THEORETICAL MODELING OF THE ENERGY EFFICIENCY OF A SHOPPING MALL

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Department of Mechanical Engineering
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ATATURK UNIVERSITY
INSTITUTE OF SCIENCES
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THEORETICAL MODELING OF THE ENERGY EFFICIENCY OF A SHOPPING MALL

(Bir Alişveriş Merkezinin Enerji Verimliliğinin Teorik Modellenmesi)

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TEZ KABUL VE ONAY TUTANAĞI

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Prof. Dr. Kadir BİLEN danışmanlığında Hamza ABUALESS tarafından hazırlanan bu çalışma, 16/08/2023 tarihinde aşağıdaki jüri tarafından Makine Mühendisliği Anabilim Dalı Termodinamik Bilim Dalı'nda Yüksek Lisans tezi olarak **oybirliği** ile kabul edilmiştir.

Jüri Başkanı:	Doç. Dr. İlhan Volkan ÖNER *Atatürk Üniversitesi*	Aslı ıslak imzalıdır
Danışman:	Prof. Dr. Kadir BİLEN *Atatürk Üniversitesi*	Aslı ıslak imzalıdır
Jüri Üyesi:	Doç. Dr. Faraz AFŞARİ *Erzurum Teknik Üniversitesi*	Aslı ıslak imzalıdır

Bu tezin Atatürk Üniversitesi Lisansüstü Eğitim ve Öğretim Yönetmeliği'nin ilgili maddelerinde belirtilen şartları yerine getirdiğini onaylarım.

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Not: Bu tezde kullanılan özgün ve başka kaynaklardan yapılan bildiriş, çizelge, şekil ve fotoğrafların kaynak olarak kullanımı, 5846 sayılı Fikir ve Sanat Eserleri Kanunundaki hükümlere tabidir.

ETİK BİLDİRİM VE İNTİHAL BEYAN FORMU

Yüksek Lisans Tezi olarak Prof Dr. Kadir BİLEN danışmanlığında sunulan "THEORETICAL MODELING OF THE ENERGY EFFICIENCY OF A SHOPPING MALL" başlıklı çalışmanın tarafımızdan bilimsel etik ilkelere uyularak yazıldığını, yararlanılan eserlerin kaynakçada gösterildiğini, Fen Bilimleri Enstitüsü tarafından belirlenmiş olan Turnitin Programı benzerlik oranlarının aşılmadığını ve aşağıdaki oranlarda olduğunu beyan ederiz.

Tez Bölümleri	Tezin Benzerlik Oranı (%)	Maksimum Oran (%)
Giriş	*3*	**30**
Kuramsal Temeller	*4*	**30**
Materyal ve Yöntem	*18*	**35**
Araştırma Bulguları ve Tartışma	*19*	**20**
Sonuç ve Öneriler	*0*	**20**
Tezin Geneli	*13*	**25**

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Beyan edilen bilgilerin doğru olduğunu, aksi halde doğacak hukuki sorumlulukları kabul ve beyan ederiz.

Tez Yazarı (Öğrenci)	Tez Danışmanı
Hamza ABUALESS	Prof Dr. Kadir BİLEN
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* Tez ile ilgili YÖKTEZ'de yayınlamasına ilişkin bir engelleme var ise aşağıdaki alanı doldurunuz.

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☐ Enstitü Yönetim Kurulunun …./…/…. tarih ve ………… sayılı kararı ile teze erişim 6 (altı) ay süreyle engellenmiştir.

APPRECIATION

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ÖZET

MNG Alışveriş Merkezi'nin enerji ayak izini azaltmak için yaptığı çalışmaları anlatıyor. Isıtma ve soğutma ayar noktası sıcaklıklarındaki değişiklikler, HVAC sistemi için ısı geri kazanımı eklenmesi, VAV'ın CAV hava dağıtım sistemine dönüştürülmesi ve duvar yalıtımı ve bağlantı programlarının değiştirilmesi kullanıldı. Bu prosedürlerin etkinliği, yakın gözlem ve istatistiksel analiz yoluyla ölçülmüştür. Alışveriş merkezi, her şeyi kapsayan bir strateji benimseyerek enerji faturasında çok para kazanmayı başardı, operasyonlarında daha verimli hale geldi, çevre üzerinde daha az etkiye sahip oldu ve sürdürülebilir bir kültürü teşvik etti. Bu vaka çalışmasından elde edilen içgörüler, diğer ticari binaların enerji verimliliklerini iyileştirmelerine yardımcı olabilir. Enerji verimli inşaat ve yenilenebilir enerji kaynakları son yıllarda irdelenmektedir. Binalar için temiz enerji üretimine örnek olarak güneş panelleri, rüzgar türbinleri ve jeotermal sistemler verilebilir. MNG Alışveriş Merkezi binası beş kattan oluşmaktadır; ilk iki kat otopark, zemin katın yarısı otoparka, diğer yarısı birinci katta perakende mağazalara, ikinci kat ise restoranlara ayrılmıştır. Toplam kullanım alanı yaklaşık 160 bin m2'dir. MNG 39.95 enlem, 41.17 boylam ve 4B ASHRAE iklim kuşağıdır. MNG Alışveriş Merkezi'nin dış yapısı, Malzemelerde İçeren Karbon ve Envanter için eşdeğer CO2 alt toplamının 59204916,8 (kgCO2) ve Gömülü Karbon Ara Toplamının 6826838,0 (kgCO2) olduğunu detaylandırır. Yapılarda Oluşan Karbon ve Envanter için eşdeğer CO2 ara toplamı 6826837,00 (kgCO2) ve Yapılaşmış Karbon Ara Toplamı 6599610,18'dir (kgCO2). Ve Glazing Gömülü Karbon ve Envanter için ara toplam eşdeğeri CO2 121491,7 (kgCO2) ve Gömülü Karbon Alt Toplamı 121491,7 (kgCO2)'dir. Ve MNG Alışveriş Merkezi için alt toplam eşdeğeri CO2 6948328,7 (kgCO2) ve Gömülü Karbonun Alt Toplamı 6721101,8 (kgCO2)'dir.

DesignBuilder modelleme

Bu tez çalışmasında MNG Alışveriş Merkezi binasının enerji performans analizi 160 bin m 2 inşaat alanına sahiptir. MNG Alışveriş Merkezi binası beş kattan oluşmaktadır; ilk iki kat otopark, zemin katın yarısı otopark, diğer yarısı ise perakende satış mağazaları; birinci kat perakende mağazaları, ikinci kat restoranlar yapılmıştır.

Bu amaçla yapı ilk olarak Revit programında üç boyutlu olarak modellenmiş ve tanıtılmıştır; ardından EnergyPlus v8.9 simülasyon motoru ile DesignBuilder v6.1.0.6 programına aktarılmıştır.

Bina kat kat Revit'te modellendi ve par ile modellenmeye başlandı; yer altındadır. Otopark katları hariç tüm katlar aynı koşullarda modellenmiştir. Ardından DesignBuilder programlarına aktarılmıştır.

Çalışma mevcut bir bina için yapıldığından tüm mimari ve mekanik tesisat projeleri verilmiş ve bu projeler binanın DesignBuilder'da tanıtılmasında kullanılmıştır. Ayrıca binada ve binanın bulunduğu alanda saha çalışması yapılarak yapının tüm bölümleri gezildi. Bina enerji yöneticisi ile istişare edilerek, projeden farklı olan sistemlerdeki değişiklikler not edilerek modelleme ve bina tanıtımında kullanılmıştır.

EnergyPlus simülasyon motoru

EnergyPlus, hesaplamalarında saatlik iklim verilerini kullanır ve geri bildirimleri dikkate alarak ısıtma ve soğutma yüklerini entegre bir şekilde hesaplar. Hesaplama sonuçları tercihe göre saatlik, aylık veya yıllık olarak alınabilir. Bu, EnergyPlus simülasyon motorundan ayrıntılı hesaplama sonuçları almayı mümkün kılar.

Simülasyon sonucunda HVAC sistem tasarımlarının bina yükleri, CO2 üretimi ve enerji tüketimleri yıllık, aylık ve saatlik olarak hesaplanmıştır. simülasyon sayesinde elde edilen enerji tüketimleri, ölçülen gerçek enerji tüketimleri ile karşılaştırılmıştır. Daha sonra makul yatırımlar ile tüm enerji tüketim sistemlerindeki enerji ihtiyacı minimize edilmiştir. Ayrıca binanın CO2 üretimi de incelenmiştir. Binanın ısıtma ve sıcak su ihtiyacı için doğalgaz tüketiminden CO2 üretimi hesaplanmıştır. CO2, elektrik tüketimi üretiminden kaynaklanırken, EnergyPlus hesaplamasında bulunan algoritmada ve binanın karbon emisyon faktörü ile toplam elektrik tüketimi çarpılarak elde edilir. Bina modellenirken ve tanıtılırken, binanın geometrisi, binanın yönü, HVAC ve aydınlatma sistemlerinin özellikleri, bina bileşenlerinin tanımı, bölgelerin kullanım amacı, iç ısıl kazançlar, konfor koşulları ve binanın bulunduğu yere ait saatlik güncel meteorolojik veriler programa girilir.

Araştırma Sonucu ve Tartışma

MNG Alışveriş Merkezi binası beş kattan oluşmakta olup, ilk iki kat otopark, zemin katın yarısı otopark, diğer yarısı perakende mağazalar, birinci kat perakende mağazalar, ikinci kat ise restoranlar olarak hizmet vermektedir. Toplam kullanım alanı yaklaşık 160 bin m2'dir.

Bu tez çalışmasında, incelenen bina design-builder v6 (EnergyPlus v8.9) ile simüle edilmiş ve binanın enerji tüketimi, dahili ısı kazançları, ısı kayıpları, ısıtma yükü ve CO 2 üretimi hesaplanmıştır. simülasyondan elde edilen enerji tüketimi (doğal gaz ve elektrik) ile gerçek enerji tüketimi karşılaştırılmıştır. MNG binasının aylık fiili doğal gaz tüketimini, MNG alışveriş merkezi binasının tüm yıllara ait gerçek enerji tüketim değerleri olarak gösterir. 2018'den 2021'e kadar olan enerji tüketim değerleri kullanılarak tüm yıllar için gerçek aylık güç kullanımı. Örneğin, aylık tüketim değeri yıllık ortalamadır. her ay, tüm yıllar boyunca MNG binaları tarafından tüketilen ortalama fiili doğal gazı gösterir. binanın enerji tüketimini en aza indirmek için yapılacak çalışmalar kapsamında, tüm yıllar için aylık ortalama fiili elektrik tüketimi. Güç ölçerdeki okumalar, tesisin enerji yöneticisinin binanın tüketimi olarak kaydettiği değerlerdir. bu bulgular MNG alışveriş merkezinin yıllık enerji tüketiminin 36.549.082,95 kwh olduğunu göstermektedir. Bu kullanımın yüzde 71,86'sını doğalgaz, yüzde 28,14'ünü ise elektrik oluşturuyor. Bina yıllık olarak tahmini 228,43 kwh/m2 enerji tüketimi kullanmaktadır.

Simulasyon sonuçları

EnergyPlus binanın aydınlatma, ısıtma, soğutma, havalandırma ve iklimlendirme sistemlerini ve sıcaklık, hız ve basınç dağılımını simüle edebilir. Isıtma ve soğutma planı, yaşanması beklenen en soğuk ve en sıcak sıcaklıklarla başa çıkmak için gerekli ısıtma ve soğutma sistemlerinin boyutunu belirler. Erzurum için DesignBuilder program hesaplaması, HVAC bileşenlerinin çalışması gereken sıcaklık aralığı için minimum -29,1°C ve maksimum 30°C'yi kullanır. MNG sahasının koordinatları (39.95, -41.17) ve ASHRAE iklim sınıflandırması 4B'dir.

Erzurum açık hava kuru termometre sıcaklığı. Ortalama kuru termometre sıcaklığı, Ocak ayında yaklaşık -2,82 santigrat derece ile Temmuz ayında yaklaşık 25,6 °C arasında değişmektedir. Atmosferik basınç değerinin aylara göre değişimi. Şekilden de görüleceği üzere atmosfer basıncı Şubat ayında 85765,66 Pa ile en düşük değerine ulaştı. Sahibi olurken -en yüksek değerine Aralık ayında 86712.01Pa ile ulaşıyor.Rüzgarın yön değişimi görülür. Aylara göre rüzgar yönü, çok şey değiştirir. Rüzgar yönü genellikle 54,57° ile 129,91° arasında değişmektedir.

Bölgenin rüzgar hızı 1,88 m/s ile 5,04 m/s arasında değişmektedir. Rüzgar hızı kışın düşük iken, ilkbahar ve yaz aylarında nispeten daha yüksektir.MNG binasına gelen aylık güneş enerjisi miktarındaki değişim. Direkt normal güneş enerjisi yaz aylarında artarak maksimuma ulaşır ve Haziran ayında maksimum 119,46 kWh/m2'ye ulaşmıştır. Yayılan yatay güneş enerjisi ise, yazın Temmuz ayındaki artışla ayda 116,7 kWh/m2 ile maksimum seviyeye ulaştı.

MNG Alışveriş Merkezi binası iç ısı kazançları, bölge duyulur ısıtma ve bölge duyulur soğutma yüklerinin aylara göre değişimi. En yüksek dahili ısı kazancı aydınlatmadan oluşur. Bu dahili ısı kazancını, dış pencere güneş enerjisi kazancı ve insanlardan, cihazlardan ve yemek pişirmeden elde edilen kazançlar takip eder. En yüksek bölge duyulur ısıtma yüküne 1,14 GWh ile Ocak ayında ulaşıldı.Enerji tüketiminin gerçekleştiği sistemler ve bu sistemlerde enerji tüketim miktarlarının aylara göre değişimi. En yüksek enerji tüketimi ısıtma yükünü karşılamakta ve 3,32 GWh ile Ocak ayında en yüksek değerine ulaşmaktadır. Kullanılan ısıtma yükünün karşılanmasında, kış aylarında doğalgaz tüketimi artarken soğutma grubu elektrik tüketimi sıfırdır. Yaz aylarında ısı üretiminde kullanılan doğalgaz tüketimi azalırken, soğutma grubunun elektrik tüketimi artıyor. Diğer değişkenlerin enerji tüketimi yıl boyunca neredeyse sabittir. Oluyor.

MNG Alışveriş Merkezi binasının sistemlere göre yıllık enerji tüketim değerleri. MNG Alışveriş Merkezi'nde tüketimi en fazla olan sistemler ısıtma ve aydınlatma sistemleridir. Isınma için tüketilen enerji 12,06 MWh iken, aydınlatma için tüketilen enerji 7,23 MWh'dir.

MNG Alışveriş Merkezi binasının aylık CO 2 üretimi. Binanın doğal gaz ve elektrik tüketimi sonucunda CO2 üretimi oluşmaktadır. Şekilden de görüleceği üzere CO2 üretimi kış aylarında artarken yaz aylarında azalmakta ve yıllık toplam CO2 üretimi 1.211.803 kg'a ulaşmaktadır.

Senaryolar ve Stratejiler

MNG Alışveriş Merkezi binasının CO2 üretimini ve enerji tüketimini azaltmak için beş senaryo ve strateji bulunmakta ve sonucu gösterilmektedir:

1. Isı geri kazanımı ekleme

Mevcut klima santrallerine ısı geri kazanımı eklenerek toplam enerji tüketimi azaltılabilir.

2. Isıtma ayar noktası sıcaklıklarını değiştirin.

Toplam enerji tüketimi, zeminin ısıtma ayar noktası sıcaklıklarını önerilen aralıklara düşürerek veya artırarak azaltılabilir.

3. Soğutma ayar noktası sıcaklıklarını değiştirin.

Toplam enerji tüketimi, zeminlerin soğutma ayar noktası sıcaklıklarını tavsiye edilen aralıklara düşürerek veya artırarak azaltılabilir.

4. Hava dağıtım sisteminin VAV'dan CAV'a uyarlanması

mevcut hava dağıtım sistemini VAV'dan CAV'a uyarlayarak enerji tüketimini azaltın.

5. Poliüretan duvar izolasyonu.

MNG Alışveriş Merkezi binasının duvar yalıtım tipi yün taştan Poliüretana değiştirilerek toplam enerji tüketimi azaltılabilir.

Senaryolar ve stratejiler ile aralarındaki farklar hakkında bilgiler, örneğin:

• Tüm en yüksek CO2 üretim ayları stratejileri arasında en yüksek değer VAV stratejisidir. Ocak ayında yaklaşık 1480181 değerindedir. En yüksek aylık stratejiler arasında

CO_2 üretiminin en düşük değeri, OCA'da yaklaşık 900065,3 değerinde ısı geri kazanım stratejisi eklemektir.

• En düşük ay stratejileri arasında en yüksek CO_2 üretimi değeri VAV stratejisidir. HAZİRAN'da yaklaşık 819814,6 değerinde. Tüm en düşük strateji ayları arasında CO_2 üretiminin en düşük değeri, HAZİRAN'da yaklaşık 541911,3 olarak değerlenen temel oluşturma stratejisidir.

• Tüm stratejiler arasında en yüksek yıllık CO_2 üretimi değeri VAV'dır. Yaklaşık 12336878.3 değerindedir. Ve tüm stratejiler arasında en düşük yıllık CO_2 üretimi değeri, yaklaşık 8407590,8 değerindeki Poliüretan Duvar yalıtımıdır.

• CO_2 üretimi için en iyi tasarruf stratejisi, ısı geri kazanımını eklemektir. Yaklaşık 1142461.4 değerindedir. Ve CO_2 üretiminin en kötü stratejisi VAV'dır; yaklaşık -3334850.9 değerindedir.

• Stratejilerin en yüksek ayları arasında en yüksek enerji tüketimi değeri, OCA'da yaklaşık 4970477 değerle VAV stratejisidir. En yüksek stratejiler arasında en düşük enerji tüketimi değeri ise Temmuz ayında yaklaşık 3582905 değerle ısı geri kazanım stratejisidir.

• Stratejilerin en düşük ayları arasında en yüksek enerji tüketim değeri VAV stratejisidir. Nisan ayında yaklaşık 2724284 değerindedir. Temel oluşturma stratejisi, stratejilerin en düşük aylarının tümü arasındaki en düşük enerji tüketimi değeridir. MAYIS ayında yaklaşık 1356465 olarak değerlenir.

• Tüm stratejiler arasında en yüksek yıllık enerji tüketimi değeri, yaklaşık 45993784,21 değerindeki VAV'dir. Ve tüm stratejiler arasında en düşük yıllık enerji tüketimi değeri ısı geri kazanımıdır. Yaklaşık 27472593,24 değerindedir.

• Enerji tüketiminde en iyi tasarruf stratejisi, ısı geri kazanımını eklemektir. Yaklaşık 4405745.57 değerindedir. Ve enerji tüketiminin en kötü stratejisi, yaklaşık -14115445,4 değerinde bir ısı geri kazanımı eklemektir.

SONUÇ

Bina Enerji Talebini Azaltma

Bina enerji talebini azaltmak için enerji kullanan sistemlerin ve makul bir harcama ile ısı kayıplarının ve kazançlarının meydana geldiği yerlerin iyileştirilmesi önemlidir. MNG perakende merkezinin enerji tüketimini azaltmak için, bu çalışma aşağıdaki sistemlerin değiştirilmesini inceledi ve ardından bu değişikliklerin uygulandığı birkaç farklı gelecek senaryosunu simüle etti ve analiz etti.

Isı geri kazanımı ekleme

MNG Alışveriş Merkezi'nin mevcut klima santrallerine ısı geri kazanım ünitesi eklendiğinde enerji tüketiminde yıllık tasarruf yüzdesi yüzde 13,8 oluyor. Bu yöntem, binaların enerji maliyetlerinden çok tasarruf etmesine yardımcı olabilir ve başka birçok avantajı da vardır.

Bir ısı geri kazanım ünitesinin dahil edilmesi, aksi takdirde boşa gidecek olan ısıyı kullandığı için HVAC sisteminin verimliliğini artırır. Bu depolanan ısıyı taze hava girişini ön koşullandırmak için kullanarak, rahat bir sıcaklığı korumak için gereken güç miktarını azaltabiliriz.

Yıllık %13,8'lik enerji tasarrufu, bir ısı geri kazanım ünitesi kurmanın önemli etkisinin açık bir göstergesidir. MNG Alışveriş Merkezi, konvansiyonel ısıtma ve soğutma sistemleri yerine geri kazanılan ısıyı kullanarak enerji kullanımını ve kullanım giderlerini en aza indirebilmektedir.

Isıtma ayar noktası sıcaklıklarını değişimi.

Ne yazık ki, MNG Alışveriş Merkezi'nin ısıtma ayar noktası sıcaklıklarının 23°C'den 22°C'ye düşürülmesi binanın enerji ihtiyacını azaltmadı. Planlanan hedef enerji kullanımını azaltmak olsa da durum bu değildi.

Enerji talebinde arzu edilen azalmanın hala gerçekleştirilmesinin gerekmesinin çeşitli nedenleri olabilir. Bazı olası faktörler şunları içerir:

- Yolcu Konforu
- Sistem Sınırlamaları
- Yetersiz Yalıtım
- Mevsimsel değişim
- Çalışan ve müşteri davranışları
- Soğutma ayar noktası sıcaklıklarını değiştirin

MNG Alışveriş Merkezi'ndeki soğutma ayar noktası sıcaklığının 26 dereceden 28 dereceye çıkarılmasıyla yıllık yüzde 10,8 oranında tasarruf sağlanabiliyor. Bu değişiklik, MNG Alışveriş Merkezi'nin enerji verimliliğini artırmak ve işletme giderlerini azaltmak için uygulanabilir ve verimli bir strateji örneğidir.

MNG Alışveriş Merkezi, soğutma ayar noktası sıcaklığını 2 derece yükseltirse, soğutma talebini ve klimalarının çalışması gereken süreyi azaltabilir. Bu ayarlama sonucunda önemli yıllık enerji tasarrufu sağlanacaktır. Yüzde 10,8'lik kümülatif enerji tasarrufu, bu yükseltmenin getirdiği iyileştirmenin kanıtıdır.

Bu ayar enerji tasarrufuna yardımcı olurken, yolcuların konforunu da göz önünde bulundurmak önemlidir. 26 dereceden 28 santigrat dereceye geçerken hava durumu, bina kullanımı ve bireysel tercihleri göz önünde bulundurmak hayati önem taşır.

Hava dağıtım sisteminin VAV'dan CAV'a uyarlanması

MNG Alışveriş Merkezi, hava dağıtım sistemini VAV'dan (Değişken Hava Hacmi) CAV'ye (Sabit Hava Hacmi) çevirerek bina enerji talebini düşürme hedefine henüz ulaşamamıştır. Bu güçlendirme çabası, enerji kullanımını azaltmayı amaçlasa da başarısız oldu.

Enerji tüketimini azaltmak için CAV güçlendirmesinin başarısız olmasının birkaç olası açıklaması vardır:

- Bina Tasarımı ile Uyumsuzluk
- Sistem Entegrasyon Zorlukları
- Yolcu Konforu ile İlgili Hususlar
- Yetersiz Enerji Verimliliği Kazanımlar

Poliüretan duvar yalıtımı

MNG alışveriş merkezindeki duvar yalıtımının taş yününden poliüretana çevrilmesi, yıllık %10,93 tasarruf yüzdesi ile bina enerji talebini azaltmak için etkili bir teknik oldu. Bu değişiklik nedeniyle, binalar için önemli ölçüde enerji tasarrufu ve diğer avantajlar sağlanacaktır.

MNG alışveriş merkezi cephesinin termal performansı, taş yünü yerine poliüretan yalıtım kullanılarak büyük ölçüde iyileştirildi. Daha iyi termal direnç ve duvarlardan daha az ısı transferi, poliüretan yalıtımın birçok avantajından ikisidir ve bu aynı zamanda daha düşük enerji kayıplarına ve ısıtma ve soğutma gereksinimlerine katkıda bulunur.

ABSTRACT

It describes the work done by MNG Shopping Centre to reduce its energy footprint. Changes in heating and cooling set point temperatures, adding heat recovery for the HVAC system, converting VAV to CAV air distribution system and modifying wall insulation and connection programmes were used. The effectiveness of these procedures was measured through close observation and statistical analysis. By adopting an all-encompassing strategy, the shopping centre was able to save a lot of money on its energy bill, become more efficient in its operations, have less impact on the environment and promote a sustainable culture. The insights from this case study can help other commercial buildings improve their energy efficiency. Energy efficient construction and renewable energy sources have been scrutinised in recent years. Examples of clean energy generation for buildings include solar panels, wind turbines and geothermal systems. The MNG Shopping Mall building consists of five floors; the first two floors are car parks, half of the ground floor is dedicated to car parking, the other half is dedicated to retail stores on the first floor, and the second floor is dedicated to restaurants. The total usage area is approximately 160 thousand m2 . MNG is located at 39.95 latitude, 41.17 longitude and 4B ASHRAE climate zone. The external structure of the MNG Shopping Centre details that the equivalent CO2 subtotal for Carbon and Inventory Contained in Materials is 59204916.8 (kgCO2) and the Subtotal for Embedded Carbon is 6826838.0 (kgCO2). The equivalent CO2 subtotal for Carbon from Buildings and Inventory is 6826837.00 (kgCO2) and the Subtotal for Carbon from Buildings is 6599610.18 (kgCO2). And the subtotal equivalent CO2 for Glazing Embedded Carbon and Inventory is 121491.7 (kgCO2) and the Subtotal Embedded Carbon is 121491.7 (kgCO2). And the subtotal equivalent for MNG Shopping Centre is CO2 6948328.7 (kgCO2) and the Subtotal of Embedded Carbon is 6721101.8 (kgCO2).

