_{elec,t}}{G_{util} \cdot \eta_{p,PV} \cdot A_{p,PV}}\right) \tag{6}$$

Subsequently, the energy generated is calculated as the product of the incident radiation, the number of panels, the area of the panels and the efficiency value, according to equation 7.

$$E_{th,p,th} = G_{util} \cdot A_{p,th} \cdot U_{p,th} \cdot \eta_{p,th} \tag{7}$$

The percentage of contribution to demand is calculated as a ratio between the energy generated and the average consumptions, with maximums of 65% and 100% for thermal and electric energy respectively.

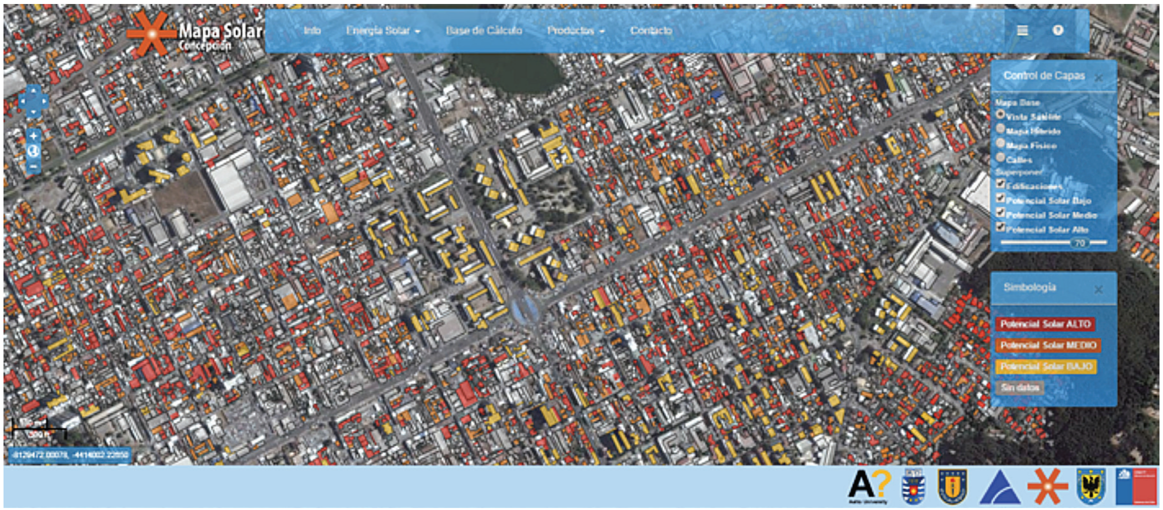
For the case of hybrid PV/T systems, the area is calculated in a similar way to the conventional thermal system with equation 5. Then, the energy generated for both DHW and electricity can be calculated with equation 7.

Finally, the equivalent number of hot showers and light bulbs is calculated. For hot water supply, the energy generated by the system is compared with one daily shower of 10 l/min for 7min at 40°C. The electric energy generated is compared with a 20W light bulb operating for 6 hours a day.

6. DISSEMINATION TO THE GENERAL PUBLIC

After establishing the urban map of buildings and the analysis procedure for residential units, the presentation is developed for an online platform (See Figure 7). This provides the inhabitants of the city with an estimate of the installation potential for each home. The website is structured on the Geographic Information System (in ArcGis software), with the records of roofs, associated data and calculations. The system is georeferenced and can be visualised above an aerial satellite picture, a physical map, a street map or a hybrid of these. Once a roof polygon has been identified, the corresponding calculation is made according to location, building type and geometric dimensions. The system Openlayers was used to set up the website, which extracts information provided by a geographic server in WMS format. The data is available on the Internet (currently at msc.ubiobio.cl) with a graphic interface made up of an initial presentation (with explanations about the characteristics and limitations of the information offered) and a map with two menus. One menu is on the upper side of the screen and another menu is to one side. The top menu gives information on the different kinds of solar energy systems and the calculation tables. The side menu indicates the different possibilities to visualise the values and an explanation for the colour codes of the polygons.

FIGURE 7: Map of solar potential in Concepción.

