SISTEME DE AER CONDITIONAT PE BAZA ENERGIEI CARE POATE FI REINNOITA

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Rezumat *– Litoralul romanesc al Marii Negre reprezinta destinatia pentru vacanta de vara pentru aproximativ 2.500.000 turisti. In lunile de vara, temperatura atinge adesea 35 grade Celsius. In astfel de situatii, este evident interesul autoritatii locale de a oferi servicii la standarde ridicate. Din moment ce costul pentru utilizarea aerului conditionat prin metode conventionale este foarte ridicat, in contextul unei dezvoltari sustenabile, au fost cautate surse de energie care pot fi reinnoite. Lucrarea analizeaza posibilitatile tehnice de a utiliza apa marii ca sursa de energie rece si sistem de absorbtie prin utilizarea energiei termice, solare. Sistemele HVAC care se bazeaza pe energia ce poate fi reinnoita se compara cu sistemele conventionale de compresie a vaporilor, din punct de vedere al eficientei.*

Cuvinte cheie: litoralul romanesc, temperatura, aer conditionat, metode conventionale, surse de energie regenerabile, apa marii, sisteme HVAC, sisteme conventionale de compresie a vaporilor.

1. Introducere

Tranzitia la economia de piata a influentat in mod radical sistemul industriei turismului, din Romania, dupa caderea sistemului comunist. Dupa 90, au fost implementate programele speciale de privatizare, care au dorit imbunatatirea eficientei economice. Eficienta energiei este unul dintre punctele slabe ale industriei turismului, din moment ce majoritatea hotelurilor au fost construite acum 20-30 ani, fara a lua in calcul costurile energiei pentru incalzire, aer conditionat, iluminat si instalatii electrice, apa curenta, lifturi si asa mai departe.

AIR CONDITIONING SYSTEMS BASED ON RENEWABLE ENERGY

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Abstract *- The Romanian Black Sea coast is the summer vacancy destination for approximately 2.500.000 tourists. In the summer months, the temperature reaches often 35 degrees Celsius. In such circumstances, the local authority interest for offering services at high standards is obvious. Since the cost for air conditioning using the conventional methods is very high, in the context of sustainable development, renewable sources of energy have been sought. The paper analyses the technical possibilities of using the seawater as source of cold energy and absorption system using solar thermal energy. The HVAC systems based on renewable energy are compared to conventional vapor compression system from the efficiency viewpoint.*

Key words: Romanian Black Sea coast, temperature, air conditioning, conventional methods, renewable energy sources, seawater, HVAC systems, vapor compression system.

1. Introduction

The market economy transition influenced radically the Romanian tourist industry system after the communist system fall. After 90s, special privatization programs meant to improve the economic efficiency have been implemented. Energy efficiency is one of the weak points of the tourist industry since most of the hotels have been built 20 – 30 years ago not considering the energy costs for heating, air conditioning, illumination and electrical appliances, running water, elevators, and so on. Until the 90s, the potential for energy saving was not properly considered or completely neglected but the

Pana in anii 90, posibilitatea de a economisi energia nu a fost luata in calcul in mod adecvat sau a fost complet neglijata, dar cerintele pentru alinierea la standardele UE au necesitat reconsiderarea politicii energiei, in industria turismului. Primul pas catre o crestere a eficientei energiei a fost luat in 1994, cand au fost imbunatatite standardele pentru rezistenta izolarii termice. In plus, in contextul cresterii calitatii si disponibilitatii serviciilor turistice, interesul pentru o intretinere mai usoara si optimizare a serviciilor, a crescut in mod continuu.

Analiza consumului de energie dintr-un hotel trebuie sa ia in calcul locatia, mediul local si arhitectura cladirii. Acesti factori determina proiectul hotelului si multe dintre caracteristicile care afecteaza consumul de energiei al echipamentelor si utilajelor. Principalele utilizari ale energiei, in cadrul unui hotel/ motel pot fi impartite in: incalzire; ventilatie; aer conditionat; realizarea apei calde menajere (DHW), iluminatul; gatitul; altele.

Figura 1 prezinta masurile de comparatie pentru diversi consumatori finali de energie.

requirements for EU standards alignment required a reconsideration of the energy policy in the tourist industry. The first step towards an increase of energy efficiency was taken in 1994s, when the standards for thermal insulation resistance have been improved. In addition, in the context of raising the tourist services quality and availability, the interest for easier maintenance and optimizing of service offered increased continuously.

