ΠΟΛΥΤΕΧΝΕΙΟ ΚΡΗΤΗΣ

ΤΜΗΜΑ ΜΗΧΑΝΙΚΩΝ ΠΕΡΙΒΑΛΛΟΝΤΟΣ

ΜΕΤΑΠΤΥΧΙΑΚΟ ΠΡΟΓΡΑΜΜΑ ΣΠΟΥΔΩΝ ΠΕΡΙΒΑΛΛΟΝΤΙΚΗΣ ΚΑΙ ΥΓΕΙΟΝΟΜΙΚΗΣ ΜΗΧΑΝΙΚΗΣ

ΣΧΕΔΙΑΣΜΟΣ ΣΤΟΝ ΤΟΜΕΑ ΤΟΥ ΗΛΕΚΤΡΙΣΜΟΥ ΓΙΑ ΤΟ ΑΥΤΟΝΟΜΟ ΣΥΣΤΗΜΑ ΤΗΣ ΝΗΣΟΥ ΚΡΗΤΗΣ

Εφαρμογή σχεδίου ανάπτυξης των Ανανεώσιμων Πηγών Ενέργειας (ΑΠΕ) και της εξοικονόμησης ενέργειας στο νησί με παράλληλη ανάλυση του περιβαλλοντικού οφέλους που προκύπτει

ΓΙΑΤΡΑΚΟΣ ΓΕΩΡΓΙΟΣ

ΟΚΤΩΒΡΙΟΣ 2007

ΣΧΕΔΙΑΣΜΟΣ ΣΤΟΝ ΤΟΜΕΑ ΤΟΥ ΗΛΕΚΤΡΙΣΜΟΥ ΓΙΑ ΤΟ ΑΥΤΟΝΟΜΟ ΣΥΣΤΗΜΑ ΤΗΣ ΝΗΣΟΥ ΚΡΗΤΗΣ

Εφαρμογή σχεδίου ανάπτυξης των Ανανεώσιμων Πηγών Ενέργειας (ΑΠΕ) και της εξοικονόμησης ενέργειας στο νησί με παράλληλη ανάλυση του περιβαλλοντικού οφέλους που προκύπτει

Εισαγωγή

Η Κρήτη, ως ένα από τα μεγαλύτερα και πιο ανεπτυγμένα τουριστικά νησιά της Μεσογείου, βιώνει κατά τη διάρκεια της τελευταίας δεκαετίας έντονη αύξηση του ρυθμού ανάπτυξης σε όλους τους τομείς, που κατά συγκεκριμένα έτη έχει ξεπεράσει το διπλάσιο του Εθνικού μέσου όρου.

Ταυτόχρονα, επιδεικνύοντας μια από τις χαμηλότερες κατατάξεις στον κρίσιμο δείκτη «ενέργεια ανά μονάδα ακαθάριστου προϊόντος» μεταξύ των Περιφερειών της ΕΕ, η Κρήτη αντιμετωπίζει σημαντικά ενεργειακά προβλήματα, συνοδευόμενα από περιβαλλοντικές «πιέσεις» στο ευαίσθητο και μοναδικό οικοσύστημά της.

Ο πληθυσμός του νησιού ξεπερνάει τους 600.000 κατοίκους, με ρυθμό αύξησης από

Εικόνα 1: Εναέρια άποψη της Κρήτης

τους μεγαλύτερους πανελλαδικά, ενώ υπερδιπλασιάζεται κατά τους θερινούς μήνες διογκώνοντας τις απαιτήσεις σε ηλεκτρική ενέργεια. Αξίζει να σημειωθεί ότι το φυσικό περιβάλλον του Νησιού, ο κυρίως πόλος έλξης των τουριστών και παραθεριστών, είναι ο πρώτος που απειλείται με την αλόγιστη χρήση των συμβατικών πηγών ενέργειας για την κάλυψη των ολοένα αυξανόμενων ηλεκτρικών και λοιπών ενεργειακών αναγκών.