DesignBuilder modelling

In this thesis, energy performance analysis of MNG Shopping Centre building has a construction area of 160 thousand m2 . MNG Shopping Centre building consists of five floors; the first two floors are car parks, half of the ground floor is car park and the other half is retail stores; the first floor is retail stores and the second floor is restaurants.

For this purpose, the building was firstly modelled and represented in three dimensions in Revit program; then it was transferred to DesignBuilder v6.1.0.6 with EnergyPlus v8.9 simulation engine.

The building was modelled floor by floor in Revit and started to be modelled with par; it is underground. All floors except car park floors were modelled under the same conditions. Then it was transferred to DesignBuilder programmes.

Since the study was carried out for an existing building, all architectural and mechanical installation projects were given and these projects were used to introduce the building in DesignBuilder. In addition, field work was carried out in the building and in the area where the building is located and all parts of the building were visited. In consultation with the building energy manager, changes in the systems that differ from the project were noted and used in modelling and building promotion.

EnergyPlus simulation engine

EnergyPlus uses hourly climate data in its calculations and calculates the heating and cooling loads in an integrated way, taking feedback into account. The calculation results can optionally be displayed hourly, monthly or annually. This makes it possible to obtain detailed calculation results from the EnergyPlus simulation engine.

As a result of the simulation, building loads, CO2 production and energy consumptions of HVAC system designs are calculated annually, monthly and hourly. energy consumptions obtained through simulation are compared with actual measured energy consumptions. Then, the energy requirement in all energy consumption systems was minimised with reasonable investments. The CO2 production of the building was also analysed. CO2 production is calculated from natural gas consumption for heating and hot water needs of the building. While CO2 is generated from electricity consumption, it is obtained by multiplying the total electricity consumption by the carbon emission factor of the building and the algorithm in the EnergyPlus calculation. When modelling and introducing the building, the geometry of the building, the orientation of the building, the characteristics of the HVAC and lighting systems, the description of the building components, the intended use of the zones, internal thermal gains, comfort conditions and hourly current meteorological data for the location of the building are entered into the program.

Research Results and Discussion

The MNG Shopping Mall building consists of five floors, with the first two floors serving as car parks, half of the ground floor as car parks and the other half as retail stores, the first floor as retail stores and the second floor as restaurants. The total area of use is approximately 160 thousand m2 .

In this thesis, the investigated building is simulated with design-builder v6 (EnergyPlus v8.9) and energy consumption, internal heat gains, heat losses, heating load and CO2 production of the building are calculated. energy consumption (natural gas and electricity) obtained from the simulation is compared with the actual energy consumption. It shows the actual monthly natural gas consumption of the MNG building as the actual energy consumption values of the MNG shopping centre building for all years. Actual monthly power utilisation for all years using energy consumption values from 2018 to 2021. For example, the monthly consumption value is the annual average. each month shows the average actual natural gas consumed by the MNG buildings over all years. the average monthly actual electricity consumption for all years, within the scope of the work to be done to minimise the building's energy consumption. The readings on the power meter are the values recorded by the facility's energy manager as the building's consumption. these findings show that the annual energy consumption of the MNG shopping centre is 36,549,082.95 kwh. Of this usage, 71.86 per cent is natural gas and 28.14 per cent is electricity. The building uses an estimated annual energy consumption of 228.43 kwh/m2 .

Simulation results

EnergyPlus can simulate the building's lighting, heating, cooling, ventilation and air conditioning systems and the distribution of temperature, velocity and pressure. The heating and cooling plan determines the size of the heating and cooling systems required to cope with the coldest and hottest temperatures expected to be experienced. The DesignBuilder programme calculation for Erzurum uses a minimum of -29.1°C and a maximum of 30°C for the temperature range over which HVAC components must operate. The coordinates of the MNG site are (39.95, -41.17) and the ASHRAE climate classification is 4B.

Outdoor dry-bulb temperature in Erzurum. The average dry bulb temperature varies between approximately -2.82 degrees Celsius in January and approximately 25.6 °C in July. Variation of atmospheric pressure value according to months. As can be seen from the figure, atmospheric pressure reached its lowest value in February with 85765.66 Pa. It reaches its highest value in December with 86712.01Pa. Wind direction changes a lot according to the months. The wind direction usually varies between 54.57° and 129.91°.

The wind speed of the region varies between 1.88 m/s and 5.04 m/s. While the wind speed is low in winter, it is relatively higher in spring and summer. The direct normal solar energy increases and reaches a maximum in summer and reached a maximum of 119.46 kWh/m2 in June. The diffuse horizontal solar energy, on the other hand, increases in summer in July, reaching a maximum of 116.7 kWh/m2 per month.

Monthly variation of MNG Shopping Centre building internal heat gains, zone sensible heating and zone sensible cooling loads. The highest internal heat gain is from lighting. This internal heat gain is followed by external window solar gain and gains from people, appliances and cooking. The highest district sensible heating load was reached in January with 1.14 GWh. The highest energy consumption meets the heating load and reaches its highest value in January with 3.32 GWh. In meeting the heating load, natural gas consumption increases in the winter months while the cooling group electricity consumption is zero. In summer, the natural gas consumption used in heat generation decreases, while the electricity consumption of the cooling group increases. Energy consumption of other variables is almost constant throughout the year. This is happening.

Annual energy consumption values of MNG Shopping Centre building according to systems. The systems with the highest consumption in MNG Shopping Centre are heating and lighting systems. While the energy consumed for heating is 12.06 MWh, the energy consumed for lighting is 7.23 MWh.

Monthly CO2 production of MNG Shopping Centre building. CO2 production occurs as a result of natural gas and electricity consumption of the building. As can be seen from the figure, CO2 production increases in winter months and decreases in summer months and total annual CO2 production reaches 1.211.803 kg.

Scenarios and Strategies

There are five scenarios and strategies to reduce the CO2 production and energy consumption of the MNG Shopping Centre building and the result is shown:

1. Adding heat recovery

Total energy consumption can be reduced by adding heat recovery to existing air handling units.

2. Change the heating setpoint temperatures.

Total energy consumption can be reduced by reducing or increasing the floor heating setpoint temperatures to the recommended ranges.

3. Change the cooling setpoint temperatures.

Total energy consumption can be reduced by reducing or increasing the cooling setpoint temperatures of the floors to the recommended ranges.

4. Adaptation of the air distribution system from VAV to CAV

reduce energy consumption by adapting the existing air distribution system from VAV to CAV.

5. Polyurethane wall insulation.

Total energy consumption can be reduced by changing the wall insulation type of the MNG Shopping Centre building from stone wool to polyurethane.

Information about scenarios and strategies and the differences between them, e.g:

- The VAV strategy has the highest value among all strategies for the highest CO2 production months. It has a value of about 1480181 in January. The lowest value of CO2 production among the highest monthly strategies is to add heat recovery strategy in OCA with a value of about 900065,3.

- The highest CO2 production value among the lowest month strategies is the VAV strategy. valued at about 819814,6 in JUNE. The lowest value of CO2 production among all the lowest strategy months is the baselining strategy, valued at about 541911,3 in JUNE.

- VAV has the highest annual CO2 production value among all strategies. It has a value of approximately 12336878.3. And the lowest annual CO2 production value among all strategies is Polyurethane Wall insulation with a value of about 8407590.8.

- The best saving strategy for CO2 production is to add heat recovery. It has a value of about 1142461.4. And the worst strategy for CO2 production is VAV; it is about -3334850.9.

- The highest energy consumption value among the highest months of the strategies is the VAV strategy with a value of about 4970477 in OCA. The lowest energy consumption value among the highest strategies is the heat recovery strategy with a value of approximately 3582905 in July.

- The highest energy consumption value among the lowest months of the strategies is the VAV strategy. It has a value of approximately 2724284 in April. The baselining strategy is the lowest energy consumption value among all the lowest months of the strategies. It is valued at approximately 1356465 in MAY.

- The highest annual energy consumption value among all strategies is VAV with a value of approximately 45993784.21. And the lowest annual energy consumption value among all strategies is heat recovery. It has a value of approximately 27472593,24.

- The best saving strategy in energy consumption is to add heat recovery. It is worth about 4405745.57. And the worst strategy of energy consumption is to add a heat recovery with a value of about -14115445.4.

CONCLUSION

Building Energy Demand Reduction

To reduce building energy demand, it is important to retrofit energy-using systems and where heat losses and gains occur at a reasonable expenditure. In order to reduce the energy consumption of the MNG retail centre, this study examined the modification of the following systems and then simulated and analysed several different future scenarios where these modifications were implemented.

Adding heat recovery

When a heat recovery unit is added to the existing air handling units of MNG Shopping Centre, the annual saving percentage in energy consumption is 13.8 percent. This method can help buildings save a lot on energy costs and has many other advantages.

The inclusion of a heat recovery unit increases the efficiency of the HVAC system as it utilises heat that would otherwise be wasted. By using this stored heat to precondition the fresh air intake, we can reduce the amount of power required to maintain a comfortable temperature.

The annual energy saving of 13.8% is a clear indication of the significant impact of installing a heat recovery unit. By using recovered heat instead of conventional heating and cooling systems, MNG Shopping Centre is able to minimise energy use and utility costs.

Change heating setpoint temperatures.

Unfortunately, reducing the heating set point temperatures of the MNG Shopping Centre from 23°C to 22°C did not reduce the energy demand of the building. Although the planned goal was to reduce energy use, this was not the case.

There may be various reasons why the desired reduction in energy demand still needs to be realised. Some possible factors include:

- Passenger Comfort
- System Limitations
- Inadequate Insulation
- Seasonal variation
- Employee and customer behaviour
- Change the cooling setpoint temperatures

By increasing the cooling set point temperature at MNG Shopping Centre from 26 degrees to 28 degrees, an annual saving of 10.8 percent can be achieved. This change is an example of a feasible and efficient strategy to increase the energy efficiency and reduce the operating expenses of MNG Shopping Centre.

If MNG Shopping Centre increases the cooling set point temperature by 2 degrees, it can reduce the cooling demand and the time its air conditioners need to operate. This adjustment will result in significant annual energy savings. The cumulative energy savings of 10.8 per cent is evidence of the improvement brought by this upgrade.

While this setting helps to save energy, it is important to consider the comfort of the travellers. When changing from 26 to 28 degrees Celsius, it is vital to consider the weather, building use and individual preferences.

Adaptation of the air distribution system from VAV to CAV

MNG Shopping Centre has not yet achieved its goal of reducing building energy demand by converting the air distribution system from VAV (Variable Air Volume) to CAV (Constant Air Volume). Although this retrofit effort aimed to reduce energy use, it failed.

There are several possible explanations for the failure of CAV retrofitting to reduce energy consumption:

- Incompatibility with Building Design
- System Integration Challenges
- Passenger Comfort Considerations
- Insufficient Energy Efficiency Gains

Polyurethane wall insulation

Changing the wall insulation in the MNG shopping centre from rock wool to polyurethane was an effective technique to reduce the building energy demand with an annual saving percentage of 10.93%. Due to this change, there will be significant energy savings and other benefits for the buildings.

The thermal performance of the MNG shopping centre façade was greatly improved by using polyurethane insulation instead of rock wool. Better thermal resistance and less heat transfer through the walls are two of the many advantages of polyurethane insulation, which also contributes to lower energy losses and heating and cooling requirements.

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ABBREVIATIONS INDEX

ACEEE	American Council for an Energy-Efficient Economy
ASHRAE	The American Society of Heating, Refrigerating, and Air-Conditioning Engineers
BEE	Building energy efficiency
CAV	Constant air volume
CFD	Contract for difference
CO_2	Carbon dioxide
DOE	The U.S. Department of Energy
EC	Energy consumption
GHG	Greenhouse gas emissions
HVAC	Heating, Ventilation, and Air Conditioning
IECC	International Energy Conservation Code
IESVE	IES Virtual Environment
LEED	Leadership in Energy and Environmental Design
NREL	National Renewable Energy Laboratory
NZEBs	Net zero energy buildings
PV	Photovoltaics
VAV	Variable air volume

INTRODUCTION

Sustainable design and engineering place a premium on buildings’ electrical compatibility (EC). Energy efficiency in buildings is essential in reducing the adverse effects of climate change because they are responsible for a substantial proportion of worldwide EC and carbon emissions (Kavgic et al., 2013). Design, construction materials, heating, ventilation, air conditioning (HVAC), and human behavior contribute to a building's EC (Zhang et al., 2018).

Energy-efficient structures have been demonstrated to cut EC and carbon emissions considerably. Passive solar design, natural ventilation, and high-performance insulation are just a few examples of energy-efficient design solutions that can cut EC in buildings by as much as 80%, according to a report by (Lomas et al. 2012).

Energy-efficient construction and renewable energy sources have been scrutinized in recent years. Examples of clean energy generation for buildings include solar panels, wind turbines, and geothermal systems (Hou et al., 2018).

Although there is a rising understanding of the necessity of energy-efficient construction, many structures still need to use more energy than is necessary. This is because there is a lack of education and awareness about the benefits of using energy-efficient design and technology and financial incentives to make the switch (Almutairi et al., 2019).

The environmental consciousness (EC) of buildings is an important issue that needs to be addressed by architects, engineers, legislators, and inhabitants. The EC of buildings can be drastically lowered using energy-efficient design principles and renewable energy sources, aiding global efforts to battle climate change.

Building Energy Efficiency in the World

By "building energy efficiency" or "BEE," we mean the planning and execution of actions that lessen a building's overall energy consumption without negatively impacting its functionality. Due to its potential to reduce emissions of greenhouse gases and cushion the blow of climate change, this idea has been getting much attention as of late.

A wide variety of subjects, such as building design, energy management systems, renewable energy technologies, and building regulations and standards, are discussed in the scholarly literature on BEE. BEE measures' economic and environmental effects have been the subject of a few studies, which have also examined the possible benefits and obstacles of implementing these policies.

BEE relies heavily on energy modeling technologies to evaluate building efficiency and find places to reduce energy consumption. These simulation tools can test energy scenarios for buildings and determine which strategies work best. EnergyPlus, IES-VE, and DesignBuilder are only some software programs that can be used for this (EnergyPlus, n.d.; Integrated Environmental Solutions, n.d.; DesignBuilder, n.d.).

Implementing suitable construction norms and standards is another crucial aspect of BEE. Energy efficiency regulations are part of the minimal requirements set forth by building codes and standards. Local building authorities are responsible for enforcing these requirements established at the national or regional level. The International Energy Conservation Code (IECC) and the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Standard 90.1 are two examples of widely recognized building energy codes in the United States (International et al., 2021; ASHRAE, 2021).

Taking BEE steps has been proven to affect the economy and the environment positively. Buildings that use less energy will cost the United States economy $1.2 trillion by 2040, according to a search by the American Council for an Energy-Efficient Economy (ACEEE) (ACEEE, 2020). Energy efficiency measures in buildings have the potential to reduce can potential emissions by 1.7 gigatons by 2050, according to another study by the Lawrence Berkeley National Laboratory (Lawrencet al. aboratory, 2016).

When it comes to designing and operating buildings sustainably, BEE is essential. The economic, environmental, and social benefits it could bring are all well-documented in scholarly works. High levels of BBE can only be attained using tools and the implementation of relevant building rules and standards.

Building Energy Efficiency in Turkey

BEE is crucial for lowering GHG emissions and accomplishing sustainable development goals. Energy consumption and EC in Turkey's construction industry are rising as the country develops and its economy expands. To guarantee energy security, lower energy costs, and lessen the effects of climate change, Turkey must enhance its BEE.

The construction industry in Turkey consumes the most energy, accounting for over 30 percent of the country's total energy consumption (EC) (IEA, 2020). Turkey has taken significant measures to improve its BEE through the implementation of different policies and regulations, such as the "Regulation on Energy Performance in Buildings" and the "Energy

Efficiency Law," both of which aim to decrease EC and boost the use of renewable energy in buildings (IEA, 2020).

Additionally, Turkey has launched a few initiatives to promote sustainable building design and construction, including the "Green Building Certification System," which aims to certify buildings with high energy efficiency and sustainable design (Republic of Turkey Ministry of Environment and Urbanization, 2021). Due to these initiatives, Turkey has an estimated 140 certified green buildings (World et al., 2021).

Despite these gains, many obstacles prevent Turkey from making the considerable improvements necessary to achieve BEE. Insufficient public knowledge and financial incentives, for instance, are impeding progress toward more energy-efficient building retrofits (IEA, 2020).

Turkey needs BEE for energy security, lower energy costs, and climate change mitigation. While great strides have been made toward making buildings more energy efficient, much work must be done before reaching our sustainable development targets.

The goal of this paper is to analyze previous research on the topic of energy efficiency in buildings. Due to buildings' substantial influence on the environment and the price of EC, energy efficiency in buildings has become an increasing priority in recent years. This analysis will examine the technology used to boost BEE and cut down on EC.

Analyzing the Literature

The efficiency of a building's heating, ventilation, air conditioning (HVAC), lighting, and other systems can be increased through building automation systems and energy management systems. According to research by Kaya et al. (2019), lowering EC by 15-30% is possible with an automation system using an energy management system resulting in a 10%-30% decrease in EC according to Li et al. (2019).

Strategies For Passive Design

Building energy efficiency has also been increased using passive design principles such as proper orientation, insulation, and ventilation. Passive design solutions led to a 10-30% decrease in EC, according to research by Ahmad et al. (2018). Kalair et al. (2018) observed that using passive design solutions like insulation and natural ventilation could reduce EC by 15-30%.

The Use of Renewable Energy Sources

Solar panels and wind turbines, two examples of renewable energy technology, have been employed to create electricity and lessen the load on conventional power plants. Solar panel installation has been shown to reduce a building's EC by 15-30%, according to research by Liu et al. (2018). Khan et al. (2018) conducted their research and discovered that using solar panels and wind turbines lowered EC by 20-40%.

Sustainable Resources

Low-E windows and cool roofs are only two examples of energy-efficient materials included in the construction. Huxtable et al. (2019) discovered that installing low-E windows can reduce EC by 10-20%. Tang et al. (2019) conducted another investigation and found that cool roofs lowered EC by 5-10%.

Analyzing the Turkish Literature on Energy-Efficient Buildings

To assess the influence of energy-efficient building design on EC in Turkey, Erturk et al. (2019) undertook a case study. Using modeling software, they compared a traditional building's EC to an energy-efficient one. According to the results, EC can be cut by as much as 60% when implementing energy-efficient building design practices. The researchers determined that Turkey may benefit financially from more energy-efficient building design.

Arslan et al. (2019) analyzed survey data to determine EC trends in Turkish homes. According to their research, HVAC systems are the single most significant contributor to home EC. The EC was also shown to be greater in older buildings compared to the newer on conclude that upgrading older buildings and increasing the efficiency of heating and cooling systems were two of the most important ways to cut EC in Turkey's homes.

Karatasou et al. (2018) analyzed commercial buildings' energy efficiency in Istanbul, Turkey. They surveyed 20 office buildings in Istanbul to compile EC and structural data. According to the research, Istanbul's office buildings have a greater EC than their European counterparts. They concluded that if Turkey is going to reach its national energy efficiency targets, it must prioritize increasing the efficiency of its office buildings.

The effect of Turkish building codes on energy efficiency was analyzed by Kose and Yilmaz (2019). They looked at information from energy performance certificates and building codes for homes built between 2010 and 2018. According to the research, Turkey has dramatically improved its energy efficiency since enforcing stricter building codes. They concluded that more stringent building codes would increase national energy efficiency.

Deniz and Arslan (2018) used simulation software to assess the Turkish school's energy performance. The EC of a traditional building was compared to that of an energy-efficient one. The research demonstrated that EC can be cut by as much as 40% using energy-efficient design solutions in construction. Their research led them to the conclusion that designing schools to use less energy is a practical option in Turkey.

Kacmaz et al. (2019) used survey data to examine EC patterns in Turkish healthcare facilities. They determined that the two most significant sources of EC in healthcare facilities were HVAC and lighting. The EC was also shown to be greater in older buildings compared to newer ones. They concluded that hospital buildings in Turkey might save money by upgrading their HVAC and lighting systems to be more energy efficient.

To assess the effect of insulation on EC in Turkish homes, Eksioglu et al. (2018) ran simulation research. They compared the EC of a standard building to that of an insulated building. Research shows that insulating a building's envelope can save EC by as much as 40%. They determined that improving insulation in building envelopes was the most cost-effective strategy for enhancing energy efficiency in Turkish homes.

Using modeling software, Erdem et al. (2020) assessed the energy efficiency of Turkish retail malls. The EC of a traditional building was compared to that of an energy-efficient one. According to the research, Turkey's retail mall structures have a higher EC than the rest of Europe. They concluded that to meet national energy efficiency standards. We must make shopping malls more energy efficient.

Aksan and Keles (2018) used modeling software to examine how energy-efficient building design affected indoor air quality in Turkey. They looked at how an energy-efficient building's indoor air quality stacked up against that of a more traditional one. Energy-efficient building design solutions were shown to reduce the number of outdoor pollutants brought into the building, improving interior air quality. They concluded that energy-efficient building design in Turkey can improve indoor air quality while reducing energy consumption.

Using survey data, Altuntop and Celik (2019) assessed the effect of energy-efficient building design on occupants' sense of thermal comfort in Turkish homes. They discovered that energy-saving building design measures could enhance household thermal comfort, including excellent insulation and efficient HVAC systems. The survey also found that people living in energy-efficient buildings report higher happiness in their living conditions. They concluded that residential structures in Turkey could benefit from energy-efficient design in two ways: in terms of reduced energy use and increased occupant comfort.

The energy efficiency of public buildings in Turkey was analyzed in a study by Yilmaz et al. (2018). Fifty public buildings in Turkey were surveyed to gather EC and building characteristics data. According to the research, public buildings in Turkey have an average EC higher than the rest of Europe. They concluded that increasing the efficiency of public buildings was important if Turkey was going to meet its national energy efficiency targets.

Inalli and Altun (2018) used survey data to examine EC trends in Turkish academic buildings. The research concluded that HVAC and lighting systems account for most EC in academic buildings. The EC was also shown to be greater in older buildings compared to newer ones. They determined that the best way to decrease EC in Turkey's university buildings was to improve the energy efficiency of HVAC systems, lighting, and upgrading.

Altun and Inalli (2020) used simulation software to assess the energy efficiency of hotel structures in Turkey. The EC of a traditional building was compared to that of an energy-efficient one. According to the research, EC can be cut by as much as half if measures are taken to make building designs more energy efficient. They concluded that hotels in Turkey might benefit significantly from energy efficiency upgrades if they were designed more carefully.

Yigit and Gokcen Akkurt (2018) used survey data to evaluate EC trends in Turkish shopping malls. The most significant sources of EC in retail malls were determined to be the lighting and HVAC systems. Research shows that more giant shopping malls have better EC than smaller ones. They concluded that Turkey's shopping malls might save considerable energy if they upgraded their lighting and HVAC systems and reduced their overall footprint.

An evaluation of the energy efficiency of commercial buildings in Ankara, Turkey, was undertaken by Ucar and Ipek (2020). They surveyed 15 office buildings in the Ankara area to compile EC and building characteristics data. According to the research, Ankara has a higher EC than the rest of Turkey regarding office buildings. They concluded that increasing the efficiency of Turkey's office buildings was vital to meeting the country's overall energy efficiency goals.

Kim and Hong (2016) surveyed the research published on cold-climate building energy performance from 2002 to 2015. They determined what aspects of a building's design, insulation, heating systems, and renewable energy technologies contribute to its energy efficiency in cold climes. The writers explored the obstacles and potential solutions for enhancing cold-climate buildings' energy efficiency.

The energy efficiency of Chinese shopping malls in hot summer and cold winter regions was analyzed by Sun et al. (2018). Mall components, including lighting, HVAC, and building envelopes, were analyzed for EC and performance using simulation models. The research concluded that EC in retail malls could be significantly reduced by optimizing HVAC systems and enhancing building insulation.

Rajapaksha and Leung (2017) examined shopping malls in Hong Kong for their energy efficiency. They utilized energy simulation software to assess the EC of mall features, including lighting, HVAC, and building envelope. According to the research, mall EC can be drastically cut by increasing the efficiency of HVAC and lighting systems.

Yu et al. (2018) investigated the EC of malls in northeast China and recommended cutting down on energy consumption. They employed simulation models to analyze the efficiency of the mall's HVAC, lighting and building envelope systems. The research indicated that EC in retail malls may be drastically cut by upgrading the malls' HVAC and lighting systems and using renewable energy solutions.