Analysis of energy consumption in a hotel should take into account the location, local environment and architecture of the building. These factors determine the design of the hotel and many of the characteristics affecting the energy consumption of equipment and plant. The main energy end-uses within a hotel/motel can be divided into: heating; ventilation; air conditioning; domestic hot water (DHW) production; lighting; cooking; others.

Figure 1 shows the comparative sizes of the different energy end uses.

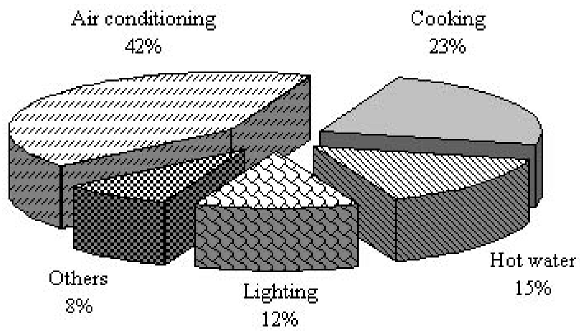

Figure 1. Structura puterii cererii pentru industria turismului / Structure of power demand for tourist industry

Pentru cladiri mari, statiuni si hoteluri, aerul conditionat reprezinta solicitarea principala in ceea ce priveste energia. Aceste cladiri mari au, in mod normal, aer conditionat cu apa rece proaspata, care circula in intreaga cladire. In mod specific, temperatura apei recirculate este intre 7 si 14 grade C. Unele unitati mari, de racire, racesc aceasta apa.

For large buildings, resorts and hotels air conditioning represents the major energy demand. These large buildings are normally air conditioned with fresh chilled water that circulates throughout the building. Typically, the temperature of the circulation water is between 7 degrees and 14 degrees C. Large refrigeration chiller units cool this water. The

Solicitarea electrica este, in mod normal, de 0.9 kilowat pe tona de aer conditionat. Un complex hotelier cu 1.000 camere poate avea o solicitare electrica pentru aerul conditionat de 1 megawat sau mai mult.

Avand in vedere consumul semnificativ de energie HVAC din hoteluri, pentru a dezvolta masurile necesare pentru un turism sustenabil, trebuie realizate in proiectarea sistemului HVAC. Aspecte importante sunt sursele conventionale si de energiei ce poate fi reinnoita si conditiile climatice si de mediu ale locului.

2. Sisteme de aer condensat, neconventionale

2.1 Racire prin presarea vaporilor

Sistemul de presare a vaporilor este cel mai utilizat sistem de racire din Romania si din lumea intreaga. Din moment ce nu exista retele comerciale de racire, construite pe litoralul Marii Negre, sistemele de racire din cladirile de cazare sunt realizare ca retele institutionale de racire sectoriala sau ca unitati individuale de racire. Coeficientul mediu al performantei - COP al unitatii de racire cu condensator cu aer racit este 3. Pentru temperatura de evaporare 3 ^{o}C si temperatura de condensare de 43 ^{o}C, teoretic, Carnot COP va fi de 6,6. COP este mai mare cu cat diferenta de temperatura intre evaporarea si condensarea temperaturii este mai mica. Sa presupunem ca temperatura COP constanta pentru evaporare poate fi imbunatatita prin scaderea temperaturii de condensare care modifica mediul de racire. Pentru aceeasi temperatura de evaporare, condensatoarele racite cu apa vor avea COPc =8,6, la o temperatura de condensare de 35 ^{o}C. Pentru a evita racirea turnului si pentru a contribui la pastrarea apei, ar fi rezonabila utilizarea apei marii pentru racirea condensatorului pe litorarul Marii Negre. Sistemul ar oferi COPc =11, la o temperatura de condensare de 28 ^{o}C.

2.2 Sistem de racire solara

Sistemul de racire solara va avea un

electrical demand is typically 0.9 kilowatts per ton of air conditioning. A hotel complex with 1,000 rooms could have an air conditioning electrical demand of 1 megawatt or more.

Bearing in mind significant HVAC energy consumption in hotels in order to develop sustainable tourism necessary sustainable measures should be done in HVAC system design. Important considerations are the availability of conventional and renewable energy sources and the climatic and environmental conditions of the location.