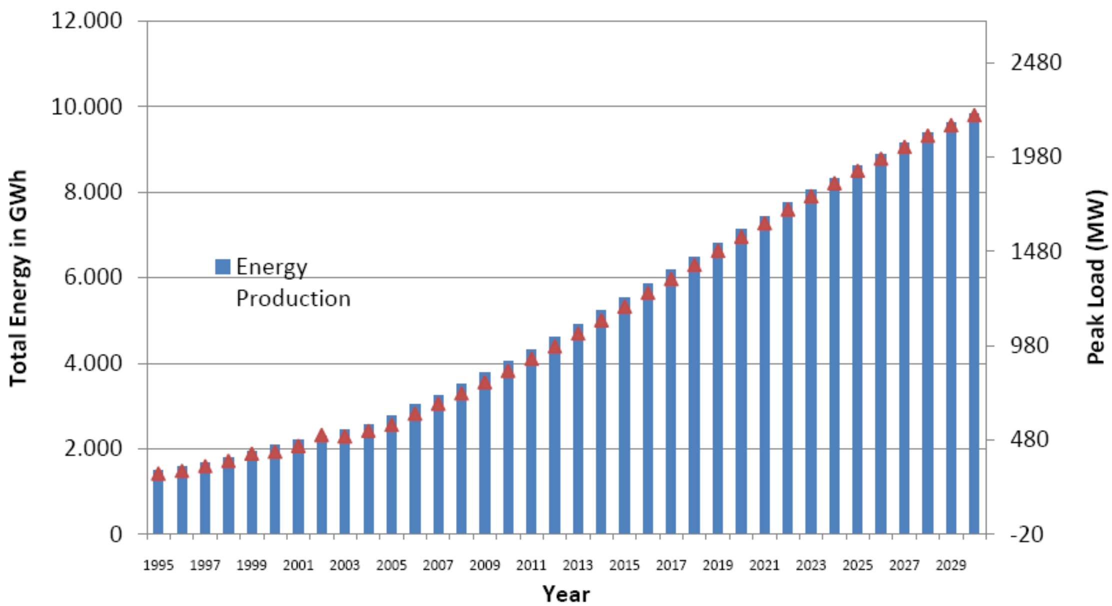
Ο «Σχεδιασμός στον τομέα του ηλεκτρισμού για το αυτόνομο σύστημα της νήσου Κρήτης» αποτελεί μια ολοκληρωμένη και υπεραναλυτική προσέγγιση στο ενεργειακό πρόβλημα της Κρήτης, καθώς και στο δυναμικό εξοικονόμησης ενέργειας και εκμετάλλευσης των ανανεώσιμων πηγών, με τελικό στόχο την δημιουργία προοπτικών βιώσιμης και αειφόρου περεταίρω οικονομικής ανάπτυξης για το νησί.

Κεφάλαιο 1ο – Αποτίμηση Οικονομικής και Ενεργειακής προοπτικής για το νησί της Κρήτης

Το πρώτο κεφάλαιο αποτελεί συνοπτική περιγραφή της Κρήτης με αριθμούς. Συγκεντρώνονται στατιστικά στοιχεία αναφορικά με τα κυρίως μεγέθη τα οποία θα λάβουν μέρος στον ενεργειακό σχεδιασμό, ενώ εξετάζεται η συσχέτιση της οικονομικής ανάπτυξης (ρυθμός αύξησης προϊόντος ανά τομέα) με την αντίστοιχη αύξηση σε ενεργειακές απαιτήσεις.

Παρατηρείται η εκθετική αύξηση των ηλεκτρικών αναγκών των δέκα τελευταίων ετών με γιγαντιαίους ρυθμούς που ξεπερνούν κατά περίπτωση το 5% ετησίως, ενώ εφαρμόζεται μεθοδολογία «λογιστικής πρόβλεψης» της αύξησης της μέσης ζήτησης καθώς τόσο η γραμμική, όσο και η εκθετική προβολή αποφέρει μη ρεαλιστικά αποτελέσματα.