The energy efficiency of Chinese Shopping malls across various climate zones was studied by Guo et al. (2017). The HVAC, mall's HVAC, lighting, and building envelopes were all analyzed using energy simulation software to determine their EC. Optimal heating, ventilation, and air conditioning (HVAC) systems and better building insulation lowered EC in Shopping Centers. The writers also talked about how renewable energy could make malls more efficient.

THEORETICAL FUNDAMENTALS

Net Zero Energy Buildings

A sustainable building design idea, "net zero energy buildings" (NZEBs), aspire to use no net external energy input (EC) (Balaras, 2019; Lomas & Haines, 2020). In other words, the buildings are planned so that their annual energy needs may be met entirely by energy produced on-site through renewable energy technologies. The potential of this strategy to reduce EC, minimize greenhouse gas emissions, and combat climate change is becoming increasingly recognized.

Energy-efficient building design and on-site renewable energy technologies must be included during the design and construction of NZEBs (IEA, 2019). NZEBs also necessitate an in-depth familiarity with the building's energy use and the habits of its tenants.

Balaras (2019) argues that NZEBs can significantly cut EC, reduce greenhouse gas emissions, and advance sustainable development. There are. However, several obstacles must be overcome before this can become the norm, including the high initial cost of construction and a need for more understanding among building experts and policymakers (UNEP, 2018).

Cost-benefit analyses of NZEBs have demonstrated several positive outcomes, including enhanced indoor air quality and occupant comfort (Lomas & Haines, 2020). Innovative financing structures and strategies to encourage the construction of NZEBs have also attracted increasing attention.

Energy Analysis of a Building

Methods for analyzing the energy consumption of a structure are an essential component of green building design because of their potential to cut down on environmental impacts (EC). Building energy performance is assessed, improvement opportunities are identified, and prospective energy savings are estimated using a variety of methodologies that make up these methods.

As concerns about climate change and energy security have grown, so has the importance of employing building energy analysis techniques. Energy consumption (EC), greenhouse gas emissions (GHG), and financial savings can all be improved by implementing the methodologies' identified areas for improvement in building energy efficiency.

Building energy analysis often uses energy modeling, simulation, measurement, and verification. Energy modeling entails generating a digital representation of the building and its systems to estimate the EC and performance of a structure. Measurement and verification methods can be used to compare the actual energy performance of a building with the expected performance. In contrast, simulation methods can evaluate various design alternatives and tactics.

Whole-building simulation software, energy auditing techniques, and benchmarking instruments are examples of the many approaches and tools available for analyzing a structure’s energy use. The energy efficiency of buildings can be assessed, and improvement opportunities can be found using helper methods, as mentioned earlier, and technologies that have seen extensive application in both academic and professional settings.

Asadi et al. (2019) and Hong et al. (2021) present evidence that building energy analysis techniques can help lower EC and advance sustainable building design. The intricacy of the methodologies, the lack of familiarity among building professionals, and the necessity of correct data and models are just a few of the obstacles that have yet to be overcome.

Energy Consumption in Buildings

Using EC in buildings is a significant cause of increased energy consumption and pollution worldwide. Building structures use about 40% of global EC (IEA, 2020), eating, cooling, lighting, and powering appliances and equipment. The consumption energy cost a building use is a significant consideration for its proprietors.

Design, construction materials, and HVAC (heating, ventilation, and air conditioning) systems are only a few variables that might affect a building's EC. Saving money on energy bills and cutting down on carbon emissions are just two of the many benefits that may come from making buildings more energy efficient.

Reducing EC in buildings is possible by implementing energy-saving technologies and practices such as passive solar architecture, high-efficiency HVAC systems, and energy-efficient lighting (Shukla et al., 2021). Control EC in buildings by various alternative methods, including building automation and demand response, is possible.

In recent studies, combining energy-efficient technologies and practices has been demonstrated to reduce EC in buildings (Jin et al., 2020; Wang et al., 2021). Nonetheless, several obstacles must be overcome, such as the high upfront cost of energy-efficient technologies, more understanding among building owners and occupiers, and the requirement for laws and regulations that encourage building energy efficiency.

Energy Simulation Software

Because simulation software enables pre-construction evaluation of a building's energy performance, it plays a crucial role in building energy analysis for architects and engineers. These programs help architects and engineers determine where energy efficiency might be enhanced by simulating the effects of various design choices, including HVAC, lighting, and building materials. There are different simulation software packages for building energy analysis, each with advantages and disadvantages.

EnergyPlus, DesignBuilder, IES Virtual Environment, OpenStudio, COMSOL Multiphysics, and TRNSYS are all examples of simulation software used in building energy analysis. The energy performance of a building can be modeled with the help of these programs by simulating factors like heat transfer, air movement, lighting, and occupant behavior. They also make it possible to compare various building layouts and management techniques, which helps zero in on the most cost- and resource-effective option.

Energy modeling software has been widely embraced in research and industry to optimize building energy performance and substantially reduce EC and greenhouse gas emissions (Crawley et al., 2001). In addition to helping designers meet their energy performance obligations, these resources are crucial for staying in line with applicable building energy laws and standards.

In conclusion, simulation software is an indispensable resource for energy analysis in buildings, enabling architects and engineers to test their designs and determine how efficient they would be before breaking ground. Building energy performance can be optimized, and compliance with energy regulations and standards can be ensured with the help of a variety of software programs, each with its own set of advantages and disadvantages.

Some common energy analysis simulation programs include the following:

EnergyPlus: A whole-building simulation software developed by the U.S. Department of Energy that models building energy use, HVAC systems, lighting, and other energy-related systems.

DesignBuilder: A building energy modeling software that integrates energy analysis with building design. It includes various building performance analysis tools such as thermal analysis, daylighting analysis, and HVAC system simulation.

IES Virtual Environment: A comprehensive building energy modeling software that allows users to simulate building performance, optimize design, and evaluate energy-saving measures. It includes thermal analysis, daylighting analysis, and energy system simulation tools.

OpenStudio: An open-source whole-building energy modeling software that allows users to model EC and greenhouse gas emissions for buildings. It is used for energy-efficient building design, code compliance analysis, and performance analysis.

COMSOL Multiphysics: A simulation software that includes CFD capabilities, often used to model airflow and temperature distribution in buildings. It is commonly used in the design and analysis of HVAC systems.

TRNSYS: A simulation software that models renewable energy systems, building energy use, and thermal energy storage. It is often used for modeling solar energy systems, ground-source heat pumps, and other renewable energy technologies.

These are only a handful of the numerous simulation software options for energy analysis in buildings. Using any tool has advantages and disadvantages; selecting the right one for a given project and skill level is often challenging.

IES virtual environment

Architects, engineers, and other building professionals can model, simulate, and assess a building's energy performance using the IES Virtual Environment (IESVE) software (Integrated Environmental Solutions, 2022). The software includes several components, such as a 3D building modeling interface, energy simulation engine, and other analysis tools to provide a complete solution for building energy analysis and optimization.

Heat transfer, airflow, and moisture transport are all modeled using the IESVE software's simulation engine. Solar radiation, weather, and the presence or absence of shade devices are only some environmental factors that can be simulated. Walls, roofs, windows, HVAC systems, and lighting systems are just some of the architectural components and systems included in the software. They can be modified to reflect a structure's unique qualities.

The energy efficiency of a building and its systems can be evaluated with the help of the many analysis tools included in the IESVE program, such as thermal comfort analysis, daylighting analysis, and life-cycle cost analysis. The software also features optimization capabilities for locating and prioritizing building-wide opportunities to reduce energy use.

The IESVE program has an extensive user community and various tools available to help users learn how to use the software effectively for building energy analysis and improvement. Each program iteration adds new features and capabilities (Integrated Environmental Solutions, 2022).

OpenStudio

For simulating energy consumption in buildings, architects, engineers, and other building professionals can utilize OpenStudio, which is energy modeling software for buildings (OpenStudio, n.d.). The program is an open-source project created by the National Renewable Energy Laboratory (NREL) and released under the Apache 2.0 license.

Heat transfer, airflow, and moisture transport are all modeled using Open Studio's simulation engine. Solar radiation, weather, and the presence or absence of shade devices are only some environmental factors that can be simulated. Walls, roofs, windows, HVAC systems, and lighting systems are just some of the architectural components and systems included in the software. They can be modified to reflect a structure's unique qualities.

The energy performance of a building and its systems can be evaluated with the help of Open Studio's many analytical tools, such as thermal comfort analysis, daylighting analysis, and life-cycle cost analysis. The software also features optimization capabilities for locating and prioritizing building-wide opportunities to reduce energy use.

OpenStudio is software that is accessible to users of all skill levels. Training materials, such as online tutorials, webinars, and user guides, are all available for the software (OpenStudio, n.d.). The product also has a sizable user base.

COMSOL

The commercial finite element analysis program COMSOL Multiphysics (COMSOL, 2022) can be used to model and study many types of physics, such as heat transfer, fluid flow, and electromagnetics. The program is widely used in academia and business for modeling and optimizing intricate processes and systems.

Because of its modular design, COMSOL Multiphysics can model various physical processes. Heat transfer, fluid flow, structural mechanics, and acoustics are just some of the many physics modules already in the program. The software has a versatile programming interface allowing users to construct unique physicals.

When it comes to simulating and evaluating structural systems and their constituent parts, COMSOL Multiphysics is an invaluable tool. Buildings' thermal and energy performance can be modeled with the help of the software's heat transfer and fluid flow modules. The software has acoustic and structural mechanics modules that can simulate how a structure will sound and behave.

Users can quickly and efficiently execute simulations, analyze findings, and visualize data with the help of COMSOL Multiphysics' intuitive interface. The software also features optimization capabilities for locating and prioritizing building-wide opportunities to reduce energy use.

To utilize it, you must get a license for COMSOL Multiphysics, which is commercial software. User manuals, video lectures, and discussion boards are only some of the tools that come with the software (COMSOL, 2022).

TRNSYS

Building energy and renewable energy systems can be modeled with TRNSYS, a commercial program (TRNSYS, n.d.). The software has a modular approach, letting users pick and choose from several simulation modules to build their unique simulation model.

Various building energy systems, including heating, ventilation, and air conditioning (HVAC), renewable energy generation, and energy storage, can be modeled with the help of TRNSYS's extensive library of pre-built simulation modules. The software also features a weather data generator, which may use simulated weather data files.

TRNSYS's intuitive interface makes developing and testing simulation models, executing simulations, and examining the outcomes simple. Energy balance calculations, performance analysis, and optimization tools are only examples of the types of analyses built within the program.

TRNSYS is widely used in academia and business for modeling and optimizing energy systems in buildings and other renewable energy sources. You may buy a license to use the program, which is not free. Users can access various helpful tools within the program, such as documentation, tutorials, and discussion boards (TRNSYS, n.d.).

eQUEST

To model and simulate the energy performance of buildings, the US Department of Energy (DOE) created a program called DOE-2 (also known as eQUEST) (DOE, n.d.). The software has a modular approach, letting users pick and choose from several simulation modules to build their unique simulation model.

HVAC, lighting, and renewable energy systems are just some of the building energy systems that may be modeled with the help of DOE-2's extensive library of pre-built simulation modules. The software also features a weather data generator, which may create simulated weather data files.

DOE-2 has a straightforward interface lets users build and tweak simulation models, run simulations, and examine the outcomes. Energy balance calculations, performance analysis, and optimization tools are only a few examples of the types of analyses within the program.

The DOE-2 is an energy modeling and optimization tool used in academia and business. The program can be obtained from the DOE website at no cost (DOE, n.d.). User guides, tutorials, and discussion boards are just some of the added benefits of this product.

EnergyPlus and DesignBuilder

Dynamic thermal modeling that can mimic the interaction between the building's thermal mass and the HVAC system is just one example of the extensive modeling capabilities of DesignBuilder software (DesignBuilder, n.d.). The software also supports incorporating-party tools and models, such as CFD simulations, to comprehensively examine the structure's energy efficiency.

DesignBuilder's compatibility with the EnergyPlus simulation engine is a standout feature. The US Department of Energy's EnergyPlus is a widely used simulation engine that can accurately estimate the energy performance of buildings (DOE, n.d.). In addition to the features and tools in the EnergyPlus software, DesignBuilder also provides a user-friendly interface for creating and configuring EnergyPlus simulations.

In conclusion, DesignBuilder is a robust piece of software for performing energy simulations on buildings, as it offers a variety of modeling options, sophisticated analysis tools, and compatibility with the EnergyPlus simulation engine. The program is frequently used in academia and business to improve energy efficiency and reduce EC.

EnergyPlus

The U.S. Department of Energy (DOE) created EnergyPlus to simulate the energy use of entire buildings. It is a practical resource for simulating the energy consumption of buildings and their heating, ventilation, air conditioning (HVAC), lighting, and other energy systems. EnergyPlus is used frequently by architects, engineers, and other building professionals for energy-efficient building design, performance optimization, and evaluation of energy-saving methods.

EnergyPlus's modular structure makes it easy to model individual building systems and components in great detail. Walls, roofs, windows, doors, lighting, HVAC, and other building components are all included. EnergyPlus also features a global weather database with hourly weather reports for thousands of sites.

EnergyPlus includes the following features:

EnergyPlus has a comprehensive thermal model that can simulate heat flow through a structure's walls, ceilings, and floors. It can simulate all three of the afore methods as mentioned earlier transport.

Modeling of heating, ventilation, and air conditioning (HVAC) systems is possible in EnergyPlus. This includes air- and ground-source heat pumps, central air handling units, and more. The HVAC system can be modeled from the air or waterside.

EnergyPlus's modeling capabilities extend to many lighting setups, from daylighting to occupancy sensors and beyond.

EnergyPlus supports modeling renewable energy sources like solar PV, solar thermal, and wind farms.

EnergyPlus has a function that verifies if a building complies with energy standards, like ASHRAE 90.1, throughout the design process.

Despite its power, EnergyPlus's user interface leaves much to be desired. However, there is a sizable user base and a wealth of information online to help newcomers get up to speed.

The U.S. Department of Energy (DOE) created EnergyPlus to simulate the energy use of an entire building (U.S. Department of Energy, n.d.). Building energy consumption, including heating, ventilation, air conditioning (HVAC), lighting, and other energy-related systems, can be modeled with this tool. EnergyPlus is used frequently by architects, engineers, and other building professionals for energy-efficient building design, performance optimization, and evaluation of energy-saving methods.

Heat transfer, airflow, and moisture transport are all modeled using EnergyPlus's simulation engine. Solar radiation, weather, and the presence or absence of shade devices are only some environmental factors that can be simulated. Walls, roofs, windows, HVAC systems, and lighting systems are some of the building components and systems included in EnergyPlus. They may be modified to reflect a building's unique qualities using the program's intuitive interface.

EnergyPlus also provides several different types of analyses, such as thermal comfort analysis, daylighting analysis, and life-cycle cost analysis, to help users assess the efficiency of a building and its many components. EnergyPlus can be used with other performance study programs like Radiance to get a more in-depth look into a building's efficiency.

EnergyPlus is a robust program for analyzing and optimizing a building's energy consumption; it has a sizable user base and a wealth of supporting materials. (U.S. Department of Energy n.d.) says that the software is regularly updated and enhanced with new features and capabilities added with each new version.

DesignBuilder

Architectural and engineering professionals may model entire buildings down to the last system and component with DesignBuilder, a program that simulates energy consumption. It is commonly employed in architectural engineering, energy performance optimization, and energy efficiency assessment.

DesignBuilder's graphical user interface makes it accessible to those with varying degrees of technical knowledge. Walls, roofs, windows, doors, electrical and HVAC systems, and more are all included, and detailed hourly weather data for thousands of sites worldwide is available within DesignBuilder's included weather database.

The DesignBuilder features include:

To simulate the flow of heat through a structure's walls, ceilings, and floors, DesignBuilder includes a comprehensive thermal model. It can simulate all three of the methods mentioned earlier of heat transport.

Mechanical ventilation and air conditioning (HVAC) systems can be modeled in DesignBuilder. This includes air- and ground-source heat pumps, central air handling units, and more. The HVAC system can be modeled from the air or waterside.

Daylighting systems, occupancy sensors, and other lighting systems can all be modeled in DesignBuilder.

DesignBuilder's modeling tools cover many renewable energy technologies, from photovoltaic panels and solar thermal systems to wind generators.

Modeling daylighting: DesignBuilder's built-in daylighting analysis tool thoroughly assesses a building's daylighting performance.

Building energy performance can be optimized in DesignBuilder based on several factors, including the HVAC system's size and the insulation amount in the building envelope.

Building energy analysis and optimization is made much easier using DesignBuilder, which boasts a sizable user base and a wealth of online information for newcomers. It can also be used with other technologies, such as EnergyPlus and Radiance, to review building performance thoroughly.

For simulating energy consumption in structures, architects, engineers, and other building professionals can utilize DesignBuilder, a building energy modeling program developed by DesignBuilder Software Ltd. (n.d.). The software includes several components, such as a 3D building modeling interface, energy simulation engine, and other analysis tools to provide a complete solution for building energy analysis and optimization.

Heat transfer, airflow, and moisture transport are just some of the phenomena that DesignBuilder's simulation engine can model. Solar radiation, weather, and the presence or absence of shade devices are only some environmental factors that can be simulated. DesignBuilder features a library of architectural components and systems that may be modified to reflect the unique qualities of a structure. These elements include walls, roofs, windows, HVAC, and lighting systems.

Various analyses, such as thermal comfort analysis, daylighting analysis, and life-cycle cost analysis, are included in DesignBuilder to help users assess the efficiency of a building's systems. The software also features optimization capabilities for locating and prioritizing building-wide opportunities to reduce energy use.

DesignBuilder is intuitive enough for first-timers yet powerful enough for professionals. The program has a sizable user base, and numerous training materials are available, such as video guides and webinars (DesignBuilder et al.).

Classification of Buildings

The energy efficiency of a building can be used to categorize it in several ways. Energy efficiency, the ratio of a building's energy use to its size, purpose, and climate, is a widespread criterion for categorizing different structures. According to their energy efficiency, the following are some of the most famous building types:

Passive House: Passive Houses are built to provide year-round comfort without mechanical heating or cooling systems, resulting in extremely low EC. To do this, they use passive solar architecture, which involves capturing and utilizing solar heat gain in conjunction with high insulation levels and airtight construction. Mechanical ventilation systems with heat recovery are also incorporated into Passive Houses to guarantee high air quality standards inside the home. Reference: (Feist & Schnieders, 2016) "net zero energy building" refers to ultra-efficient structures that generate as much energy as they use in a year. They do this by incorporating energy-saving features into their designs, developing renewable energy on-site (through solar panels), and storing it for later use. All types of buildings, from homes to offices to schools, can qualify as "Net Zero Energy Buildings," whether linked to the grid or not. An international group of researchers (Huang et al., 2020)

Low-Energy Buildings need far less energy to provide the same comfort as traditional buildings. They can do this by including energy-saving features in the building's layout and construction and using high-performance heating, cooling, and lighting systems. Existing buildings can be converted into Low Energy Buildings or new constructions can be planned with energy efficiency in mind. The International Energy Agency has predicted that by the year 2019, global.

"Zero Energy Building" refers to structures that are so energy efficient that they generate as much energy as they need in a year without relying on energy storage. This is possible using renewable energy sources like solar panels and energy-efficient design features. All structures, from homes to offices to schools, can qualify as "Zero Energy Buildings," whether connected to the grid or not. (Environmental Protection Agency, 2019)

“green building” refers to structures designed, built, operated, and maintained by ecologically responsible concepts and practices. Renewable energy sources and other environmentally friendly features can fall under this category. The Leadership in Energy and Environmental Design (LEED) program of the U.S. Green Building Council is one example of an independent body that certifies green buildings. According to the USGBC's 2022 report,

Buildings with Nearly Zero Energy Consumption use far less energy than typical structures to provide the same comfort level. Still, they may generate less energy than they utilize. They can accomplish this through high-performance construction materials and systems and an energy-efficient design. Residential, commercial, and institutional structures be converted into Nearly Zero Energy Buildings by retrofitting or new construction. European Union Institutions (2018)

A High-Performance Building meets stringent requirements for environmental friendliness, indoor air quality, and occupant satisfaction. Energy-efficient architecture, high-performance materials, and cutting-edge HVAC systems are all examples of what this category encompasses. All types of buildings, from homes to offices to schools, can benefit from being upgraded to High-Performance Building standards. Standardization and Technology, NIST (2021)

The term "energy-positive building" refers to structures that are so energy-efficient that they generate more energy than they need in a year. They do this by integrating energy-saving architecture, renewable energy generation on-site, and energy storage technologies like batteries. Energy-Positive Structures can be either connected to the grid or completely self-sufficient. (The Institute for a Sustainable Future)

As new technology and design techniques emerge, the overall definitions of building types in terms of energy performance continue to shift. Reducing EC, minimizing environmental damage, and providing inhabitants with healthy, comfortable spaces are perpetual goals.

MATERIAL AND METHOD

General Information

MNG Shopping Center building consists of five floors; the first two floors are parking, the ground floor half serves for parking, the other half is retail shops on the first floor is retail shops, and the second-floor is restaurants. The total used area is approximately 160 thousand m ^{2}.

The site location of MNG 39.95 is latitude, 41.17 is longitude, and 4B is ASHRAE climate zone. Figure 2 shows monthly average air temperature values for Erzurum province for many years.

Figure 1. View of MNG Shopping Center from Google Earth

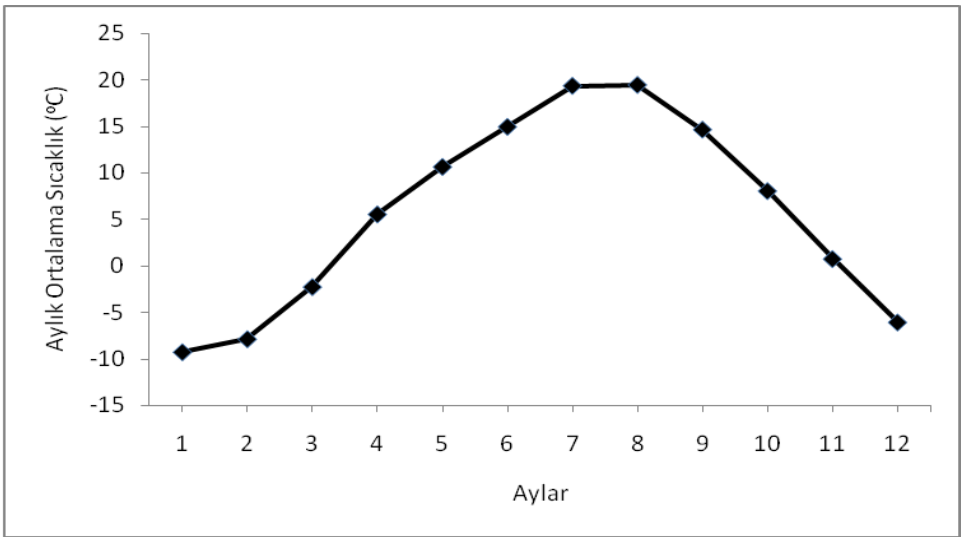


Figure 2. Monthly average outdoor temperatures for Erzurum

The MNG Shopping Centre, exterior structure details, are given in Table 1. is shown that the sub-total of equivalent CO2 for Materials Embodied Carbon and Inventory is 59204916.8 (kgCO2), and the Sub Total of Embodied Carbon is 6826838.0 (kgCO2). The subtotal of equivalent CO2 for Constructions Embodied Carbon and Inventory is 6826837.00 (kgCO2), and the Sub Total of Embodied Carbon is 6599610.18 (kgCO2). And subtotal equivalent CO2 for Glazing Embodied Carbon and Inventory is 121491.7 (kgCO2), and the Sub Total of Embodied Carbon is 121491.7 (kgCO2). And the sub subtotal equivalent CO2 for The MNG Shopping Center is 6948328.7 (kgCO2), and the Sub Total of Embodied Carbon is 6721101.8 (kgCO2).

Table 1. Embodied and Equivalent Carbon for the MNG Shopping Center.