2. Non-conventional air condensing systems

2.1 Vapour compression cooling

Vapour compression system is the most utilized cooling system in Romania and worldwide. Since there is still no commercial district-cooling network built on the Black Sea coast, cooling systems in tourism facilities are made as institutional district cooling network or like individual cooling split units. Average coefficient of performance - COP of refrigeration unit with air cooled condenser is 3. For evaporation temperature 3 ^{o}C and condensing temperature of 43 ^{o}C, theoretical, Carnot COP would be 6,6. COP is bigger as temperature difference between evaporation and condensing temperature is smaller. Assuming constant evaporation temperature COP might be improved by lowering condensing temperature changing the cooling media. For the same evaporating temperature, water-cooled condensers would have COPc =8,6, at condensing temperature of 35 ^{o}C. In order to avoid cooling tower and to contribute to the water conservation, it would be reasonable to use seawater for the condenser cooling on the Black Sea coast. That system would give COPc =11, at condensing temperature of 28 ^{o}C.

2.2 Solar cooling system - absorption cooling

Solar cooling system would take full

avantaj intreg al energiei solare ca sursa de reinnoire a energiei pentru racire. Este una dintre cele mai atractive aplicatii ale energiei solare din moment ce cea mai mare solicitare de racire este pe durata celei mai ridicate izolari solare.

Sistemul proiectat pentru complexul de turisti este realizat dintr-o unitate de absorbtie de LiBr-H_2O. Generatorul de absobtie este actionat de apa fierbinte din recipientul de colectare, prin rezervorul de depozitare termala cu sprijin al incalzitorului electric, in timp ce amortizorul si condensatorul sunt racite cu apa de mare. De aceea, racirea turnului este evitata, la fel ca tratamentul si consumul de apa proaspata. Din moment de litoralul Marii Negre nu are retea de gaz, racitorul de amortizare poate fi utilizat doar actionat de petrol, ceea ce nu se aplica si nu este profitabil din punct de vedere economic.

2.3 Sistem de racire cu apa de mare

Considerand apa marii ca o sursa de energie, nelimitata, a fost analizata utilizarea in vederea racirii.Sistemul de racire cu apa de mare, este la baza, foarte simplu si este realizat din trei componente primare, statie de pompare la tarm si unitate de schimb caldura si retea distributie apa calda.

In general, apa la 6 ^oC se poate gasi intre 600- pana la 700-metri adancime iar apa rece la 4 ^oC poate fi obtinuta la o adancime de 800 metri. Statiunile, hotelurile si orasele platesc o energie scumpa si costul monetar pentru a raci A/C apa rulata. Pentru cele de pe linia litoralului adiacente apei marii care este adanca si rece, o funizare nelimitata de apa rece este adesea situata la o distanta de cativa kilometri in larg.

In cazul vemtilarii cu aer conditionat a spatiilor turistilor de pe litoralul Marii Negre prin utilizarea metodei SWC, un important avantaj este reprezentat de prezenta unui Strat Rece Intermediar, unde temperatura scade sub 8 ^oC la o adancime de aproximativ 50 m. Pe langa avantajul sursei de apa rece de adancime scazute, spatiile turistice sunt pozitionate in

advantage of solar energy as a renewable source of energy for cooling. It is one of the most attractive applications of solar energy since the biggest cooling demand is during the highest solar insolation.

System designed for tourist complex consists of absorption LiBr-H_2O unit. Absorption generator is powered by hot water from the collector field, through thermal storage tank with back up electric heater, while the absorber and condenser are cooled with seawater. Therefore cooling tower is avoided as well as fresh water treatment and consumption. Since Black Sea coast is not supplied with gas pipeline, absorption chillier might be use only powered by oil, that won't be applicable and economically valuable.

2.3 Seawater cooling system

Considering seawater as an unlimited source of energy, utilization for cooling purpose was analysed. Seawater cooling system is basically very simple and consists of three primarily components: the seawater transfer pipeline, shore pumping station and heat exchanger unit, and cold water distribution network

Generally, water at 6 ^oC can be found between 600- to 700-meter depths and water as cold as 4 ^oC can be obtained at 800 meters. Resorts, hotels, towns, and cities pay enormous energy and monetary cost to chill A/C circulating water. For those on the coastline adjacent to deep, cold seawater, an unlimited supply of cold water is often a few kilometers offshore.