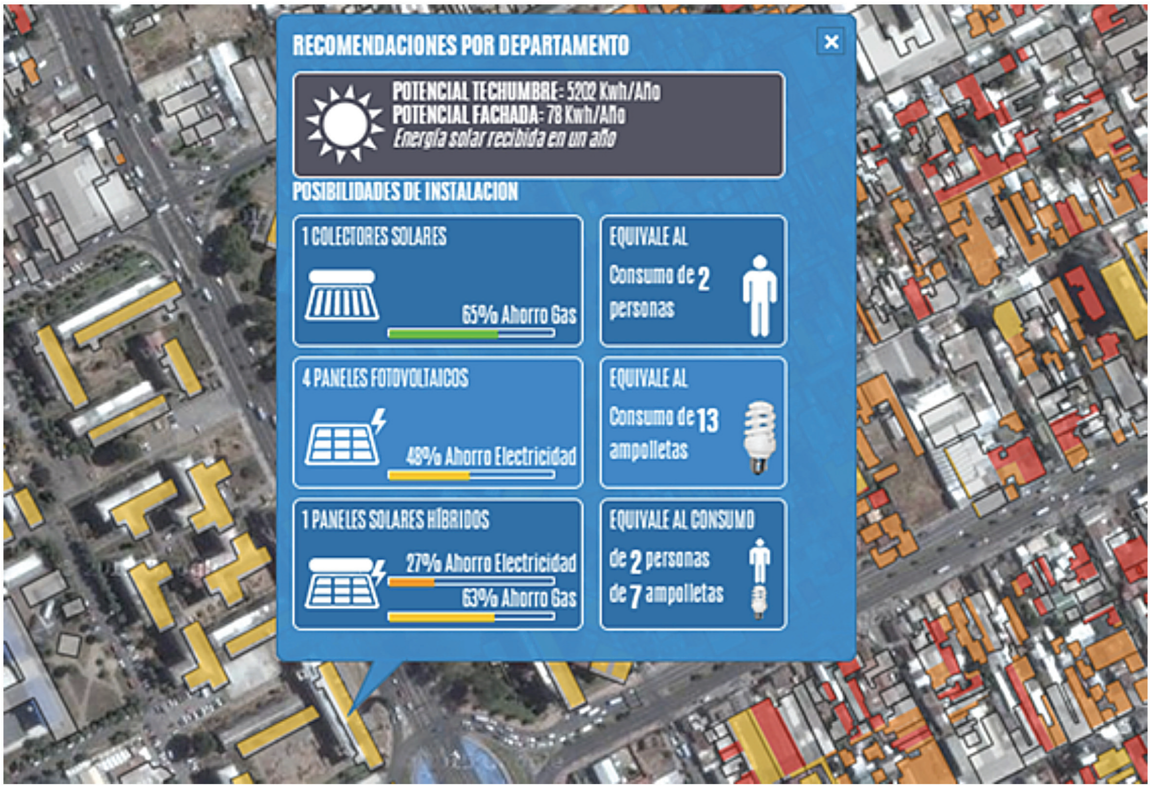


The polygons correspond to the perimeter of each building (equivalent to the roof), with a colour code corresponding to the radiation levels they receive; red for high potential; orange for medium potential; yellow for low potential; and grey for the buildings without available data (non-residential). The solar installations are determined according to the whole polygon for single-family homes, or are divided by the estimated number of residential units and storeys in the multi-family buildings. Once the polygon is selected, the information appears in an overlying frame giving the annual solar radiation received as the useful area of roofs and walls (in the case of apartment buildings) with values in kWh. The information (See Figure 8) also includes the amount of thermal, photovoltaic or hybrid panels, indicating the percentage of savings in gas and electricity expenses according to demand estimates. The amount of energy generated by the thermal panel is also exemplified by comparison with the number of daily hot showers, and in the case of the photovoltaic panels, with the number of 20W bulbs operating 6 hours daily. The platform and the data provided are intended for the public since surveys in the region demonstrate a low level of awareness on the issue. The system has been available online since November 21, 2014, when a presentation was made in the municipal offices. To date, the site has been mentioned dozens of times in the press and on other web-sites. There have also been numerous consultations for more detailed information.

7. CONCLUSIONS

This study describes a methodology to show housing residents that they can generate their own energy by incorporating solar technologies in their buildings. In this way, the city and more specifically the residential sector could reduce dependence on non-renewable sources of energy and decrease greenhouse-gases emissions into the atmosphere.

FIGURE 8: Information for a selected residence.



The methodology proposed can be applied to other cities since it involves basic information of the dwelling typologies with low data processing. Moreover, some cities that are not located in a complex topography can be analysed by estimating only obstructions caused by neighbouring buildings. Also, the procedure developed includes information of different solar capture technologies related to household demands, provided in an online graphic interface covering a wide range of examples.

According to the information analysed, the urban area of Concepción shows high solar potential due to the peripheral zone being largely homogeneous with single-homes capable of significant collection capacity to supply between 40 and 60% of total energy consumption, especially in detached houses using roof-mounted hybrid systems. In the downtown, there are height differentials between buildings, which generates internal solar obstruction, but even here, there is potential for solar capture. Overall, the city of Concepción offers the possibility of a significant contribution to current energy consumption by using domestic solar installations.

The process that has been developed must be verified in terms of estimations for specific buildings and the scope of information for public use. In both senses, according to the initial experience of six-month use, there has been growing public interest and no incorrect data has been identified. However, these aspects must be reviewed over longer periods and solar installations must be implemented to verify its performance. However, as the city grows and evolves, the current data can become quickly outdated. This information needs to remain linked to the city's building processes and regularly updated as urban planning is carried out to generate accurate indications for inhabitants and authorities.

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