Materials Embodied Carbon and Inventory	**Area (m2)**	**Embodied Carbon (kgCO2)**	**Equivalent CO2 (kgCO2)**	**Mass (kg)**
Rock wool - unbonded MNG1	17619.9	222011.2	236811.9	211439.2
Rock wool - unbonded MNG2	17619.9	74003.7	78937.3	70479.7
Plywood (Heavyweight)	3.1	17.8	18.4	21.9
Timber Flooring	34818.9	299387.4	305895.8	650842.2
Clay Tile (roofing)	7.0	161.1	168.1	350.2
External Rendering	1730.8	5625.3	5625.3	56252.5
Floor/Roof Screed	33088.0	444703.3	444703.3	2779396.0
Plasterboard	68724.8	931853.6	980898.5	2452246.3
Gypsum Plastering	6569.6	32453.7	34161.7	85404.3

Table 1. (Continued)

Gypsum Plasterboard	5268.0	14223.5	15408.8	118529.2
Urea Formaldehyde Foam	33088.0	78156.0	84303.1	43907.8
MW Stone Wool (rolls)	1730.8	8080.1	8618.8	7695.3
MW Glass Wool (rolls)	33484.9	88835.4	97544.8	58062.4
XPS Extruded Polystyrene - CO2 Blowing	6569.6	52645.9	175120.6	18279.8
Concrete Block (Medium)	41809.4	665608.9	665608.9	8320112.0
Cast Concrete	33088.0	529408.8	529408.8	6617609.7
Cast Concrete (Lightweight)	3.1	30.1	30.1	376.2
Cast Concrete (Dense)	170923.5	2871515.0	2871515.0	35893935.1
Brickwork Outer	6569.6	245701.7	256870.0	1116825.9
Roofing Felt	7.0	32.3	32.3	33.6
Asphalt 1	33481.8	35155.9	35155.9	703117.3
Sub Total		6599610.0	6826838.0	59204916.8

Constructions Embodied Carbon and Inventory	**Area (m2)**	**Embodied Carbon (kgCO2)**	**Equivalent CO2 (kgCO2)**
Project unoccupied pitched roof	7.0	193.4	200.4
Project partition	2634.0	14223.5	15408.8
Project ground floor	23.3	949.9	958.8
The pro-below-graduate wall	6569.6	404380.3	539731.3
Project basement ground floor	33064.8	1348118.0	1360708.4
external wall MNG	17619.9	1356735.0	1401137.3
Project flat roof	33481.8	587103.7	620187.0
The project’s internal floor Reversed	105482.9	1772112.3	1772112.3
Project semi-exposed ceiling	3.1	98.8	102.5
Project external floor	1730.8	16293.0	16887.9
Project internal floor	65440.6	1099402.3	1099402.3
Sub Total	266057.8	6599610.18	6826837.00

Table 1. (Continued)

Glazing Embodied Carbon and Inventory	Area (m2)	Embodied Carbon (kgCO2)	Equivalent CO2 (kgCO2)
Project roof glazing	1160.6	31336.8	31336.8
Project external glazing	4821.1	90154.9	90154.9
Local shading		0.0	0.0
Window shading		0.0	0.0
Sub Total	5981.7	121491.7	121491.7
Building Total	**272039.5**	**6721101.8**	**6948328.7**

HVAC system

HVAC systems in MNG Shopping Center building with all details of HVAC system equipment in MNG Shopping Center building are shown, Air MNG Shopping Center Single Duct VAV Reheat in Table 2, Coil heating water in Table 3, Air Loop HVAC in Table 4, Fan Variable Volume in Table 5, Controller Outdoor Air in Table 6, Coil Cooling Water in Table 7, Controller Water Coil in Table 8, Pump Variable Speed in Table 9, Boiler Hot Water in Table 10, Heat Exchanger Fluid To Fluid in Table 11, Chiller Absorption in Table 12, Condenser Loop in Table 13, Cooling Tower Single Speed in Table 14, Plant Loop in Table 15, and the flow diagrams of HVAC systems are shown in Figure 3.

Table 2. Air Terminal Single Duct VAV Reheat.

Maximum Air Flow Rate [m3/s]	Constant Minimum Air Flow Fraction	User-Specified Constant Minimum Air Flow Fraction	Minimum Air Flow Rate [m3/s]	Maximum Flow per Zone Floor Area during Reheat [m3/s-m2]	Maximum Flow Fraction during Reheat []	Maximum Reheat Water Flow Rate [m3/s]	Reheat Coil Sizing Air Volume Flow Rate [m3/s]	Reheat Coil Sizing Inlet Air Temperature [C]	Reheat Coil Sizing Inlet Air Humidity Ratio [kgWater/kgDryAir]
169.29	0.093931	0.300000	50.79	0.002427	0.300000	0.076591	89.60	16.00	0.008000
99.05	0.167067	0.300000	29.72	0.001365	0.300000	0.067171	78.58	16.00	0.008000
85.39	0.207498	0.300000	25.62	0.001099	0.300000	0.067338	78.77	16.00	0.008000
115.62	0.153557	0.300000	34.69	0.001485	0.300000	0.098844	115.62	16.00	0.008000

Table 3. Coil Heating Water.

	Design Size Rated Capacity [W]	Design Size Maximum Water Flow Rate [m3/s]	Design Size U-Factor Times Area Value [W/K]
Second floor	3204990.83	0.076591	79482.64
first floor	2810817.22	0.067171	69706.82
ground floor	2817828.28	0.067338	69881.12
-1floor	4136199.44	0.098844	102577.83
Air loop AHU heating coil	6074144.84	0.145156	77185.54

Table 4. Air Loop HVAC

	Sum of Air Terminal Maximum Heating Flow Rates [m3/s]	Sum of Air Terminal Heating Flow Rates [m3/s]	Sum of Air Terminal Maximum Flow Rates [m3/s]	Adjusted Heating Design Air Flow Rate [m3/s]	Adjusted Cooling Design Air Flow Rate [m3/s]	Adjusted Main Design Air Flow Rate [m3/s]	User Heating Air Flow Ratio []	Calculated Heating Air Flow Ratio []	Design Supply Air Flow Rate [m3/s]
Air loop	140.81	140.81	469.36	362.57	437.04	437.04	0.300000	0.829607	437.04

Table 5. Fan Variable Volume

	Design Size Maximum Flow Rate [m3/s]
Air loop AHU extract fan	437.04
Air loop AHU supply fan	437.04

Table 6. Controller Outdoor Air.

	Maximum Outdoor Air Flow Rate [m3/s]	Minimum Outdoor Air Flow Rate [m3/s]
Air loop AHU outdoor air controller	437.04	200.13

Table 7. Coil Cooling Water

	Coil load [w]	Water flow rate [m3/s]	Air flow rate [m3/s]	Inlet air temperature [c]	Inlet water temperature [c]	Outlet air temperature [c]	Inlet air humidity ratio	Outlet air humidity ratio
Air loop AHU cooling coil	9996565.31	0.649505	437.04	27.93	6.00	12.00	0.009897	0.009265

Table 8. Controller Water Coil

	Maximum Actuated Flow [m3/s]	Controller Convergence Tolerance
Air loop AHU cooling coil controller	0.649505	0.000001
Air loop AHU heating coil controller	0.145156	0.000003

Table 9. Pump Variable Speed.

	Design Flow Rate [m3/s]	Design Power Consumption [W]
HW loop supply pump	0.455100	12965.80
CHW loop supply pump	0.649505	18504.42
Condenser loop supply pump	2.57	73092.27

Table 10. Boiler Hot Water

	Design Size Nominal Capacity [W]	Design Size Design Water Flow Rate [m3/s]
Boiler	19094036.48	0.455100

Table 11. Heat Exchanger Fluid To Fluid

	Loop Supply Side Design Fluid Flow Rate [m3/s]	Loop Demand Side Design Fluid Flow Rate [m3/s]	Heat Exchanger U-Factor Times Area Value [W/C]	Loop-to-loop Temperature Difference Used to Size Heat Exchanger U-Factor Times Area Value [C]
HX	0.649505	0.649505	526153.54	19.00

Table 12. Chiller Absorption

	Design Size Nominal Capacity [W]	Design Size Nominal Pumping Power [W]	User-Specified Nominal Pumping Power [W]	Design Size Design Chilled Water Flow Rate [m3/s]	Design Size Design Condenser Water Flow Rate [m3/s]
Chiller1	9996917.35	44986.13	250.00	0.649505	0.956767
Chiller2	9996917.35	44986.13	250.00	0.649505	0.956767

Table 13. Condenser Loop

	Maximum Loop Flow Rate [m3/s]	Condenser Loop Volume [m3]
Condenser loop	2.57	307.86

Table 14. Cooling Tower Single Speed.

	Design Water Flow Rate [m3/s]	Fan Power at Design Air Flow Rate [W]	Design Air Flow Rate [m3/s]	U-Factor Times Area Value at Design Air Flow Rate [W/C]	Free Convection Regime Air Flow Rate [m3/s]	Free Convection U-Factor Times Area Value [W/K]
Cooling tower 1	2.57	630488.96	1954.66	2904585.70	195.47	290458.57
Cooling tower 2	2.57	630488.96	1954.66	2904585.70	195.47	290458.57

Table 15. Plant Loop.

	Maximum Loop Flow Rate [m3/s]	Plant Loop Volume [m3]
HW loop	0.455100	54.61
CHW loop	0.649505	77.94

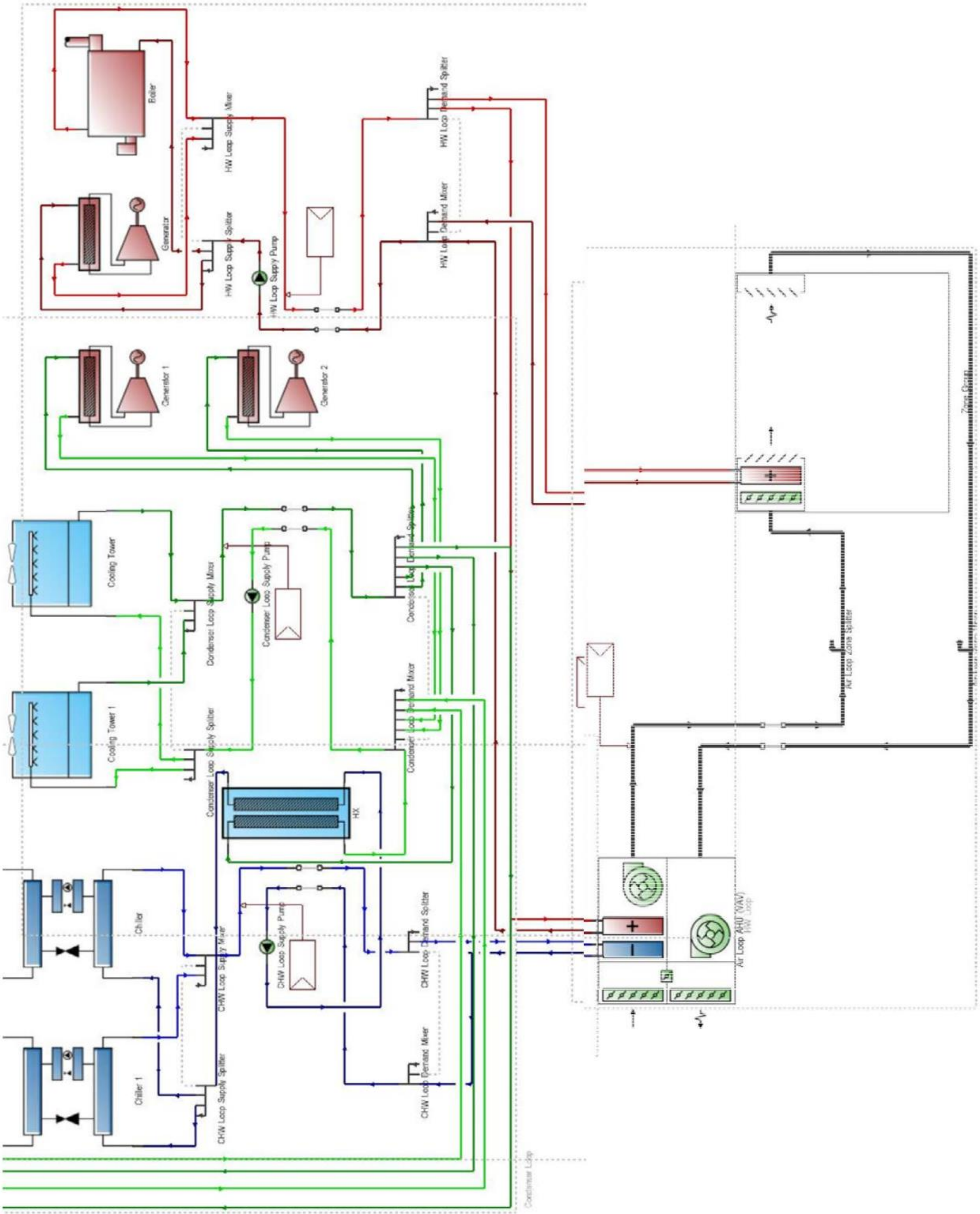


Figure 3. Plant Loop

Method

DesignBuilder modelling

In this thesis, the energy performance analysis of the MNG Shopping Center building has a construction area of 160 thousand m ^{2}. MNG Shopping Center building consists of five floors; the first two floors are parking, the ground floor half serves for parking, and the other half is retail shops; the first-floor retail shops, and the second-floor restaurants, have been made.

For this purpose, the building was first modeled and introduced in three dimensions in the Revit program; after that, it transferred to DesignBuilder v6.1.0.6 program with EnergyPlus v8.9 simulation engine.

The building is modeled floor by floor in Revit and started modeling with par; it is underground. All floors are modeled in the same conditions except the parking floors. After that, it transferred to the DesignBuilder programs shown in Figure 4.

Since the study was carried out for an existing building, all architectural and mechanical installation projects were provided, and these projects were used to introduce the building in DesignBuilder. In addition, a field study was carried out in the building and the area where the building is located, and all parts of the building were visited. In consultation with the building energy manager, the changes in the systems that are different from the project were noted and used in modeling and building promotion.

EnergyPlus simulation engine

EnergyPlus uses hourly climate data in its calculations and calculates the heating and cooling loads in an integrated manner, considering the feedback. Calculation results can be obtained hourly, monthly, or annually depending on preference. This makes it possible to get detailed calculation results from the EnergyPlus simulation engine.

As a result of the simulation, building loads, CO_2 production, and EC of HVAC system designs are calculated annually, monthly, and hourly. The ECs obtained because of the simulation were compared with the actual ECs measured. Then, the energy demand in all energy consumption systems was minimized with reasonable investments. In addition, the CO_2 production of the building was also examined. The CO_2 production from natural gas consumption is calculated for the building's heating and hot water needs. CO_2 results from electricity consumption production whereas EnergyPlus calculation in the algorithm found and the building It is obtained by multiplying the carbon emission factor of the location and the total electricity consumption. It is being done.

While modeling and promoting the building, the geometry of the building, the direction of the building, the characteristics of the HVAC and lighting systems, the definition of the building components, the purpose of use of the zones, internal thermal gains, comfort conditions and hourly actual meteorological data of the location of the building are entered into the program, the data entered in the Location template tab of the program is in Figure 5, The data entered in the Activity tab of the program is in Figure 6, the data entered in the Construction tab is in Figure 7, the data entered in the Lighting tab is in Figure 8, and the data entered in the Generation tab is in Figure 9, the data entered in the Region tab is in Figure 10.