In the case of air conditioning of tourist facilities on the Black Sea coast using SWC method, an important advantage is represented by the presence of a Cold Intermediate Layer where temperature drops below 8 ^oC at a depth of approximately 50 m. Beside the advantage of low depth cold water source, the tourist facilities are located in the very proximity of the shore; therefore, the length of sea water pipes and power demand for pumping are considerably reduced.

apropierea tarmului; de aceea, lungimea tevilor de apa de mare si solicitarea energiei pentru pompare pot fi reduse in mod considerabil.

Sistemul de racire al apei marii este realizat din doua noduri principale. In primul nod, pompele centrifuge atrag apa marii de la o adancime de 50m si apoi circula apa marii prin schimbatorul de caldura care este pozitionat in camera mecanica de la subsolul cladirii ce va fi racite. Unitatea schimbatorului de caldura este un schimbator din placa de titan, rezistenta la proprietatile agresive ale apei marii. Apa marii, incalzita, este apoi returnata in mare. Al doilea nod transporta apa de racire a cladirii. In schimbatorul de caldura, aceasta apa este racita pe masura ce caldura este transferata in apa marii. O pompa recircula apoi apa racita prin cladire. In cele din urma, aerul rece este livrat la fiecare etaj printr-un evantai de circulare a aerului care misca aerul cald al cladirii printr-o bobina de racire care este parte a nodului de racire a apei. Pentru a minimaliza costurile de pompare, pompele pentru apa mari sunt pozitionate cat mai aproape de nivelul apei marii.

Temperaturile tipice ale sistemului de circulare sunt in jurul a 8°C pentru apa marii si 8,8°C pe partea nodului cu apa proaspata – dupa racirea cu schimbatorul de caldura.

3. Analiza sistemelor

Sistemele proiectate au fost modelate si analizate prin utilizarea SIMULINK. Pentru cele trei sisteme descrise mai sus, analiza este realizata pentru un sezon de racire, 15 iunie – 15 septembrie. Analiza a fost realizata pentru fiecare zi a perioadei luate in calcul cu o etapa de o ora. Programul SIMULINK necesita definirea informatiilor de intrare, care contin temperaturile masurate pe ora si radiatia solara, debitul si parametrii pentru fiecare componenta a sistemului.

O incarcatura de racire de 180 kW este calculata pentru un complex de apartamente turistice care este format din 200 camere cu o zona totala de 6000 m^2. Pe langa pierderile de

The seawater cooling system consists of two main loops. In the first loop, centrifugal pumps draw cold seawater from the depth of 50 m and then circulate the seawater through heat exchanger that are located in the basement mechanical room of the building to be cooled. Heat exchanger unit is titanium plate heat exchanger resistant to seawater aggressive properties. The warmed seawater is then returned back to the sea. The second loop carries the building's cooling water. In the heat exchanger, this water is chilled as heat is transferred to the seawater. A pump then circulates the chilled water throughout the building. Finally, cool air is delivered to each floor by an air circulation fan that moves the warm building air through a cooling coil that is part of the cooling water loop. To minimize pumping costs, the seawater pumps are located as close to the seawater level as possible.

Typical temperatures in the circulation system are on the order of 8 ^{o}C on the seawater side and 8.8 ^{o}C on the fresh water loop side--after cooling by the heat exchanger.

3. Systems analysis

Designed systems were modeled and analyzed using SIMULINK. For three above described systems analysis is made for one cooling season, June 15th – September 15th. The analysis has been performed for each day in the period considered with the time step of one hour. SIMULINK program requires definition of input data, containing hourly measured temperatures and solar radiation, outputs and parameters for each component of the system.

A cooling load of 180 kW is calculated for tourist apartment complex consisting of 200 rooms with a total area of 6000 m^2. Besides transmission losses, hourly influence of the solar irradiation, infiltration and ventilation losses on the building structure are taken into account as well. Buildings are transmisie, influenta pe ora a iradierii solare, pierderile de infiltrare si ventilatie la structura cladirii, vor fi luate in calcu, de asemenea. Cladirile sunt proiectate in conformitate cu principiile unei arhitecturi pasive, prevenind iradierea solara, directa prin ferestre, si cu caracteristici termice ale materialului cladirii, de k=0.4 W/m^{2}K. Incarcatura estimata pentru racire pe metru patrat este de 30 W/m^2.