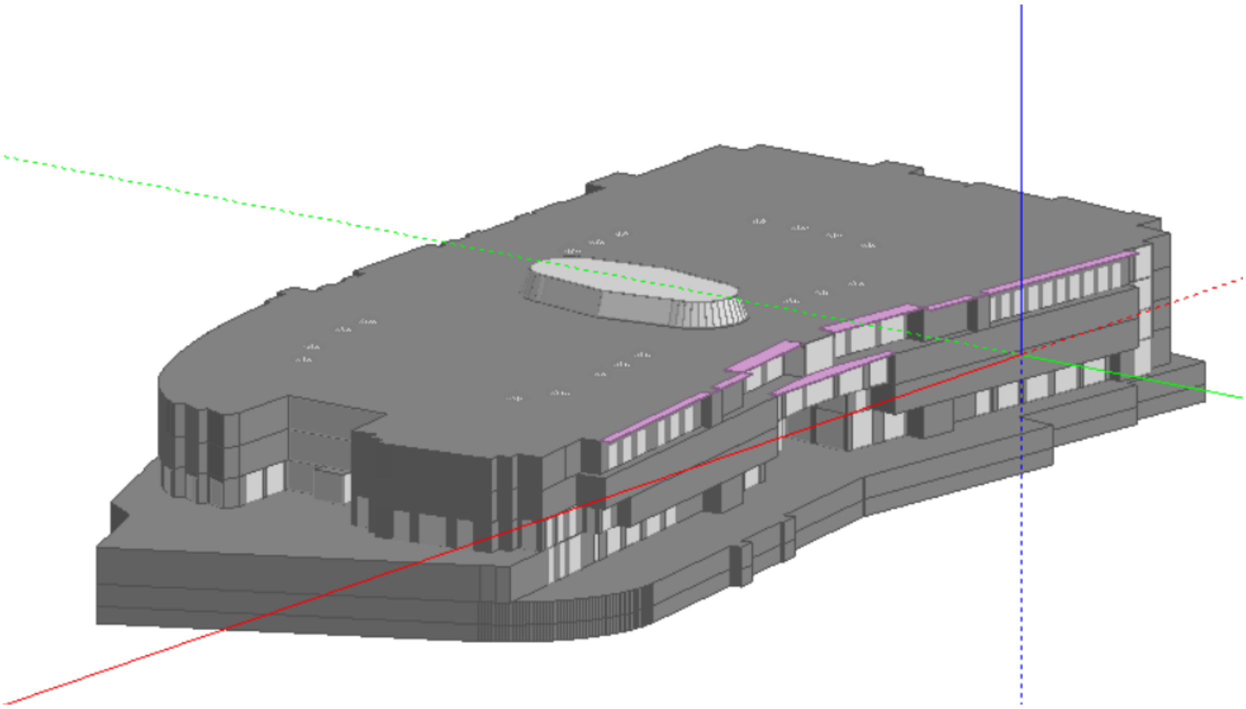


Figure 4. 3D view of the MNG Shopping Center building

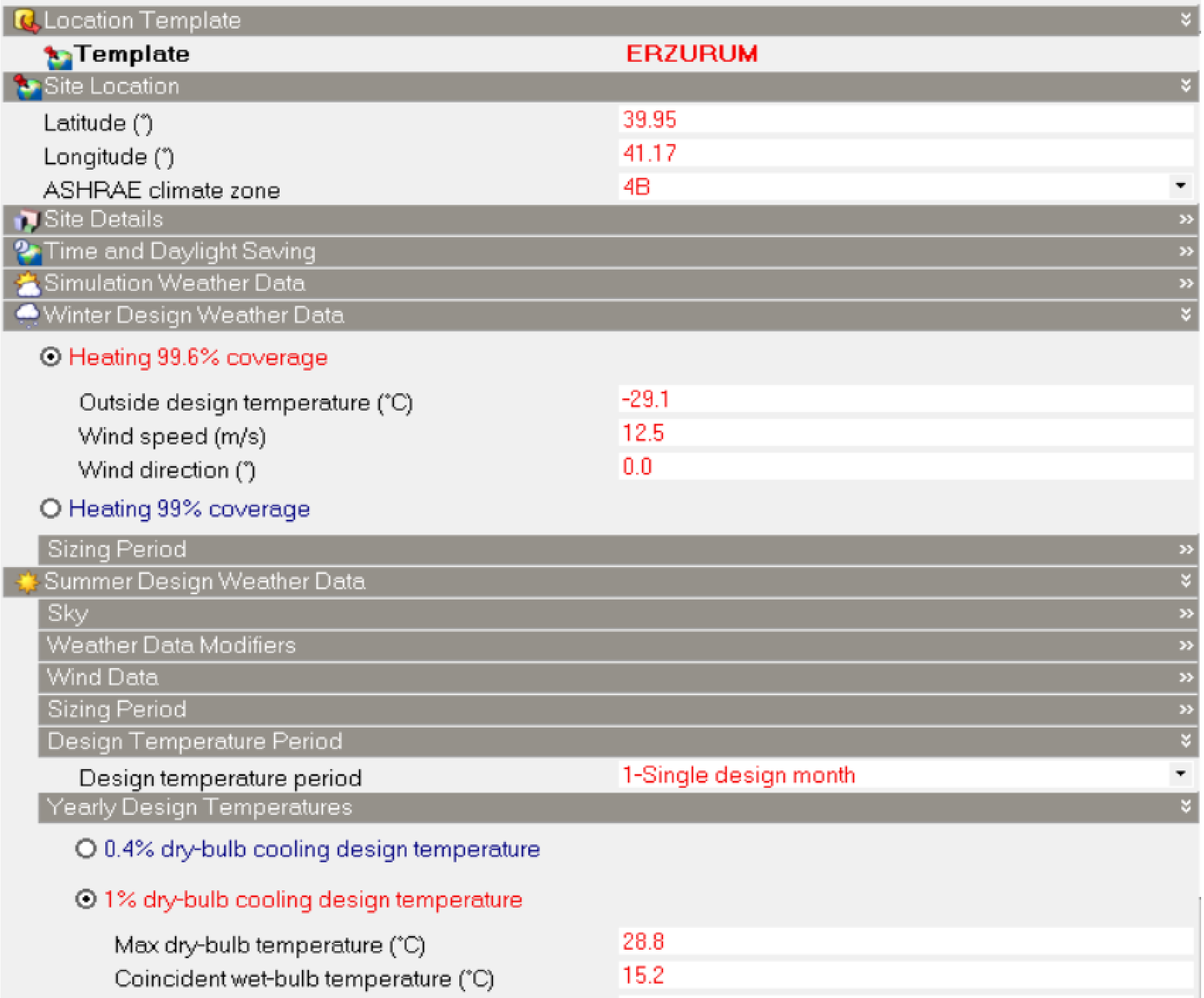


Figure 5. Location template tab

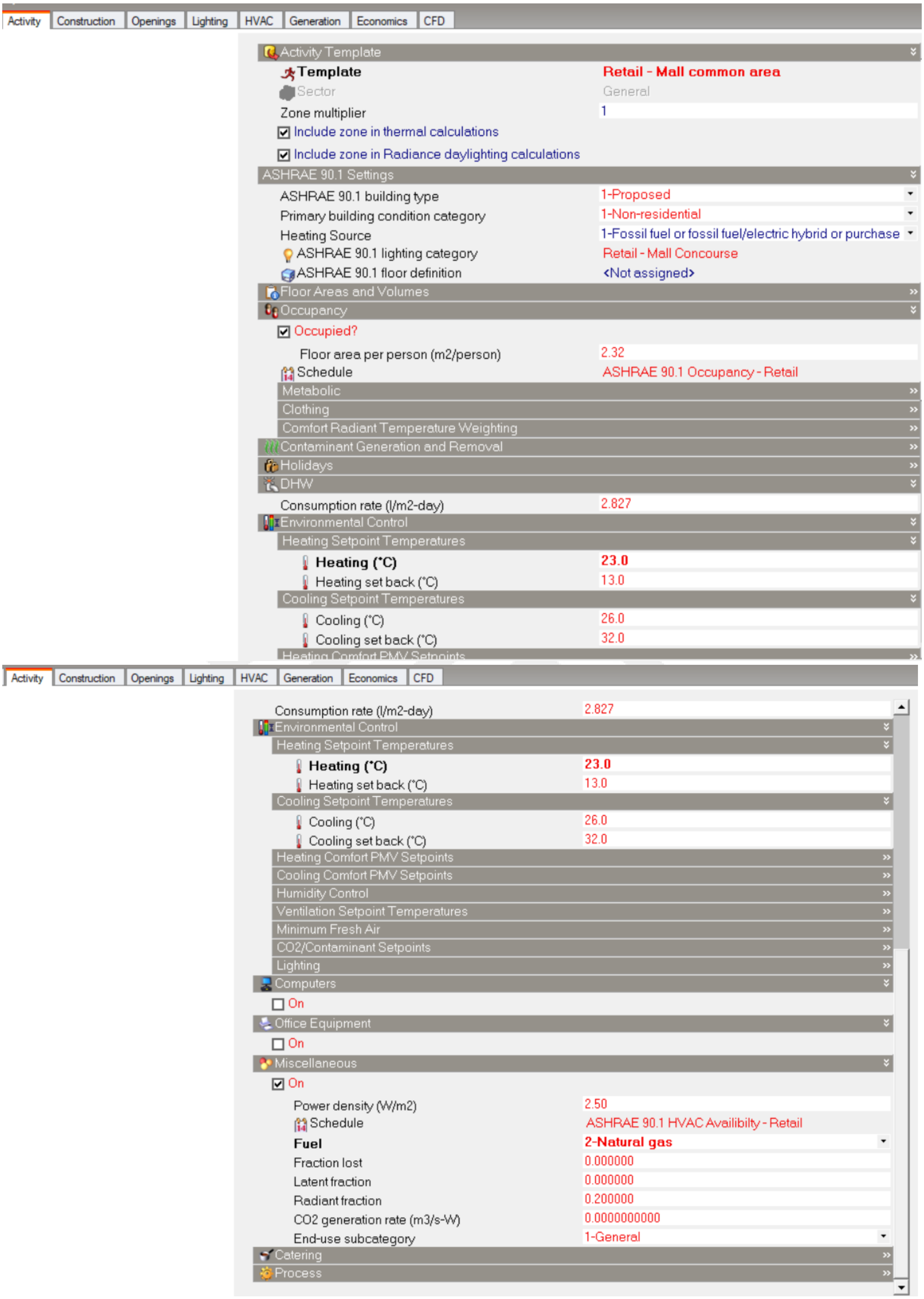


Figure 6. Activity tab

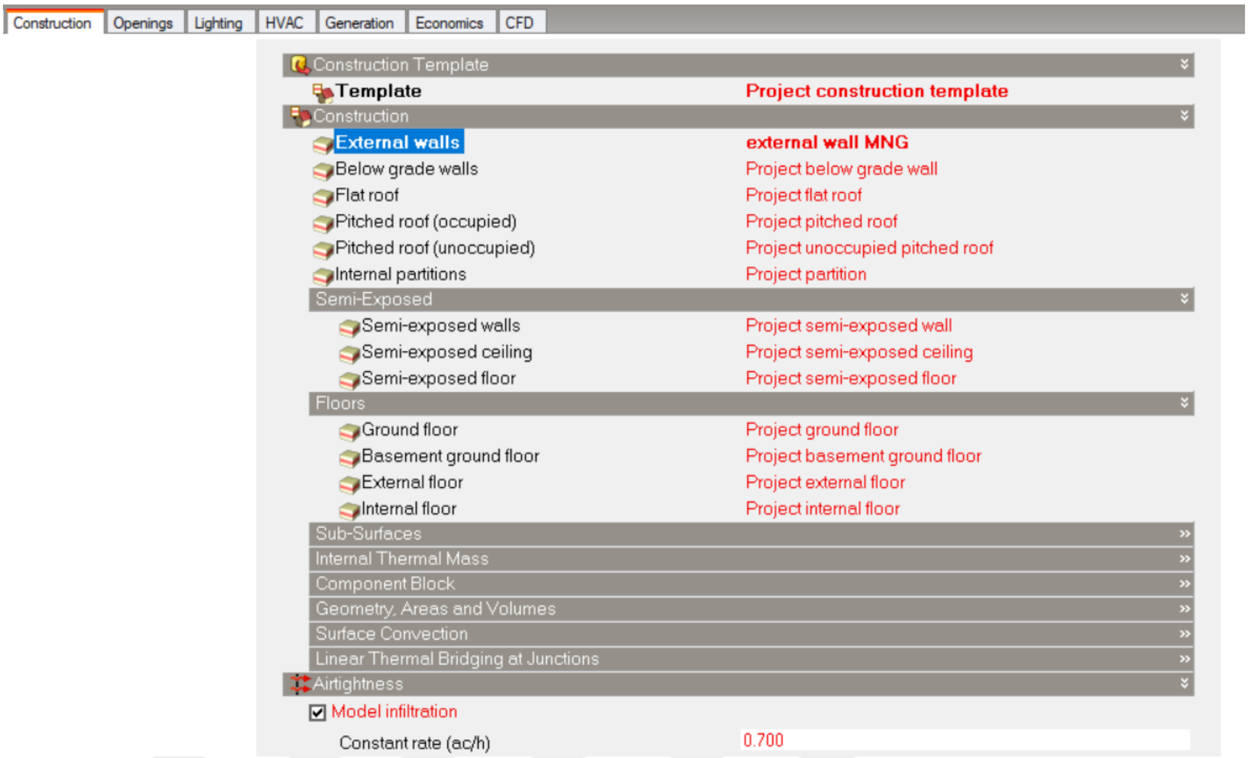


Figure 7. Construction tab

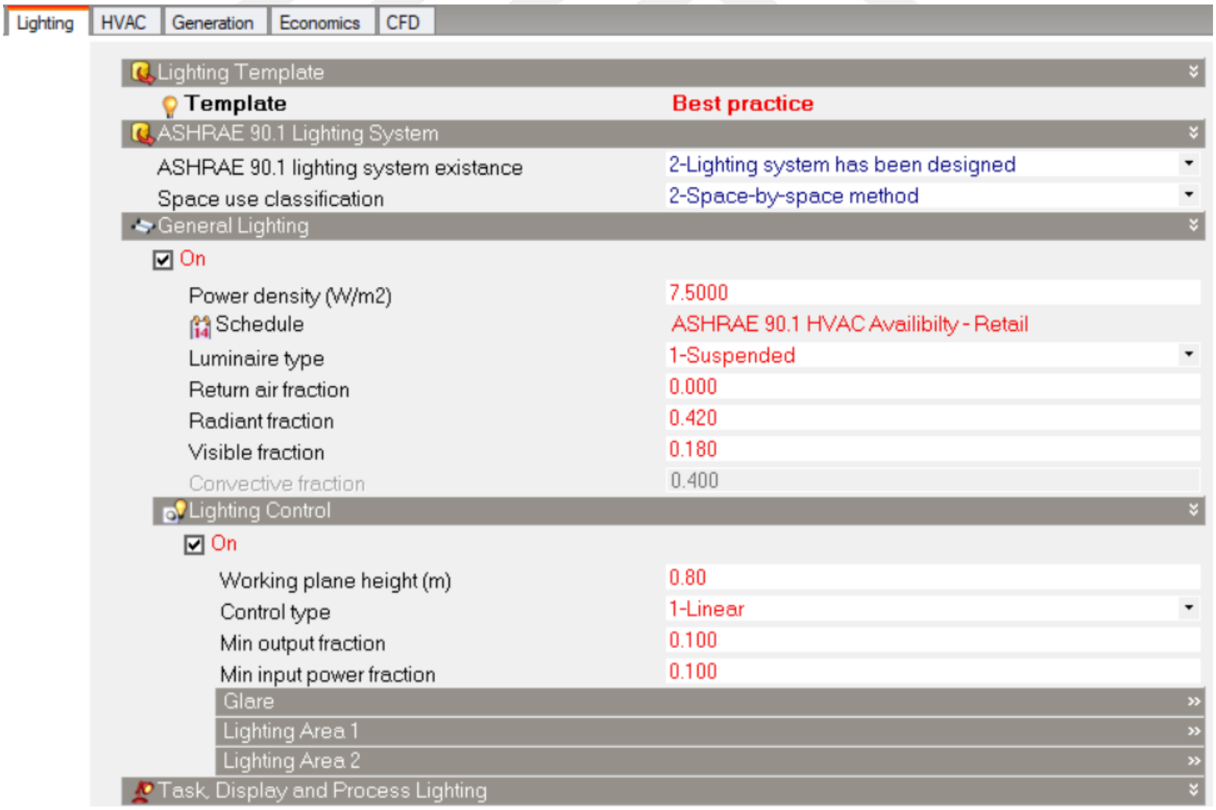


Figure 8. Lighting tab

Figure 9. Generation tab

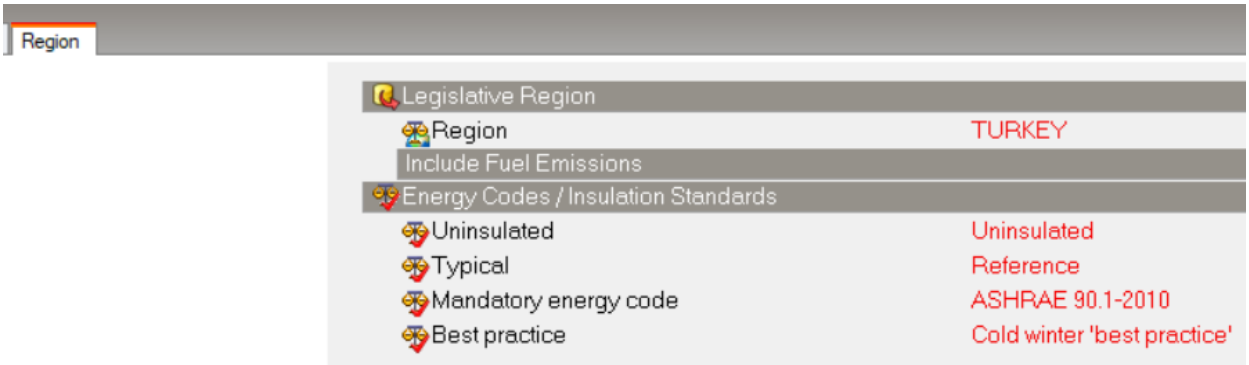


Figure 10. Region tab

Research Result and Discussion

MNG Shopping Center building consists of five floors, the first two floors are parking, the ground floor half serves parking, the other half is retail shops, the first floor is retail shops, and the second floor is restaurants. The total used area is approximately 160 thousand m^2.

In this thesis, the building studied was simulated with design-builder v6 (EnergyPlus v8.9), and the EC, internal heat gains, heat losses, heating load, and CO_2 production of the building were calculated. The EC obtained from the simulation (natural gas and electricity), and the actual EC were compared.

Annual Real EC Values

Table 16 displays the actual monthly natural gas consumption of the MNG building as the actual EC values of the MNG Shopping Centre building across all years. Table 17 provides the actual monthly power usage for all years, using EC values from 2018 through 2021. The monthly consumption value, for instance, is an annualized average. Table 16 displays, every month, the average actual natural gas consumed by MNG buildings over all years. Within the scope of the works to be done to minimize the EC of the building, Table 17 provides the monthly average actual electricity consumption for all years. The readings on the power meter are what the facility's energy manager recorded as the building's consumption. These findings indicate that the MNG Shopping Center's annual EC was 36,549,082.95 kWh. Natural gas accounts for 71.86 percent, and electricity for 28.14 percent of this usage. Annually, the building uses an estimated 228.43 kWh/m2 of EC.

Table 16. Average monthly natural gas consumption of the MNG Shopping Center building in 2018-2021

	Natural Gas Consumption (m^3)	Natural Gas Consumption (kWh)
January	250,079	2,638,333.450
February	203,279	2,144,593.450
March	210,544	2,221,239.200
April	132,100	1,393,655.000
May	123,762	1,305,689.100
June	196,503	2,073,106.650
July	226,573	2,390,345.150
August	235,720	2,486,846.000
September	228,794	2,413,776.700
October	233,390	2,462,264.500
November	226,477	2,389,332.350
December	222,249	2,344,726.950
Total	2,489,469	26,263,897.950

Table 17. Average monthly actual EC of the MNG Shopping Center building in 2018-2021

	Natural Gas Consumption (kWh)	Electricity Consumption (kWh)	Total Consumption (kWh)
January	2,638,333.450	1,045,338	3,683,671.45
February	2,144,593.450	963,838	3,108,431.45
March	2,221,239.200	945,618	3,166,857.2
April	1,393,655.000	653,075	2,046,730
May	1,305,689.100	549,083	1,854,772.1
June	2,073,106.650	747,645	2,820,751.65
July	2,390,345.150	871,885	3,262,230.15
August	2,486,846.000	940,750	3,427,596
September	2,413,776.700	913,138	3,326,914.7
October	2,462,264.500	913,043	3,375,307.5
November	2,389,332.350	875,898	3,265,230.35
December	2,344,726.950	865,878	3,210,604.95
Total	26,263,897.950	10,285,185	36,549,082.95

Simulation Results

EnergyPlus can simulate the building's lighting, heating, cooling, ventilation, and air conditioning systems and the temperature, velocity, and pressure distribution. The heating and cooling plan establishes the size of the heating and cooling systems necessary to deal with the coldest and warmest temperatures that are expected to be experienced. The DesignBuilder program calculation for Erzurum uses a minimum of -29.1°C and a maximum of 30°C for the temperature range within which HVAC components must function. The coordinates for the MNG site are (39.95, -41.17), and the ASHRAE climatic classification is 4B. Figures 11, 12, 13, and 14 depict the atmospheric pressure, average outside dry bulb temperature, wind speed, and change in wind direction, respectively. EnergyPlus provides this average weather information for Erzurum.

Figure 11 depicts the dry bulb temperature in the open air in Erzurum. The average dry bulb temperature ranges from around -2.82 degrees Celsius in January to about 25.6 °C in July.

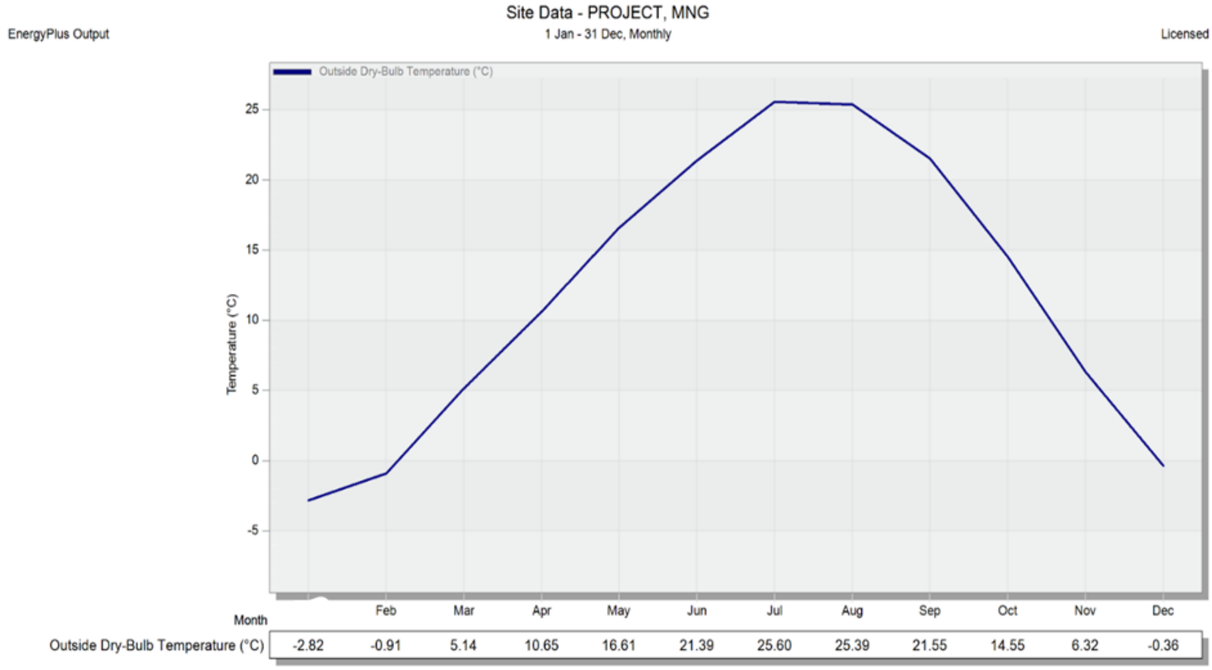


Figure 11. Change in the average outdoor dry bulb temperature of the location of the MNG shopping centre building According to months.

Figure 12 shows the variation of atmospheric pressure value according to months. As can be seen from the figure, atmospheric pressure reached its lowest value of 85765.66 Pa in February. Owner while -most high to its value 86712.01Pa with December per month is reaching.

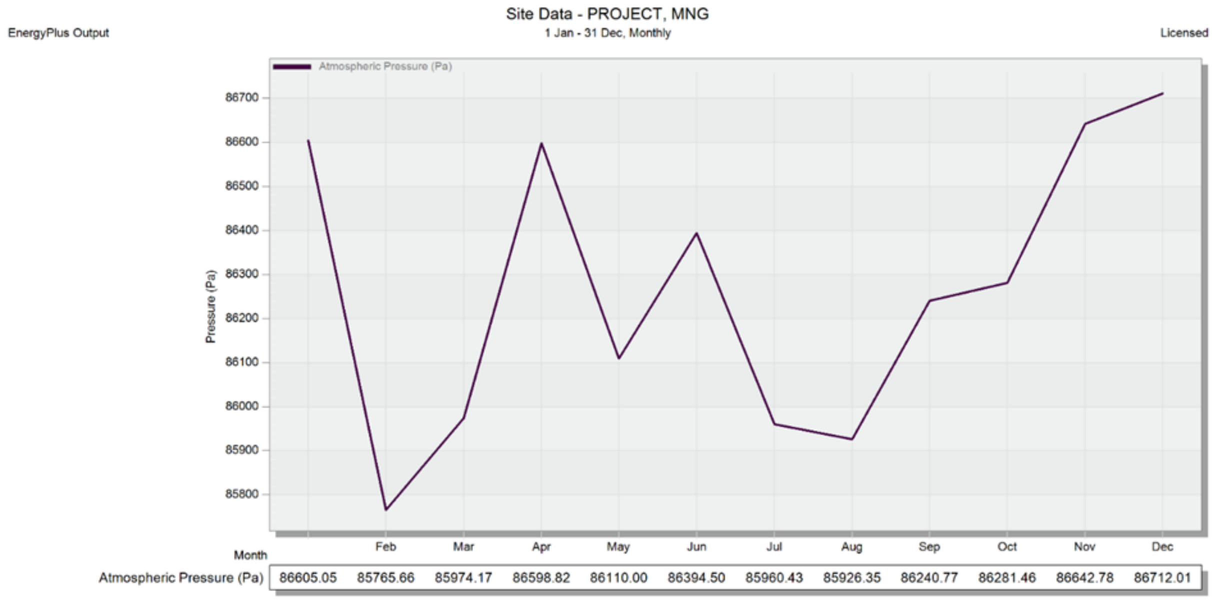


Figure 12. Atmospheric pressure change of the location of the MNG Shopping Center building according to months.

Figure 13 wind of the direction exchange is seen. Wind direction to months, according to, A lot does change much. Wind direction generally varies between 54.57° and 129.91°.

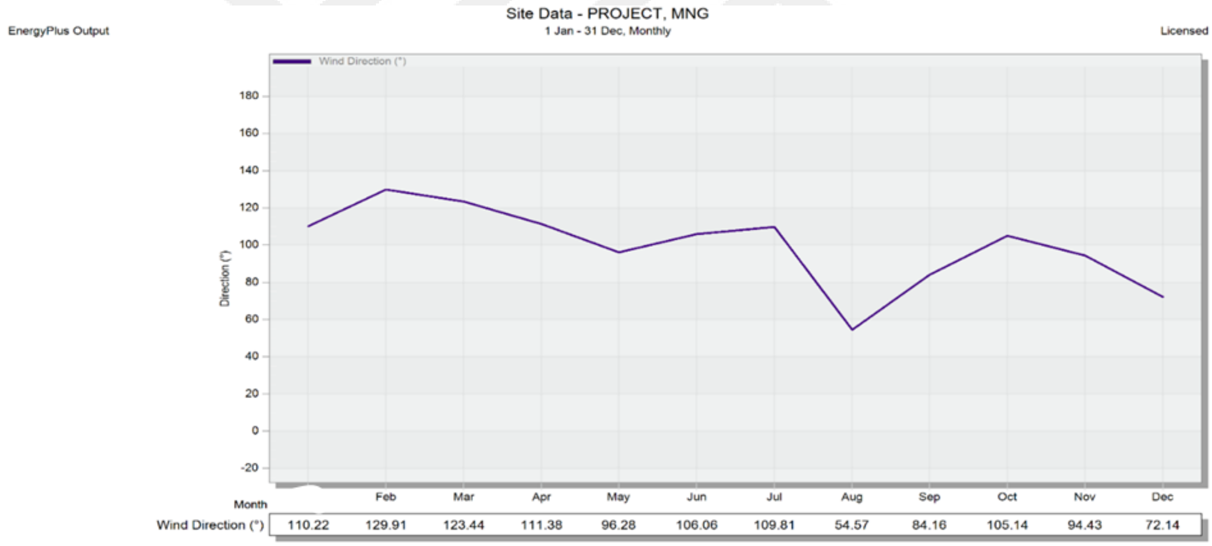


Figure 13. Change of wind direction of the MNG Shopping Center building location According to months.

The wind speed variation of the location of the MNG building is shown in Figure 14. The wind speed of the location varies between 1.88 m/s and 5.04 m/s. While the wind speed is low in winter, it is relatively higher in spring and summer.

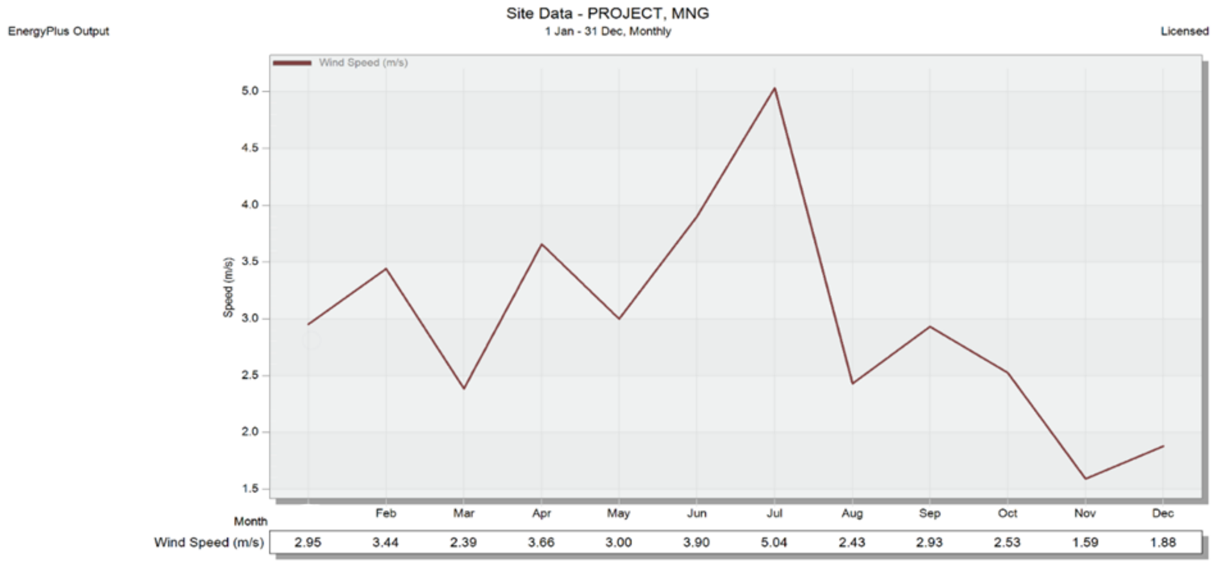


Figure 14. Wind speed change of the location of the MNG Shopping Center building According to months.

Figure 15 shows the variation in the monthly amount of solar energy coming to the MNG building. Direct normal solar energy increases in summer and reaches a maximum of 119.46 kWh/m ^{2} in June has reached. Diffuse horizontal sun energy, whereas, in summer, the month's increase showed July 116.7 kWh/ m2 per month with a maximum level reached.

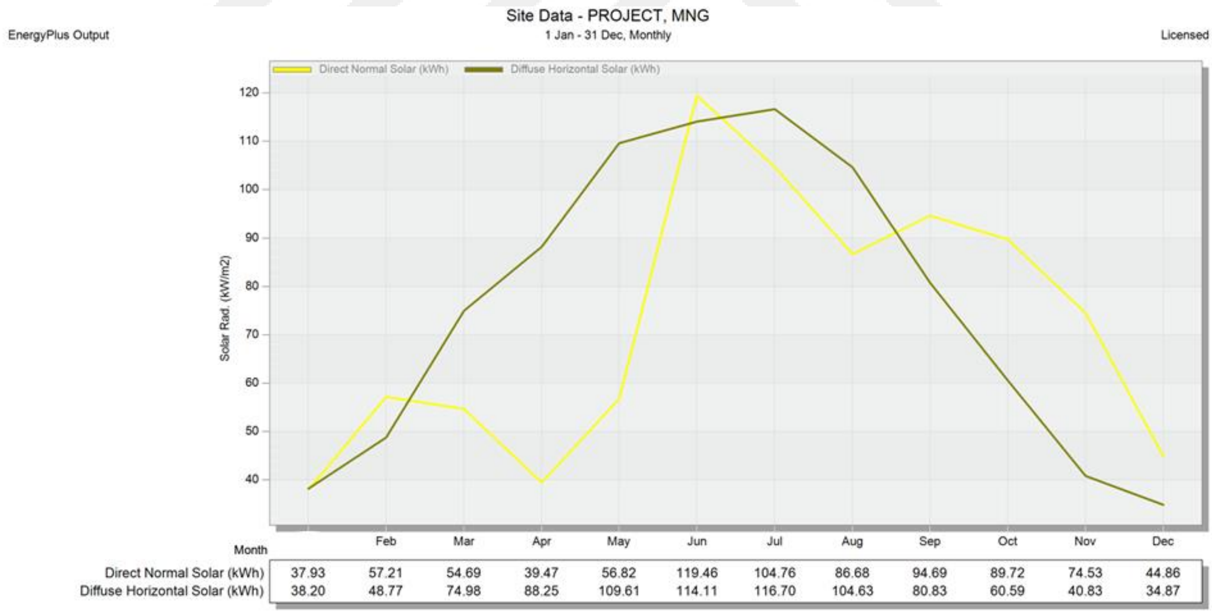
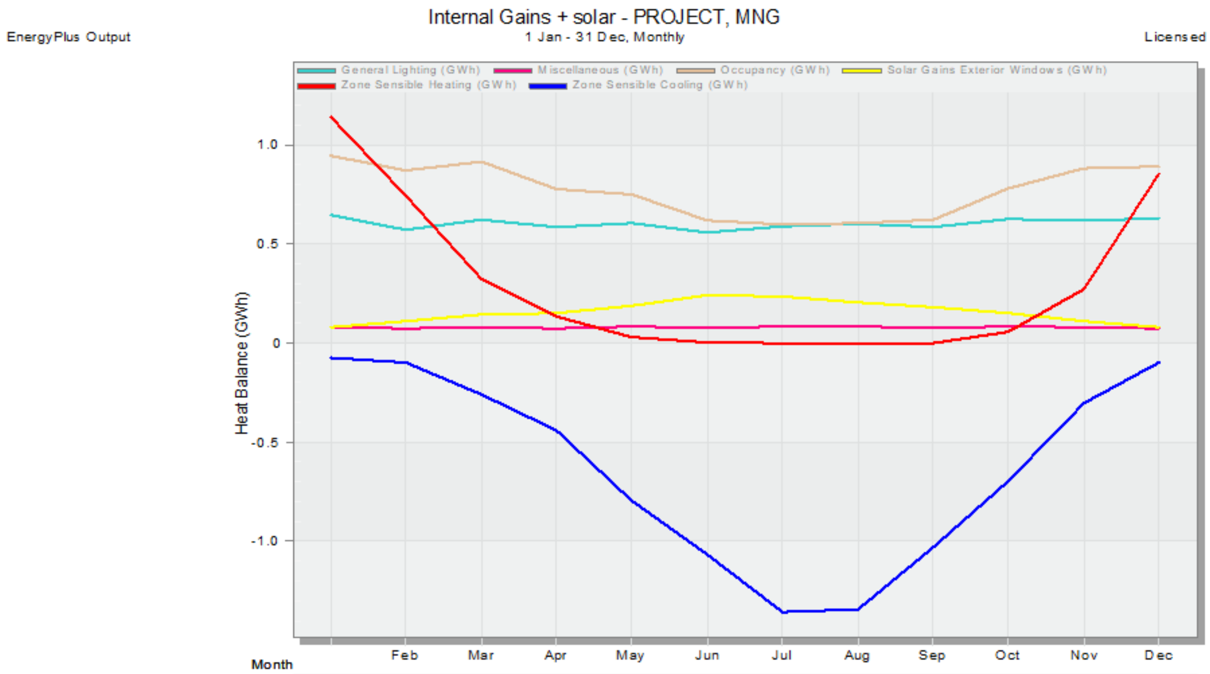


Figure 15. The amount of solar energy coming to the MNG Shopping Center building According to months.

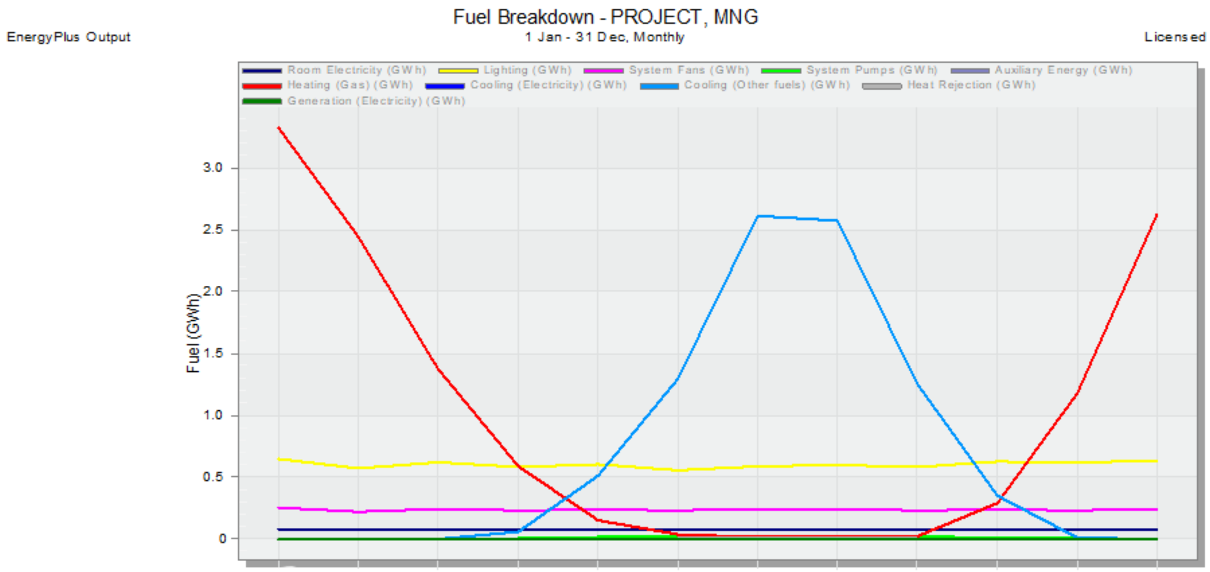
Figure 16 shows the Variation of the internal heat gains, zone sensible heating, and zone sensible cooling loads of the MNG Shopping Center building by months. The highest internal heat gain consists of lighting. This internal heat gain is followed by exterior window solar gain and gains from people, devices, and cooking. The highest zone sensible heating load was reached in January with 1.14 GWh.



Month		Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
General Lighting (GWh)	0.65	0.57	0.62	0.58	0.61	0.56	0.59	0.60	0.58	0.63	0.62	0.63
Miscellaneous (GWh)	0.08	0.07	0.08	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.07
Occupancy (GWh)	0.94	0.87	0.91	0.78	0.75	0.62	0.60	0.61	0.62	0.78	0.88	0.89
Solar Gains Exterior Windows (GWh)	0.08	0.11	0.14	0.15	0.19	0.24	0.24	0.21	0.18	0.15	0.11	0.08
Zone Sensible Heating (GWh)	1.14	0.74	0.32	0.13	0.03	0.00	0.00	0.00	0.00	0.06	0.27	0.85
Zone Sensible Cooling (GWh)	-0.08	-0.10	-0.26	-0.44	-0.79	-1.07	-1.36	-1.34	-1.03	-0.70	-0.30	-0.10

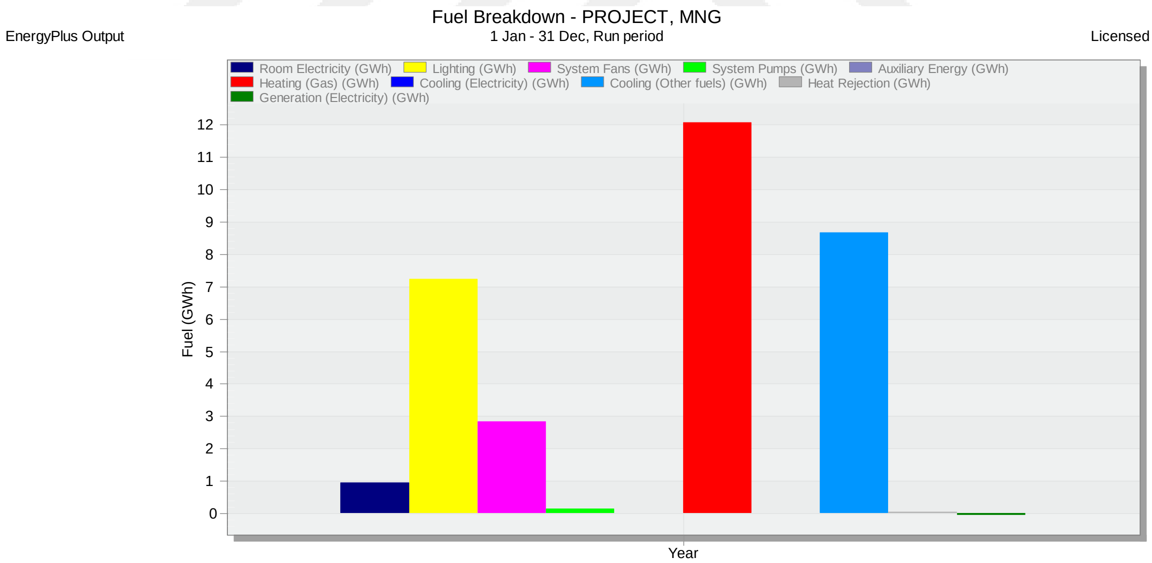
Figure 16. Variation of the internal heat gains, zone sensible heating, and zone sensible cooling loads of the MNG Shopping Center building according to months.

Figure 17 shows the systems where EC takes place and the change of EC amounts in these systems according to months. The highest EC meets the heating load and reaches its highest value in January with 3.32 GWh. In meeting the heating load used, natural gas consumption in winter months while increasing the cooling group electricity consumption is zero. In the summer months, the natural gas consumption used in heat generation decreases, and the electricity consumption of the cooling group increases. The EC of other variables is almost constant throughout the year. Is happening.



Month		Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Room Electricity (GWh)	0.08	0.07	0.08	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.07
Lighting (GWh)	0.65	0.57	0.62	0.58	0.61	0.56	0.59	0.60	0.58	0.63	0.62	0.63
System Fans (GWh)	0.25	0.22	0.24	0.23	0.24	0.23	0.24	0.24	0.23	0.24	0.23	0.24
System Pumps (GWh)	0.00	0.00	0.00	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.00	0.00
Auxiliary Energy (GWh)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heating (Gas) (GWh)	3.32	2.44	1.38	0.58	0.15	0.04	0.01	0.01	0.02	0.29	1.18	2.62
Cooling (Electricity) (GWh)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cooling (Other fuels) (GWh)	0.00	0.00	0.00	0.06	0.51	1.30	2.61	2.57	1.25	0.35	0.01	0.00
Heat Rejection (GWh)	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00
Generation (Electricity) (GWh)	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00

Figure 17. Heat losses and zone sensible heating load for the design day of the MNG Shopping Center building According to months.



	Year
Room Electricity (GWh)	0.95
Lighting (GWh)	7.23
System Fans (GWh)	2.84
System Pumps (GWh)	0.13
Auxiliary Energy (GWh)	0.00
Heating (Gas) (GWh)	12.06
Cooling (Electricity) (GWh)	0.00
Cooling (Other fuels) (GWh)	8.66
Heat Rejection (GWh)	0.03
Generation (Electricity) (GWh)	-0.05

Figure 18. Annual energy of MNG Shopping Center building according to systems consumption

Figure 18 shows the annual EC values of the MNG Shopping Center building according to the systems. The systems with the highest consumption in the MNG Shopping Center are heating and lighting systems. Energy consumed for heating While it is 12.06 MWh, the energy consumed for lighting is 7.23 MWh.

Figure 19 shows the monthly CO_2 production of the MNG Shopping Center building. CO_2 production occurs as a result of the natural gas and electricity consumption of the building. As can be seen from the figure, while CO_2 production increases in the winter months, it decreases in the summer months, and the annual total CO_2 production reaches 1,211,803 kg.

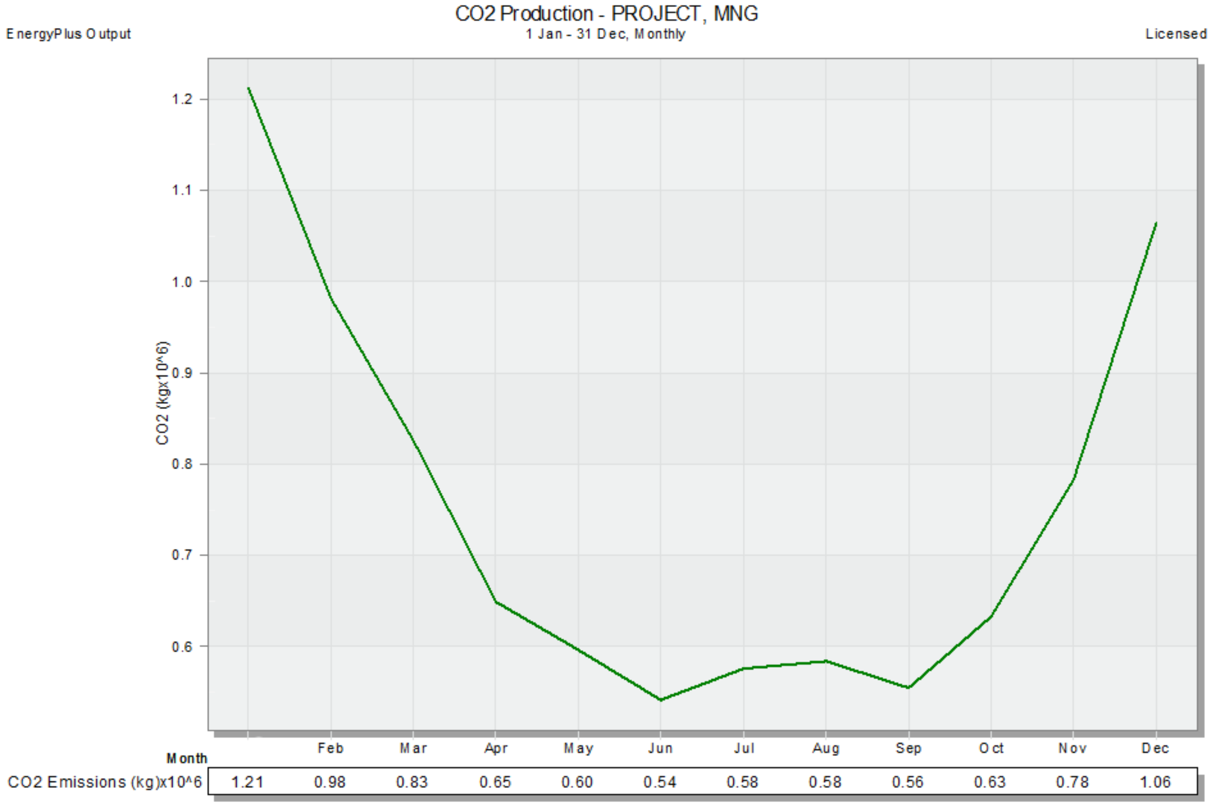
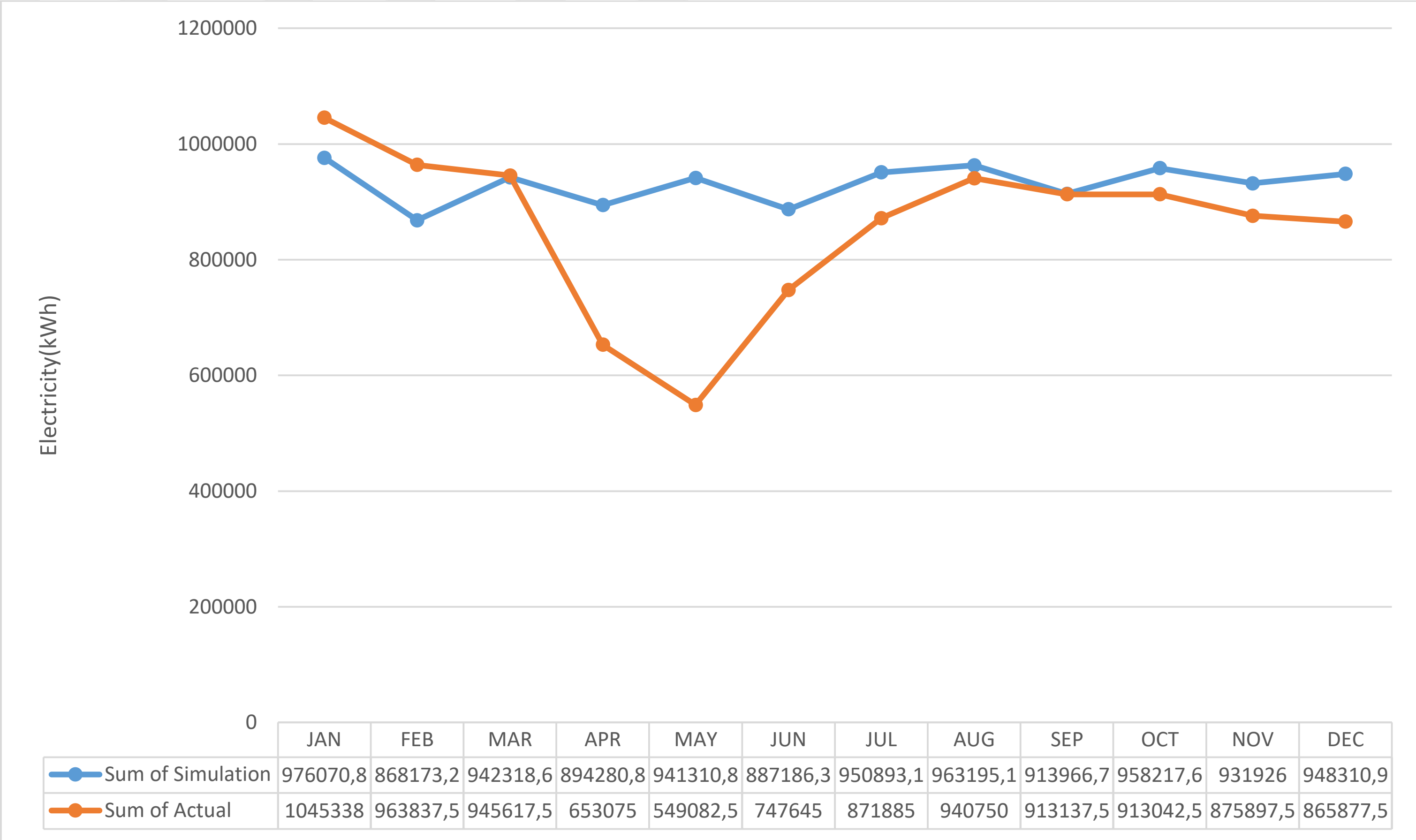


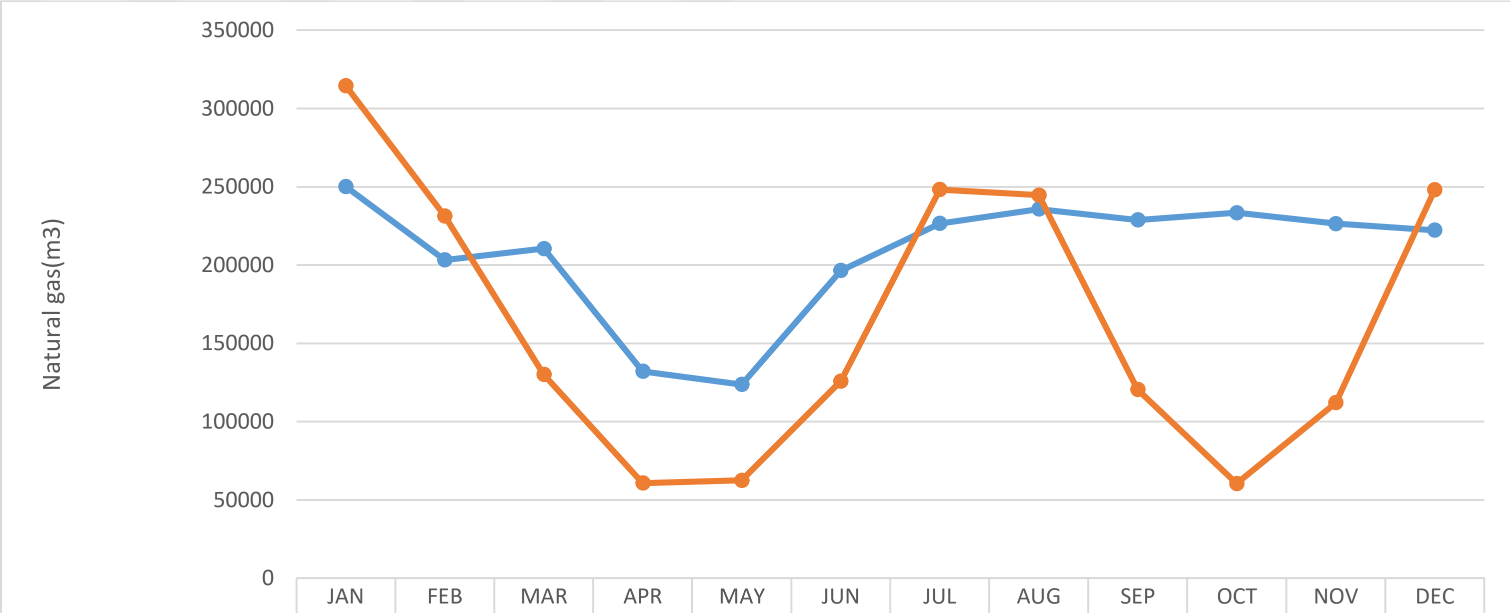
Figure 19. Monthly CO 2 production of MNG Shopping Center building.

Figure 20 shows the comparative between the actual electricity consumption and its simulation. The results show that actual electricity is higher than the simulation one. The first reason is that the data was taken for 2018-2021. In 2020 and 2021 years the consumption was very low, and because of the coronavirus, we had a curfew these years. The second reason is the operating conditions of the HVAC and lighting systems, sanitary hot water usage rates, and the net internal energy gain from computers, domestic appliances, and people. In one way, detection is not possible. This is why Modelling with their input actual values does not exactly match. Figure 21 shows the compression between the actual natural gas consumption and its simulation. The results show that the actual natural gas is higher than the simulation for the same reasons as in electricity consumption and its simulation.



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Sum of Simulation	976070,8	868173,2	942318,6	894280,8	941310,8	887186,3	950893,1	963195,1	913966,7	958217,6	931926	948310,9
Sum of Actual	1045338	963837,5	945617,5	653075	549082,5	747645	871885	940750	913137,5	913042,5	875897,5	865877,5

Figure 20. Actual electricity consumption of the MNG Shopping Center building and the EnergyPlus software result of simulation



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Sum of Actual	250079	203279,3	210544	132100	123762,3	196502,5	226573,3	235719,8	228793,5	233390	226476,5	222248,5
Sum of Simulation	314420,2	231258,8	130032,5	60766,6	62495,6	125898,3	248230,8	244674,4	120460,8	60404,63	112093,5	248075,9

Figure 21. Actual natural gas consumption of MNG Shopping Center building and natural gas consumptions obtained from simulation

The Scenarios and Strategies

There are five scenarios and strategies to reduce the CO_2 production and EC of the MNG Shopping Center building, and its result is shown:

1. Adding heat recovery

The total energy consumption could be reduced by adding heat recovery into the existing AHUs. The result from adding heat recovery is shown in Figure 22. and Figure 23.

2. Change the heating setpoint temperatures.

The total energy consumption could be reduced by decreasing or increasing the floor's heating setpoint temperatures to the recommended ranges. The result of the change in the heating setpoint temperatures is shown in Figure 24. and Figure 25.

3. Change the cooling setpoint temperatures.

The total energy consumption could be reduced by decreasing or increasing the floors' cooling setpoint temperatures to the recommended ranges. The result from the Change of the cooling setpoint temperatures is shown in Figure 26. and Figure 27.

4. Retrofitting the air distribution system from VAV to CAV

reduce energy consumption by retrofitting the existing air distribution system from VAV to CAV. The result from the Change of retrofitting the current air distribution system from VAV to CAV is shown in Figure 28. and Figure 29.

5. Polyurethane wall insulation.

The total energy consumption could be reduced by changing the wall insulation type for the MNG Shopping Center building from wool rock to Polyurethane. The result from Change wall insulation to Polyurethane is shown in Table 19

From Table 18 it shows much information about the scenarios and strategies and the differences between them, such as:

- The highest value of CO_2 production among all of the highest months of strategies is the VAV strategy. It is valued at about 1480181 in JAN. And the lowest value of CO_2 production among all of the highest months of strategies is adding heat recovery strategy, valued at about 900065.3 in JAN.
- The highest value of CO_2 production among all of the lowest months of strategies is the VAV strategy. Valued at about 819814.6 in JUN. The lowest value of CO_2 production among all of the lowest months of strategies is the baseline building strategy, valued at about 541911.3 in JUN.

- The highest annual value of CO_2 production among all the strategies is VAV. It is valued at about 12336878.3. And The lowest annual value of CO_2 production among all the strategies is Polyurethane Wall insulation, valued at about 8407590.8.
- The best saving strategy for CO_2 production is adding heat recovery. It is valued at about 1142461.4. And the worst strategy of CO_2 production is VAV; it is a value of about -3334850.9.
- The highest value of EC among all the highest months of strategies is the VAV strategy, valued at about 4970477 in JAN. And the lowest value of EC among all the highest months of strategies is adding heat recovery strategy, valued at about 3582905 in JUY.
- The highest value of EC among the lowest months of strategies is the VAV strategy. It is valued at about 2724284 in APR. The baseline building strategy is the lowest value of EC between all of the lowest months of strategies. It is valued at about 1356465 in MAY.
- The highest annual value of EC among all the strategies is VAV, valued at about 45993784.21. And The lowest annual value of EC among all the strategies is adding heat recovery. It is valued at about 27472593.24.
- The best saving strategy of EC is adding heat recovery. It is valued at about 4405745.57. And the worst strategy of EC is adding heat recovery, which is a value of about -14115445.4.

Table 18. The scenarios and strategies were made to reduce the CO2 production and EC of the MNG Shopping Center building.