4. Rezultate

Rezultatele simularii au aratat ca sistemele de racire a apei marii utilizeaza 18.7% electricitate, in comparatie cu sistemele de racire pe baza presarii vaporilor. In acelasi timp, sistemul SWC furnizeaza o energie necesara pentru racire cu surse de energie, reinnoite, de 95%. Se presupunea ca sistemele de racire pentru absorbitie, actionate de apa fierbinte de la rezervoarele solare vor fi de calitatea a doua, dar analiza sistemelor a aratat ca acest sistem este cu 27% mai prost decat sistemul VC pe durata celei mai calde saptamani. Acesta este efectul solicitarii de energie suplimentara pentru sistemul de sustinere a incalzitorului electric, pentru a produce apa calda. In al doilea rand, a fost utilizat sistemul ABSOL care modeleaza rezervoare din tabla plata. Insa, sistemul VC este un sistem foarte eficient cu un COP teoretic cu 66% mai mare decat sistemul de presare a vaporilor cu condensator cu aer racit. Prin compararea sistemului ABSOL cu un astfel de sistem VC cu condensator cu aer racit, va oferi rezultatele asteptate, care arata ca sistemul de absorbtie are avantaje si posibile economii (figura 2). Condensatorul racit cu apa este mai convenabil in cazul in care sistemul este prevazut pentru functionare pe durata iernii, ex. daca hotelul lucreaza in sezonul de iarna cand sistemul de presare a vaporilor lucreaza in modul pompa incalzire. Insa, sistemul ABSOL nu necesita un echipament suplimentar pentru functionare pe durata iernii care contribuie la sustinerea sistemului. Apa calda pentru incalzire este furnizata din rezervoarele solare, existente, in timp ce, in cazul iradierii solare, este utilizat acelasi

designed according to principles of passive architecture, preventing direct solar irradiation through windows, and with thermal characteristics of building material of k=0.4 W/m^{2}K. Estimated cooling load per square meter is 30 W/m^2.

4. Results

The results of the simulation showed that seawater cooling system uses 18.7% electricity in comparison with the vapour compression cooling system. At the same time SWC system supply necessary cooling energy with 95% of renewable energy sources. It was expected that absorption cooling system powered by the hot water from the solar collectors will be second best, but analysis of the system showed that this system is 27% worst than VC system during the warmest week. This is the effect of supplementary power demand for the electrical heater back up system for the hot water production. Secondly, in the ABSOL system modeling flat plate collectors was used. However, VC system is high efficient system with theoretical COP 66% bigger than vapour compression system with air-cooled condenser. Comparing ABSOL system with such VC system with air cooled condenser would actually give expected results, which shows that absorption system has advantage and possible savings (figure 2). Water-cooled condenser is more convenient if system is predicted for winter operation, e.g. if hotel works during the winter season when vapour compression system works in heat pump mode. However, ABSOL system doesn't require any additional equipment for winter operation that contributes to the sustainability of system. Hot water for heating is provided from existing solar collectors, while in the case of low solar irradiation the same back up heater is used.

incalzitor.

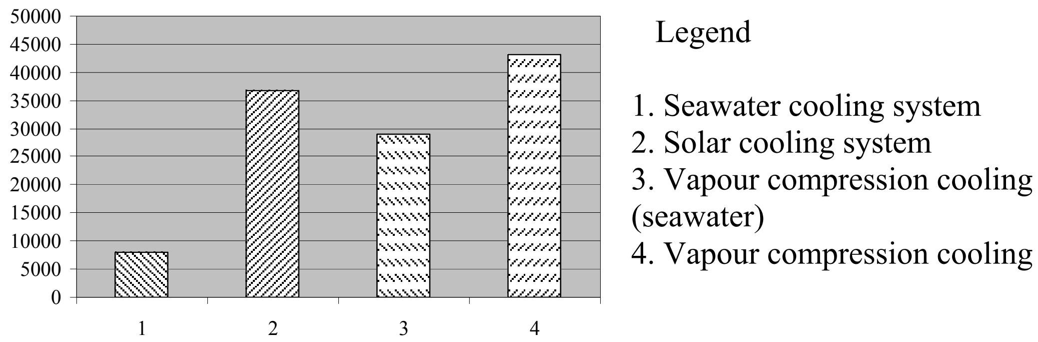

Figura 2. Solicitare energie in kWh – 15 Iunie – 15 Septembrie / Figure 2. Power demand in kWh – June 15th – September 15th