Scenarios	Reduce EC result (Nor p)	CO_2 production figures result(kg)	Highest months of CO_2 production(kg)	lowest months of CO_2 production (kg)	Annual CO_2 production (kg)	Annual Saving CO_2 production(kg)
Baseline building	-	Figure 19	1211792 JAN	541911.3 JUN	9002027.4	-
Adding heat recovery	P	Figure 23	900065.3 JAN	544943.3 JUN	7859566	1142461.4
Heating from 23°C to 22°C	N	Figure 25	1211792 JAN	541911.3 JUN	9002027.4	0
Cooling from 26°C to 28°C	P	Figure 27	1211803 JAN	551526.1 JUN	9052759.5	-50732.1
From VAV to CAV	N	Figure 29	1480181 JAN	819814.6 JUN	12336878.3	-3334850.9
Polyurethane Wall insulation	P	Figure 31	1209184 JAN	551873.6 JUN	8407590.8	594436.6
Polyurethane Wall insulation (production effect)	p	Table 1 And table 19	-	-	6678814.1 6886306.5	42287.7 62022.2
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Table 18. (Continued)

Scenarios	EC figures result (kWh)	Annual EC (kWh)	Annual savings of EC (kWh)	Annual saving percentage of EC(%)	Highest months of EC (kWh)	Lowest months of EC(kWh)
baseline building	Table 17	31878338.81	-	-	4293203.8 JAN	1535368.38 APR
Adding heat recovery	Figure 22	27472593.24	4405745.57	13.8%	3582905 JUY	1484794 APR
Heating from 23°C to 22°C	Figure 24	31878338.81	0	0	4293204 JAN	1535368 APR
Cooling from 26°C to 28°C	Figure 26	28432267.21	3446071.6	10.81%	4293222 JAN	1356465 MAY
From VAV to CAV	Figure 28	45993784.21	-14115445.4	-44.27%	4970477 JAN	2724284 APR
Wall insulation	Figure 30	28394095.76	3484243.05	10.93%	4278864 JAN	1356676 MAY
Wall insulation (production effect)	Table 19	-	-	-	-	-

Table 19. Embodied and Equivalent Carbon for MNG Shopping Center with Polyurethane wall insulation.

Materials Embodied Carbon and Inventory	Area (m2)	Embodied Carbon (kgCO2)	Equivalent CO2 (kgCO2)	Mass (kg)
Miscellaneous materials - polyurethane expanded 21	35239.9	253727.1	253727.1	84575.7
Plywood (Heavyweight)	3.1	17.8	18.4	21.9
Timber Flooring	34818.9	299387.4	305895.8	650842.2
Clay Tile (roofing)	7.0	161.1	168.1	350.2
External Rendering	1730.8	5625.3	5625.3	56252.5
Floor/Roof Screed	33088.0	444703.3	444703.3	2779396.0
Plasterboard	68724.8	931853.6	980898.5	2452246.3
Gypsum Plastering	6569.6	32453.7	34161.7	85404.3
Gypsum Plasterboard	5268.0	14223.5	15408.8	118529.2
Urea Formaldehyde Foam	33088.0	78156.0	84303.1	43907.8
MW Stone Wool (rolls)	1730.8	8080.1	8618.8	7695.3
MW Glass Wool (rolls)	33484.9	88835.4	97544.8	58062.4
XPS Extruded Polystyrene - CO2 Blowing	6569.6	52645.9	175120.6	18279.8
Concrete Block (Medium)	41809.4	665608.9	665608.9	8320112.0
Cast Concrete	33088.0	529408.8	529408.8	6617609.7
Cast Concrete (Lightweight)	3.1	30.1	30.1	376.2
Cast Concrete (Dense)	170923.5	2871515.0	2871515.0	35893935.1
Brickwork Outer	6569.6	245701.7	256870.0	1116825.9
Roofing Felt	7.0	32.3	32.3	33.6
Asphalt 1	33481.8	35155.9	35155.9	703117.3
Sub Total		6557323.0	6764815.0	59007573.5

Table 18. (Continued)

Constructions Embodied Carbon and Inventory	Area (m2)	Embodied Carbon (kgCO2)	Equivalent CO2 (kgCO2)
Project unoccupied pitched roof	7.0	193.4	200.4
Project partition	2634.0	14223.5	15408.8
Project ground floor	23.3	949.9	958.8
Project below-grade wall	6569.6	404380.3	539731.3
Project basement ground floor	33064.8	1348118.0	1360708.4
external wall MNG 21	17619.9	1314447.3	1339115.2
Project flat roof	33481.8	587103.7	620187.0
The project’s internal floor Reversed	105482.9	1772112.3	1772112.3
Project semi-exposed ceiling	3.1	98.8	102.5
Project external floor	1730.8	16293.0	16887.9
Project internal floor	65440.6	1099402.3	1099402.3
Sub Total	266057.8	6557322.44	6764814.89

Glazing Embodied Carbon and Inventory	Area (m2)	Embodied Carbon (kgCO2)	Equivalent CO2 (kgCO2)
Project roof glazing	1160.6	31336.8	31336.8
Project external glazing	4821.1	90154.9	90154.9
Local shading		0.0	0.0
Window shading		0.0	0.0
Sub Total	5981.7	121491.7	121491.7
Building Total	272039.5	6678814.1	6886306.5

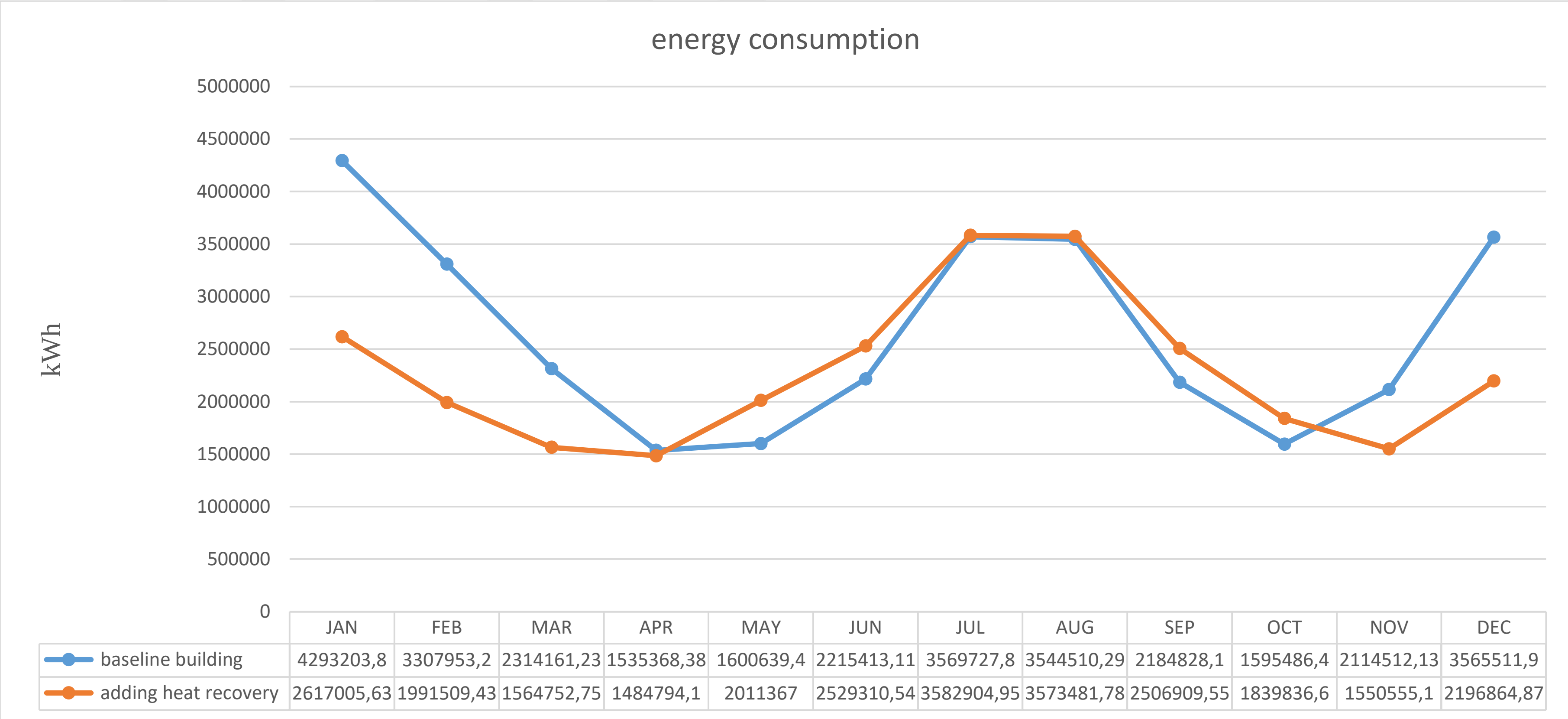
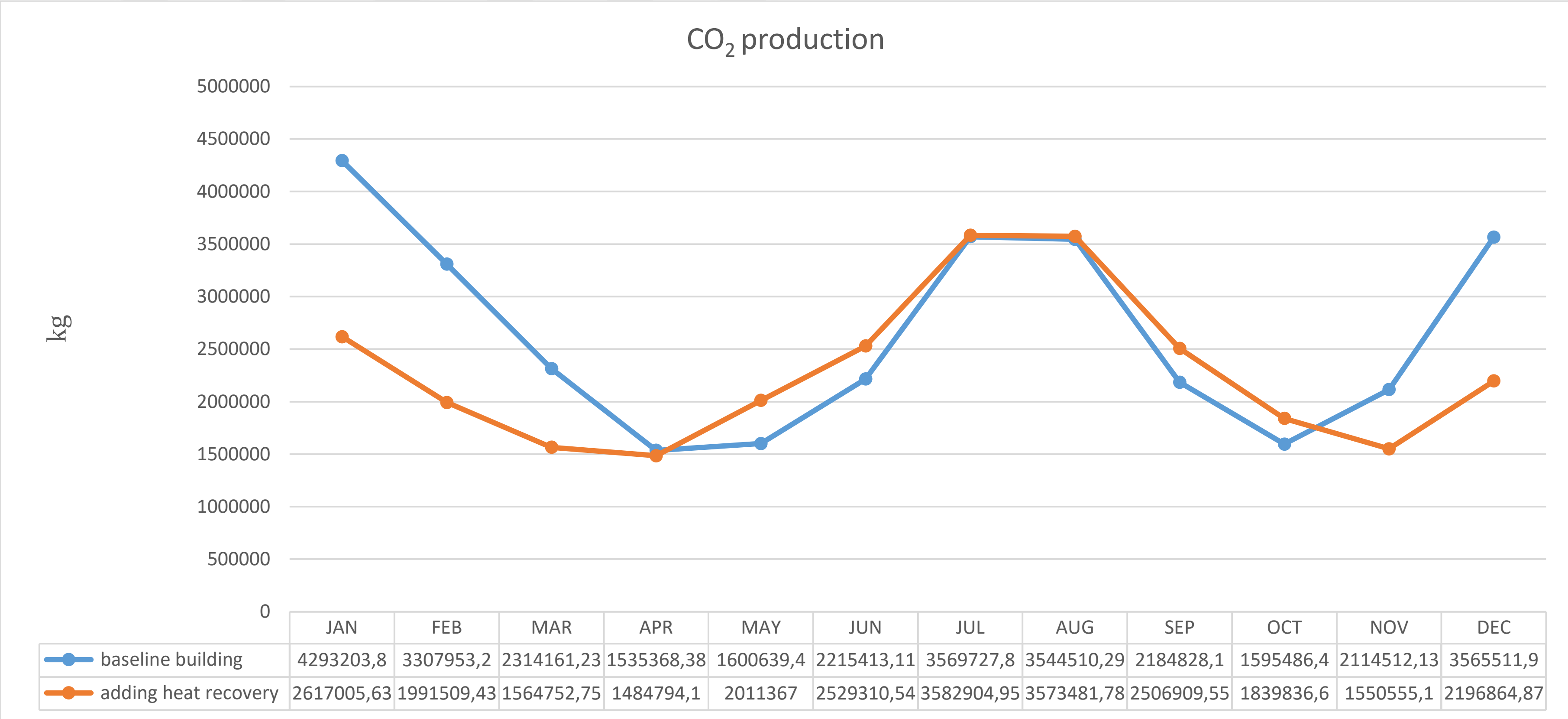
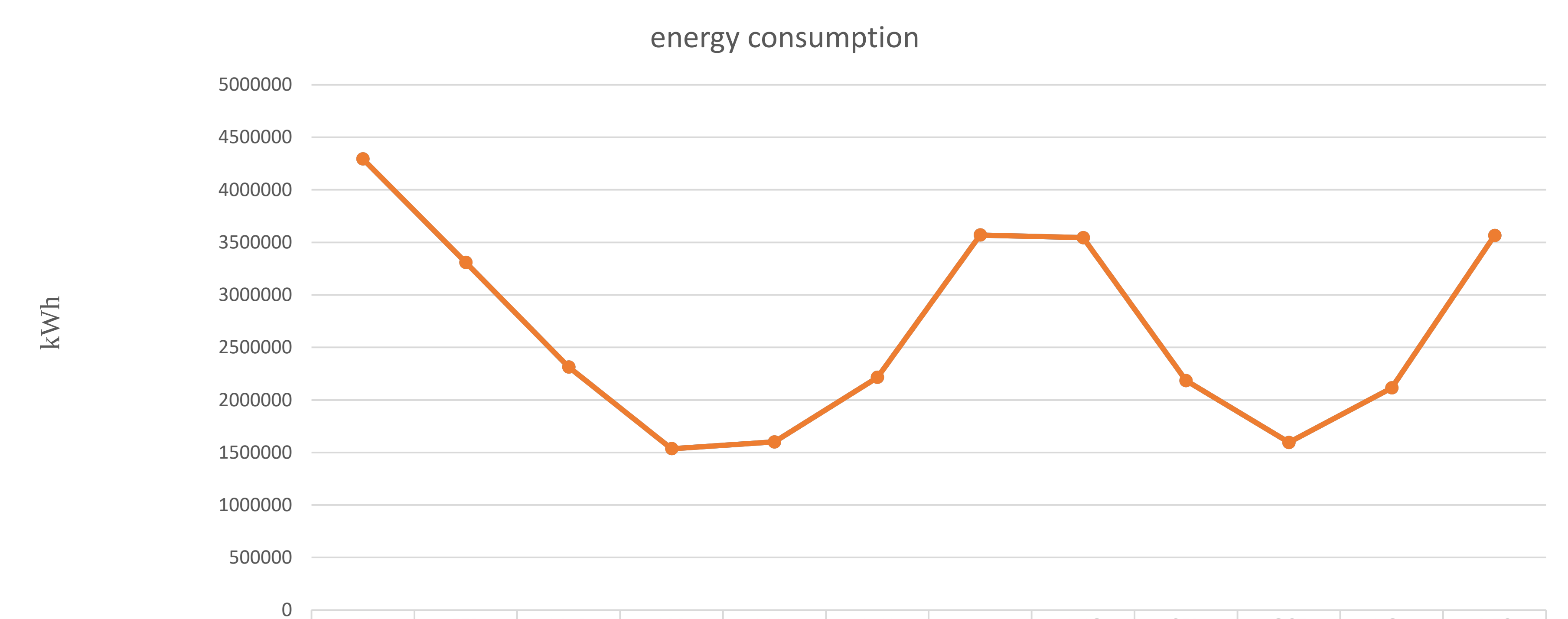


Figure 22. The effect of adding the rotary heat recovery in the monthly energy consumption in the MNG Shopping Center



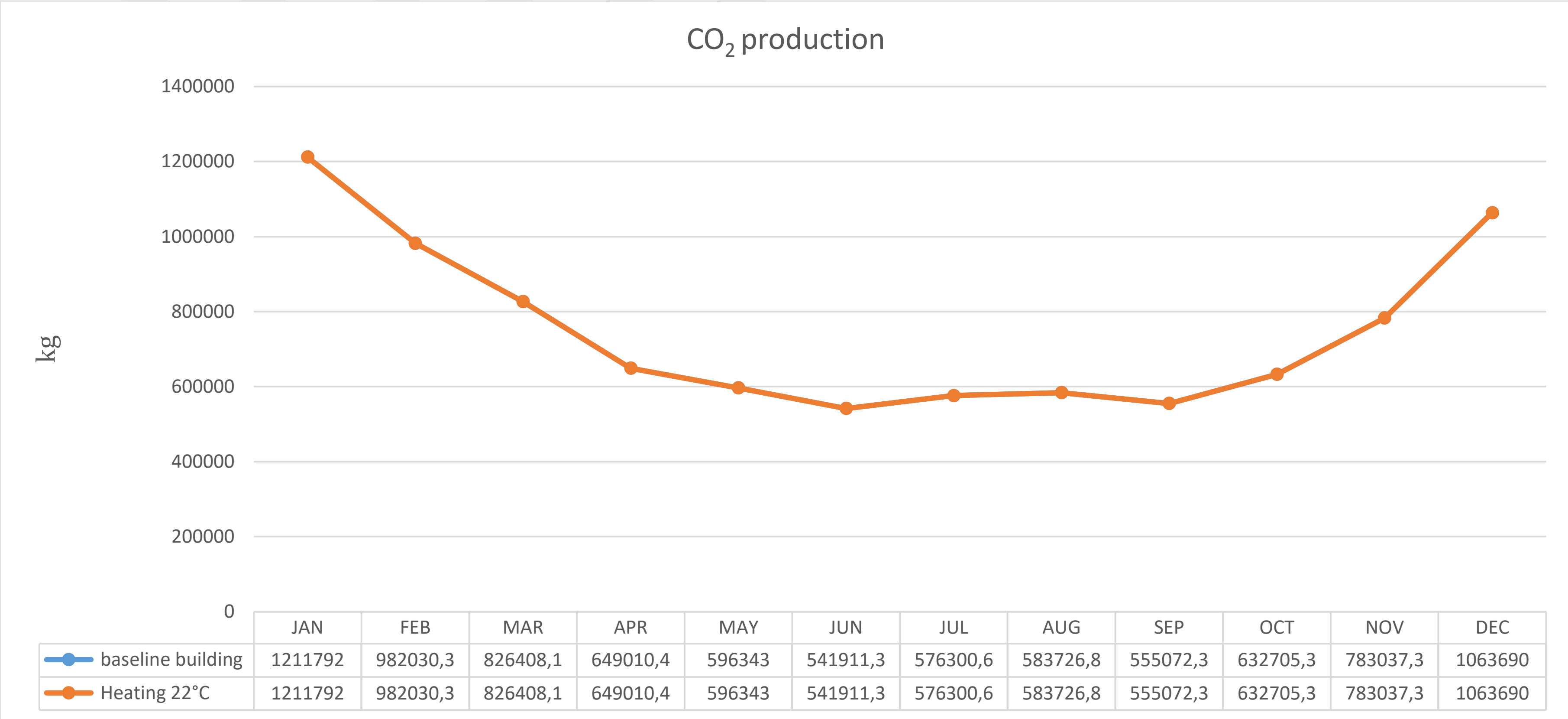
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
baseline building	4293203,8	3307953,2	2314161,23	1535368,38	1600639,4	2215413,11	3569727,8	3544510,29	2184828,1	1595486,4	2114512,13	3565511,9
adding heat recovery	2617005,63	1991509,43	1564752,75	1484794,1	2011367	2529310,54	3582904,95	3573481,78	2506909,55	1839836,6	1550555,1	2196864,87

Figure 23. The effect of adding the rotary heat recovery in the monthly CO 2 production in the MNG Shopping Center



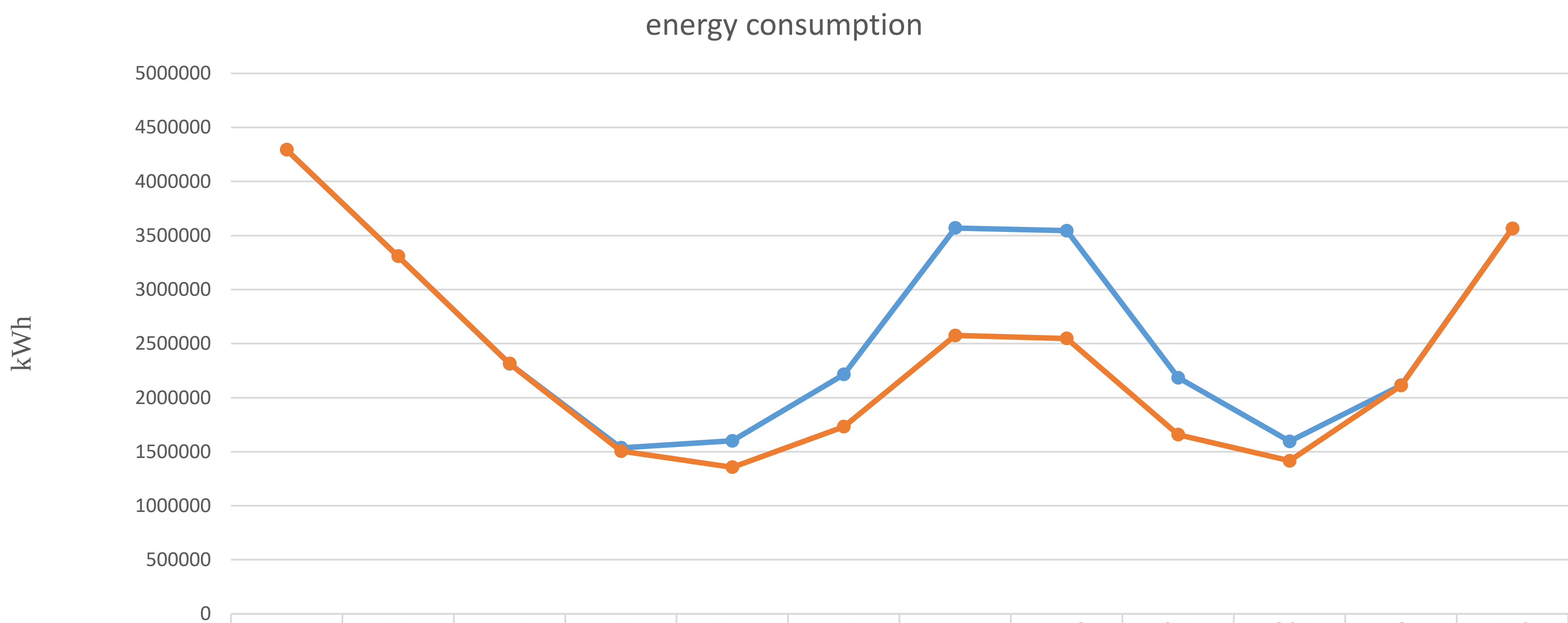
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Sum of baseline building	4293203,8	3307953,2	2314161,23	1535368,38	1600639,4	2215413,11	3569727,8	3544510,29	2184828,1	1595486,4	2114512,13	3565511,9
Sum of Heating 22°C	4293203,8	3307953,2	2314161,23	1535368,38	1600639,4	2215413,11	3569727,8	3544510,29	2184828,1	1595486,4	2114512,13	3565511,9

Figure 24. The effect of Changing the heating setpoint temperatures in the monthly energy consumption MNG Shopping Center



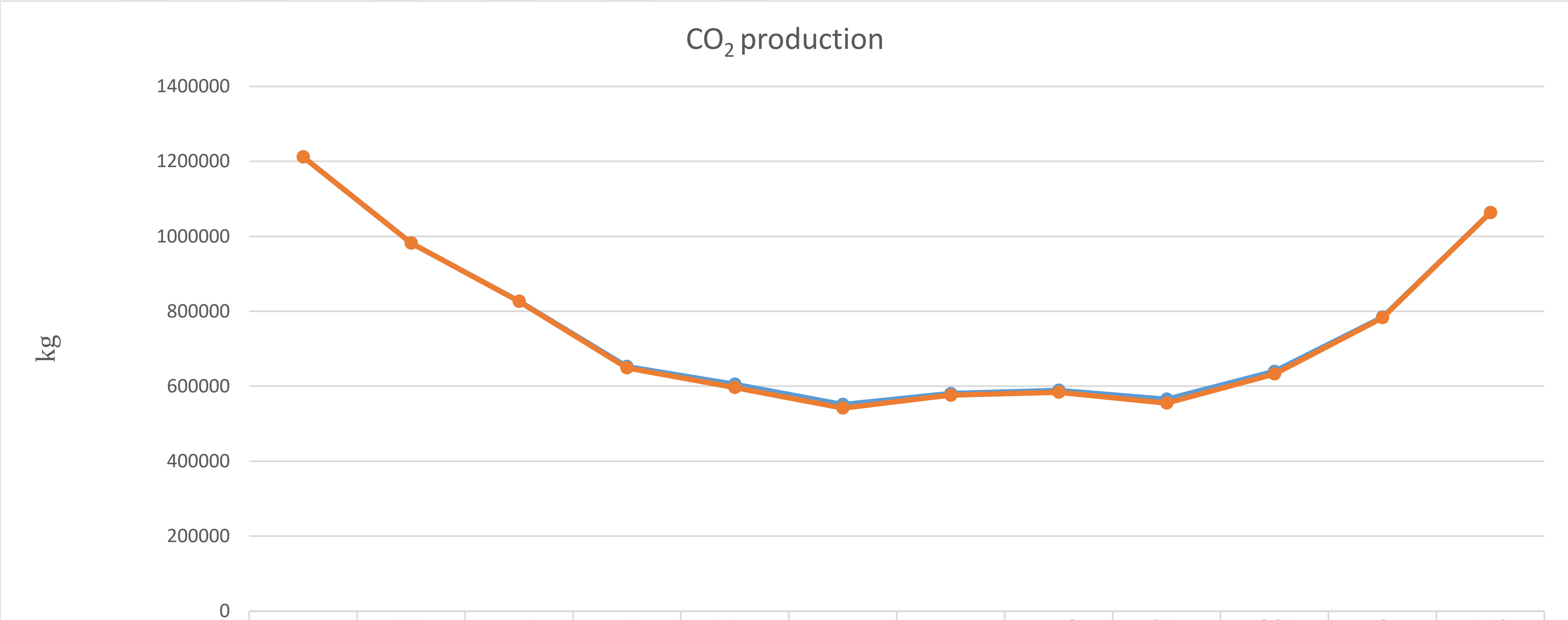
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
baseline building	1211792	982030,3	826408,1	649010,4	596343	541911,3	576300,6	583726,8	555072,3	632705,3	783037,3	1063690
Heating 22°C	1211792	982030,3	826408,1	649010,4	596343	541911,3	576300,6	583726,8	555072,3	632705,3	783037,3	1063690

Figure 25. The effect of Changing the heating setpoint temperatures in the monthly CO2 production in the MNG Shopping Center



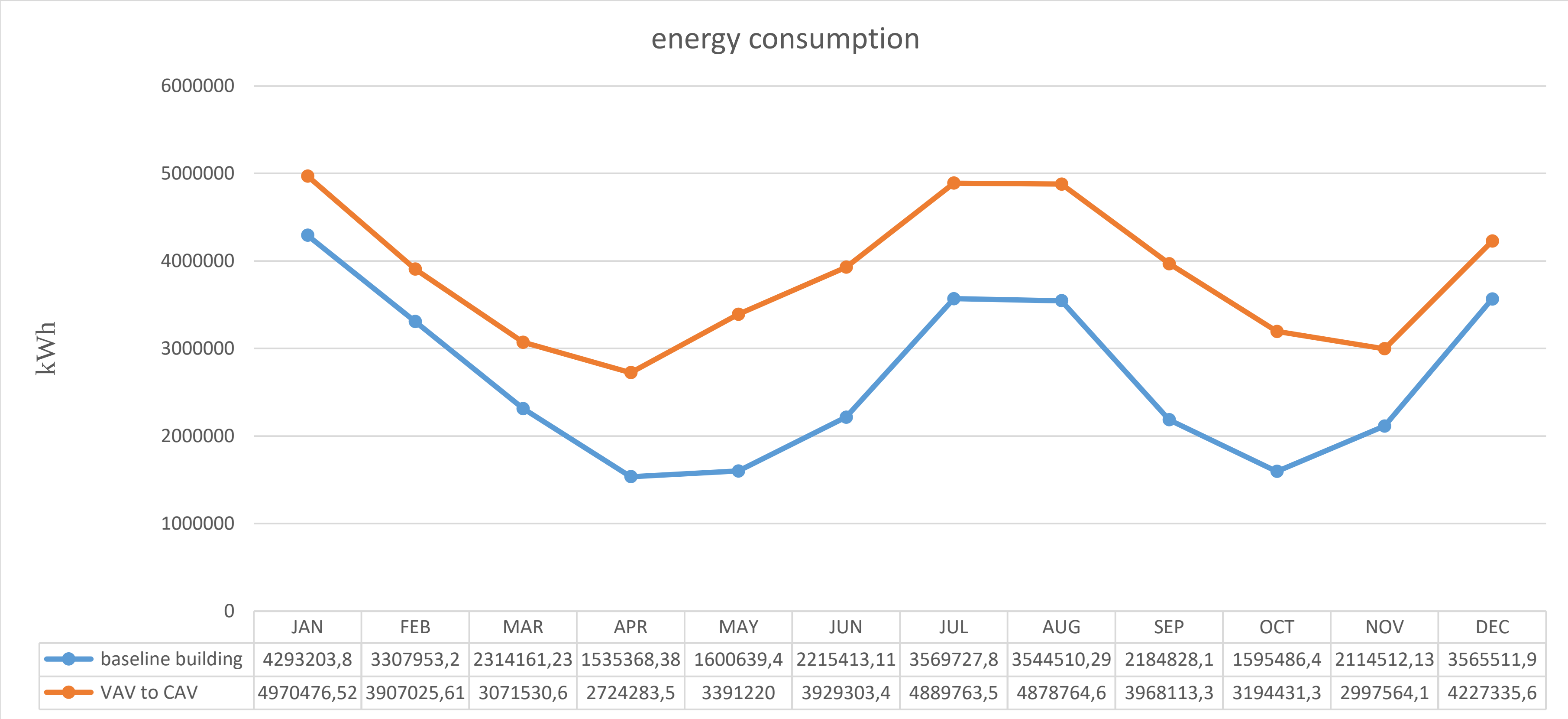
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
baseline building	4293203	3307953	2314161	1535368	1600639	2215413	3569727	3544510	2184828	1595486	2114512	3565511
cooling 28	4293221	3307953	2314570	1504938	1356465	1731833	2575687	2547002	1657029	1416152	2111549	3565511

Figure 26. The effect of Change of the cooling setpoint temperatures in the monthly energy in consumption MNG Shopping Center



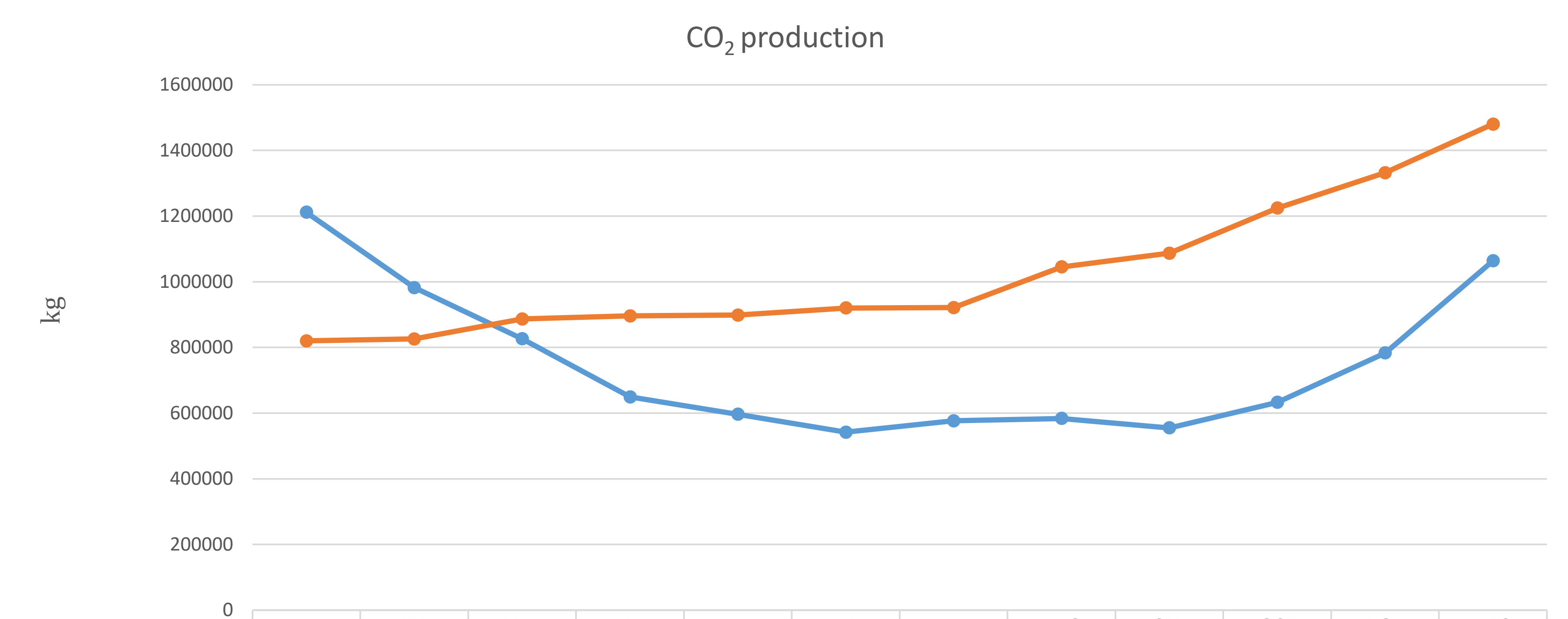
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Cooling 28°C	1211803	982030,3	826771,8	652585,2	605274,3	551526,1	580719,3	588904,6	565475,1	639701,9	784277,9	1063690
Baseline building	1211792	982030,3	826408,1	649010,4	596343	541911,3	576300,6	583726,8	555072,3	632705,3	783037,3	1063690

Figure 27. The effect of changing the cooling setpoint temperatures in the monthly CO2 production in the MNG Shopping Center



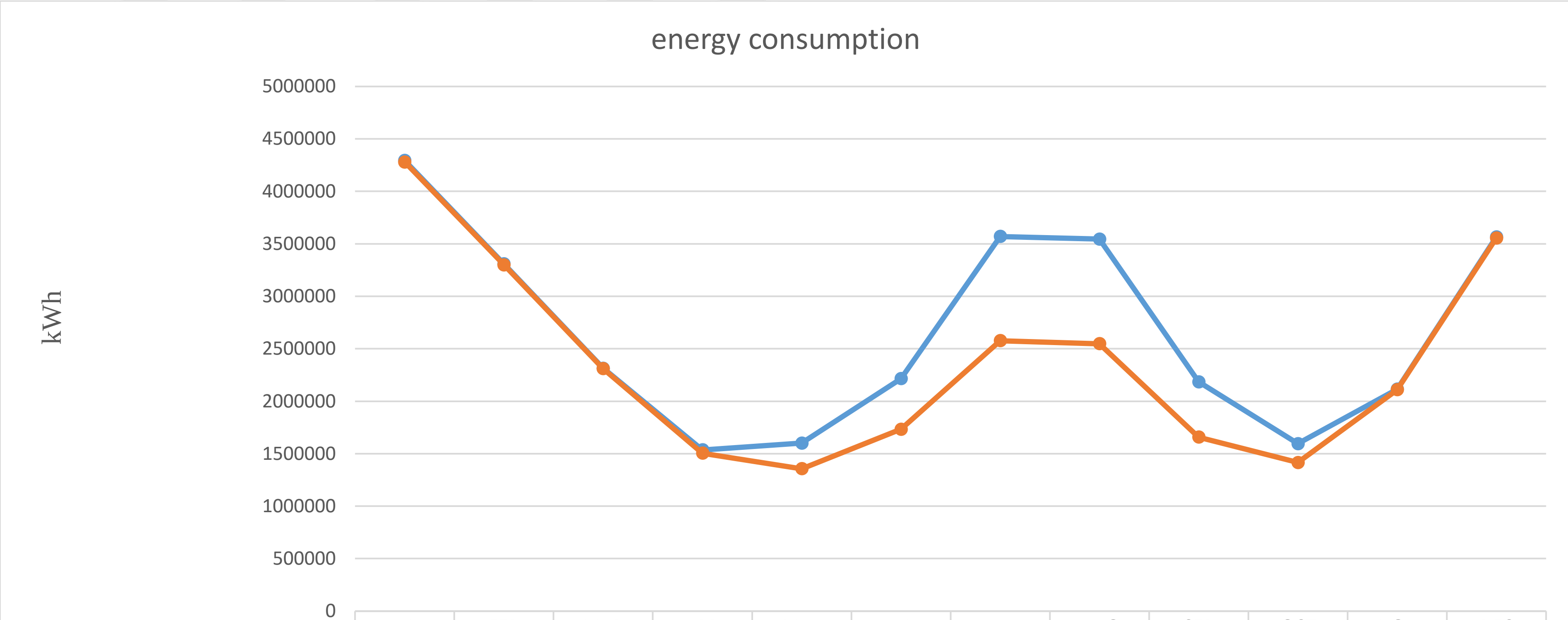
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
baseline building	4293203,8	3307953,2	2314161,23	1535368,38	1600639,4	2215413,11	3569727,8	3544510,29	2184828,1	1595486,4	2114512,13	3565511,9
VAV to CAV	4970476,52	3907025,61	3071530,6	2724283,5	3391220	3929303,4	4889763,5	4878764,6	3968113,3	3194431,3	2997564,1	4227335,6

Figure 28. The effect of Change of the Retrofitting of the air distribution system from CAV to VAV in the monthly energy in consumption MNG Shopping Center



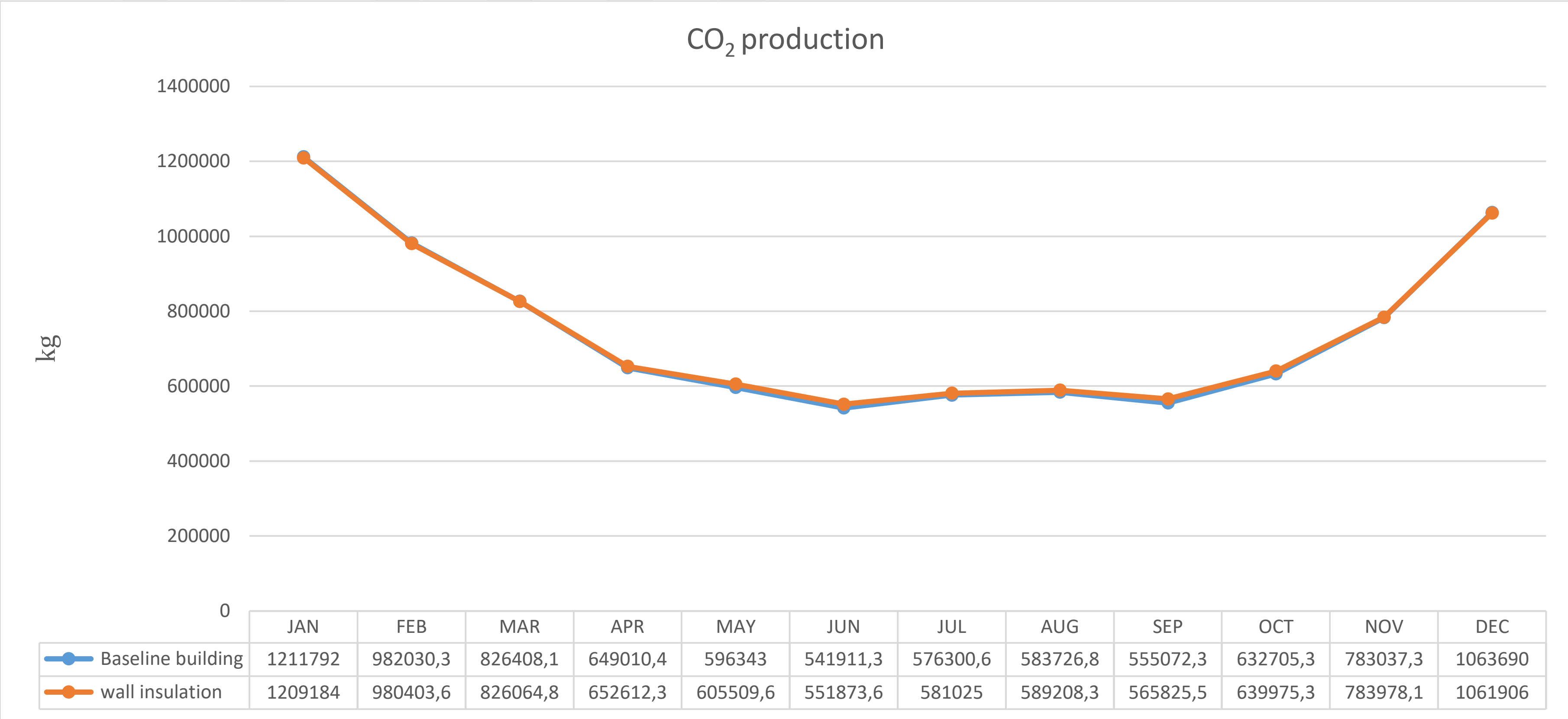
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
baseline building	1211792	982030,3	826408,1	649010,4	596343	541911,3	576300,6	583726,8	555072,3	632705,3	783037,3	1063690
from VAV to CAV	819814,6	825659,1	886752,1	896001,9	898661,1	919924,7	921362,8	1045153	1087002	1224341	1332025	1480181

Figure 29. The effect of changing the air distribution system from CAV to VAV in the monthly CO 2 production in the MNG Shopping Center



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
baseline building	4293203	3307953	2314161	1535368	1600639	2215413	3569727	3544510	2184828	1595486	2114512	3565511
Polyurethane Wall insulation	4278863	3298689	2309894	1504080	1356676	1732612	2576414	2547915	1657859	1416390	2109020	3555313

Figure 30. The effect of the Change of Polyurethane wall insulation on the monthly energy consumption in the MNG Shopping Center



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Baseline building	1211792	982030,3	826408,1	649010,4	596343	541911,3	576300,6	583726,8	555072,3	632705,3	783037,3	1063690
wall insulation	1209184	980403,6	826064,8	652612,3	605509,6	551873,6	581025	589208,3	565825,5	639975,3	783978,1	1061906

Figure 31. The effect of change Polyurethane wall insulation in the monthly CO2 production in MNG Shopping Center

CONCLUSION

Reducing Building Energy Demand

Improving energy-using systems and the locations where heat losses and gains occur with a reasonable amount of expenditure is important to reduce building energy demand. To reduce the MNG retail center's energy consumption, this study examined modifying the following systems and then simulated and analyzed several different future scenarios in which these modifications were implemented.

Recommended to be done on the MNG Shopping Center to Reduce Building Energy Demand

Adding heat recovery,

The annual savings percentage for energy consumption is 13.8 percent when a heat recovery unit is added to the MNG Shopping Center's existing air handling systems. This method can help buildings save much money on energy costs and has many other advantages as well.

Including a heat recovery unit increases the HVAC system's efficiency since it makes use of heat that would have been wasted otherwise. By using this stored heat to precondition entering fresh air, we can reduce the amount of power required to maintain a comfortable temperature.

The yearly energy savings of 13.8% are a clear indication of the significant effect of installing a heat recovery unit. The MNG Shopping Center can minimize its energy usage and utility expenses by using the recovered heat instead of conventional heating and cooling systems.

Adding a heat recovery system also helps with the quality of air inside the building. The system guarantees a healthier and more comfortable atmosphere for the MNG Shopping Center's tenants by filtering and conditioning the entering fresh air using the recovered heat.

Greenhouse gas emissions from heating and cooling systems are reduced, so this strategy is in line with sustainability objectives. By optimizing energy consumption and reducing carbon emissions, the MNG Shopping Center can make a direct contribution to climate change mitigation.

Factors including building size, occupancy rates, weather, and the heat recovery unit's effectiveness can all affect the amount of money you save on your energy bill. Therefore, in order to appropriately calculate the possible energy savings, an in-depth examination and analysis tailored to the targeted MNG Shopping Center should be carried out.

Energy savings of 13.8% per year can be achieved by installing a heat recovery unit in conjunction with preexisting air handling devices. Using this method can help you save money on utilities, improve air quality within your home, and even align with environmental goals.

Change the heating setpoint temperatures

Unfortunately, lowering the MNG Shopping Center's heating setpoint temperatures from 23°C to 22°C did not lessen the building's energy demand. Although reducing energy use was the planned objective, this was not the case.

There could be various reasons why the desired reduction in energy demand still needs to be realized. Some possible factors include:

- Occupant Comfort: The Shopping Center's occupants may have felt uneasy due to the shift in heating setpoint temperature. Let's say they found the new temperature to be too cold. There would have been no energy savings if the inhabitants responded to the more relaxed environment by turning up the thermostat or asking for additional space heaters.
- System Limitations: The need for higher heating setpoint temperatures to maintain a comfortable indoor atmosphere may result from heat loss caused by inadequate insulation inside the building envelope. Claiming a lower heating setpoint temperature may be challenging if the building is poorly insulated.
- Insufficient Insulation: The MNG Shopping Center's heating system may have restrictions that prevent us from lowering the temperature as much as we'd like. Likely, the current system can’t keep the reduced heating setpoint temperature or distribute heat uniformly throughout the building since it wasn't built or outfitted.
- Seasonal Variation: Seasonal fluctuations may affect the efficiency of the temperature-reduction technique. Changing the thermostat at a time of year when external temperatures are lower and heating needs are lower may have a more pronounced effect.
- Employee and customer behaviors can also majorly impact a building's energy demand. The expected reduction in energy consumption might not have been reached if occupants were not aware of the setpoint temperature adjustment or did not actively participate in energy-saving initiatives.

Changing the heating setpoint temperatures in the MNG Shopping Center from 23°C to 22°C to reduce building energy demand did not have the anticipated effect. Evaluating and resolving any barriers to the strategy's performance is crucial. These barriers may include occupant comfort, insulation, system limits, seasonal fluctuations, and occupant behavior. To effectively minimize energy demand in the future, it is essential to conduct a thorough analysis of these elements.

Change the cooling setpoint temperatures

An annual savings percentage of 10.8 percent can be achieved by increasing the cooling setpoint temperature in the MNG Shopping Center from 26 to 28 degrees Celsius. This modification exemplifies a feasible and efficient strategy for improving MNG Shopping Center's energy efficiency and reducing operating expenses.

The MNG Shopping Center can reduce its cooling demand and how long its air conditioners must run if it raises the cooling setpoint temperature by 2 degrees. There will be significant annual energy savings as a result of this adjustment. The cumulative energy savings of 10.8 percent are evidence of the improvement brought about by this upgrade.

While this adjustment aids in energy conservation, keeping occupant comfort in mind is also essential. Considering the weather, building use, and individual preferences while changing from 26 to 28 degrees Celsius is vital.

The annual energy savings of 10.8 percent helps cut costs and advances green goals. The MNG Shopping Center can help fight global warming and reduce its carbon footprint by reducing energy use.

Building size, design, insulation, and HVAC efficiency might affect energy savings. Therefore, detailed research and evaluation tailored to the building is necessary to measure potential energy savings accurately.

Raising the cooling thermostat from 26 degrees Celsius to 28 degrees Celsius means annual energy savings can amount to 10.8 percent. This method provides a workable and efficient strategy to improve energy efficiency, save operational costs, and conform to sustainability targets without sacrificing occupant comfort.

Retrofitting of the air distribution system from VAV to CAV

The MNG Shopping Center has yet to reach its target of lowering building energy demand by converting its air distribution system from VAV (Variable Air Volume) to CAV (Constant Air Volume). Although this retrofitting effort aimed to reduce energy use, it was unsuccessful.

There are several potential explanations for the failure of CAV retrofitting to reduce energy consumption:

Incompatibility with Building Design: It's possible that the building's layout and architecture needed to be made with a CAV system in mind. When planning an air distribution system retrofit, it's essential to consider the building's mechanical and structural features. It may have been difficult or impractical to upgrade to a CAV system if the building was initially designed around a VAV system.

System Integration Challenges: Complex engineering and system integration tasks are required for air distribution system retrofitting. Changes to the ducting, controls, and machinery might be necessary. These integration issues hampered the retrofit's efficiency and capacity to cut energy use if adequately addressed or handled.

Occupant Comfort Considerations: It's important to consider how the switch from VAV to CAV might have affected occupant comfort. VAV systems provide customized comfort with precise temperature regulation and airflow modulation at the individual level. Constant airflow from a CAV system may have reduced occupant discomfort and discontent.

Insufficient Energy Efficiency Gains: While CAV systems may save energy in some situations, such as in buildings with stable and predictable cooling and heating demands, the MNG Shopping Centre may have needed to match these criteria, leading to insufficient energy efficiency gains. Energy efficiency improvements from retrofitting a CAV system may be constrained by the mall's different space requirements, changing occupancy patterns, and thermal loads.

Cost and ROI Considerations: Cost and return on investment should be considered before switching from a VAV to a CAV air distribution system. The project may not have been deemed economically viable since the retrofit's savings and return on investment (ROI) fell below expectations.

The retrofitting of the air distribution system from VAV to CAV in the MNG Shopping Center did not achieve the desired reduction in building energy demand. Factors such as building design compatibility, system integration challenges, occupant comfort considerations, insufficient energy efficiency gains, and cost considerations may have contributed to this outcome. It is essential to thoroughly assess these factors and consider alternative strategies or solutions to reduce energy demand in the future effectively.

Polyurethane wall insulation

With an annual savings percentage of 10.93%, switching the wall insulation in the MNG shopping center from rock wool to polyurethane was an efficient technique for lowering building energy demand. Due to this modification, there will be significant energy savings and other advantages for buildings.

The thermal performance of the MNG shopping center façade was greatly enhanced by replacing rock wool with polyurethane insulation. Better thermal resistance and reduced heat transfer through walls are two of the many benefits of polyurethane insulation, which also contribute to lower energy losses and heating and cooling requirements.

The significant impact of this insulation upgrade is demonstrated by the annual energy savings of 10.93%. Reduced need for mechanical heating and cooling systems and decreased energy consumption and operating costs are benefits of increased thermal efficiency.

Polyurethane insulation has many benefits beyond just reducing energy costs. In comparison to rock wool, polyurethane has a greater R-value per inch. Therefore fewer insulation layers can be used. Air leakage and draughts can be significantly reduced with polyurethane insulation because of its air-sealing solid qualities.

The energy savings gained may differ depending on building size, weather, and installation quality. The upgrade's cost-effectiveness, both initial outlay and anticipated ROI in energy savings, must also be considered.

There is significant potential for yearly energy savings of 10.93 percent if rock wool insulation is replaced with polyurethane insulation. This modification increases thermal efficiency, reduces heating and cooling needs, and helps save money and resources. Maximizing the benefits of this insulation upgrade requires careful research, implementation, and consideration of project costs.

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