O analiza ulterioara a sistemelor de aer conditionat, neconventionale, ar trebui sa includa si viabilitatea si calculul perioadei de rambursare. Perioada de rambursare trebuie sa fie definita din moment ce costul capitalului total este impartit in economii anuale. Economiile permise de sistemele de racire cu apa marii sunt definite ca valoarea solicitarii electrice a racitorului la un sistem de racire cu aer conditionat din care se scade valoarea solicitarii electrice pentru pomparea apei de mare intr-un sistem cu apa de mare. De obicei, economiile sunt 80% sau mai bine, fara a include circularea apei proaspete si costurile ventilatorului din interiorul cladirii care sunt fixe atat pentru sistemele conventionale cat si pentru cele cu apa de mare. Se presupune ca intretinerea intre cele doua sisteme poate fi comparabila.

5. Concluzii

Incepand cu ultimul deceniu, prioritatile Guvernului Romaniei includ dezvoltarea sustenabila, mai ales pentru sistemele de energie si mediu, ca o componenta a strategiei de integrare a UE. Pentru a asigura standarde ridicate pentru industria turistica – care necesita cote de solicitare putere ridicata – infrastructura energiei trebuie sa fie restructurata. Componenta majora a solicitarii

Further analysis of non-conventional air conditioning systems should include economic viability and computation of payback period. The payback period should be defined as the total capital cost divided by the annual savings. Savings afforded by the seawater air conditioning system are defined as the value of chiller electrical demand in a conventional air conditioning system minus the value of electrical demand for the seawater pumping in a seawater system. The savings are typically 80 percent or better, not including the freshwater circulation and fan costs inside the building that are fixed for both conventional and seawater systems. Maintenance between the two systems is assumed to be comparable.

5. Conclusions

Starting with the last decade, the Romania's Government priorities include sustainable development, especially for energy and environment systems, as a component of EU integration strategy. In order to ensure high standards for tourist industry – which requires high power demand quotas – the power infrastructure should be restructured. The major component of power demand in tourist industry is represented by electrical energy, energiei din industria turismului este reprezentata de energia electrica, utilizata in mod conventional pentru aer conditionat, din moment ce lunile cu temperatura ridicata au cel mai mare flux de turisti.

Proiectarea noilor sisteme inovative cu o utilizare maximizata a surselor de energie ce poate fi reinnoita vor realiza economii semnificative in ceea ce reprezinta energia electrica, care este urmata de economiile semnificative, proportionale, in ceea ce priveste CO_2, prin utilizarea apei naturale racite, nu exista necesitatea agentilor de racire care cauzeaza golirea de ozon sau avertizarea globala. De asemenea, necesitatea unor turnuri de racire si utilizarea apei pentru racire, care este tratata chimic, va fi eliminata. Eliminarea utilizarii turnurilor de racire poate reduce consumul de apa rece si zgomotul.

Analiza celor trei sisteme proiectate, pot fi realizare imbunatatiri si economii cu o planmuire buna si un sistem sustenabil. Sistemul SWC poate fi anexat la cladirile existente sau utilizate pentru noi dezvoltari. Pentru noile structuri unde poate fi luat credit pentru ne instalarea racitoarelor conventionale, returnarea platii este semnificativ mai buna.

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conventionally used for air conditioning, since the high temperature months have highest affluence of tourists.

Designing new innovative systems with maximized use of renewable energy sources will accomplish significant savings in electrical energy, which is followed, by proportional CO_2 emission savings. Besides significant energy and CO_2 emission savings, using naturally chilled water there is no need for refrigerants that cause ozone depletion or global warming. Also, need for cooling towers and the use of chemically treated cooling water is eliminated. Eliminating cooling tower use can reduce fresh water consumption and noise.

Analysis of three designed systems showed that with good planning and sustainable system approach improvements and savings could be accomplished. The SWC system can be attached to existing buildings or used for new developments. For new structures where credit can be taken for not installing conventional chillers, the payback is significantly better.

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