Ταυτόχρονα, οι προβλέψεις για το μέλλον, ακόμα και με τους συγκρατημένους ρυθμούς αύξησης των αναγκών σε σχέση με τους σημερινούς (μεθοδολογία «λογιστικής» πρόβλεψης) είναι δυσοίωνες για την ισορροπία του οικοσυστήματος και την ποιότητα ζωής των κατοίκων και επισκεπτών του νησιού. Στο παρακάτω γράφημα παρουσιάζεται η αναμενόμενη εξέλιξη της ζήτησης από πλευράς ενέργειας και φορτίου κορυφής για κάθε έτος.



Γράφημα 1: Πρόβλεψη ζήτησης έως το έτος 2030

Εν συνεχεία, τίθενται συνοπτικά οι στόχοι της μελέτης, οι οποίοι συνοψίζονται στους κάτωθι:

- Εκτίμηση των επί μέρους μελλοντικών ενεργειακών αναγκών με μεθοδολογία η οποία ανταποκρίνεται επιτυχώς στο ενεργειακό κατεστημένο ενός ταχέως αναπτυσσόμενου, αυτόνομου (μη-διασυνδεδεμένου) νησιού όπως η Κρήτη
- Εξέταση των δυνατοτήτων των προσφερόμενων εργαλείων ενεργειακού σχεδιασμού και επιλογή των καταλληλότερων για την επίτευξη των στόχων της παρούσας διατριβής
- Ανάλυση των υπαρχουσών τεχνολογιών ηλεκτροπαραγωγής (συμβατικές μονάδες ΔΕΗ, αιολικά πάρκα κ.α.) και του δικτύου μεταφοράς και διανομής ηλεκτρικής ενέργειας, καθώς και της προοπτικής ανάπτυξης αυτών τα επόμενα χρόνια

- Ανάλυση των υπαρχουσών και των επερχόμενων τεχνολογιών εξοικονόμησης ενέργειας μέσω προγράμματος «διαχείρισης ζήτησης»
- Διαπίστωση, μέσω της ανάπτυξης σεναρίων διαχείρισης ζήτησης του σχεδιαστικού μοντέλου, της αποτελεσματικότητας των επιλεγόμενων λύσεων στην συμπίεση των ηλεκτρικών αναγκών
- Αναλυτική παρουσίαση, μοντελοποίηση και ανάλυση κύκλου ζωής του συνόλου των εφαρμόσιμων ανανεώσιμων τεχνολογιών και αξιολόγηση των επενδυτικών κινήτρων που προκύπτουν από το υπάρχον θεσμικό πλαίσιο
- Ελαχιστοποίηση των εκπομπών του θερμοκηπίου, με εξοικονόμηση στη χρήση ορυκτών καυσίμων, η οποία προκύπτει από τη βιώσιμη και τεχνικά εφικτή ενσωμάτωση εναλλακτικών μορφών όπως οι ανανεώσιμες και το φυσικό αέριο
- Εξαγωγή αποτελεσμάτων ενεργειακής ανάλυσης και αξιολόγηση αυτής με περιβαλλοντικά και χρηματοοικονομικά κριτήρια

Κεφάλαιο 2ο – Παρουσίαση διαθέσιμων εφαρμογών ενεργειακού σχεδιασμού

Στο δεύτερο κεφάλαιο εξετάζονται τα δυνητικά εργαλεία – πακέτα εφαρμογών τα οποία κυρίως στόχο έχουν τη διαφοροποίηση της προσέγγισης του ερευνητή στο ζήτημα του ενεργειακού σχεδιασμού.

Οι διαθέσιμοι «τύποι» μοντέλων προσέγγισης κατηγοριοποιούνται στους εξής:

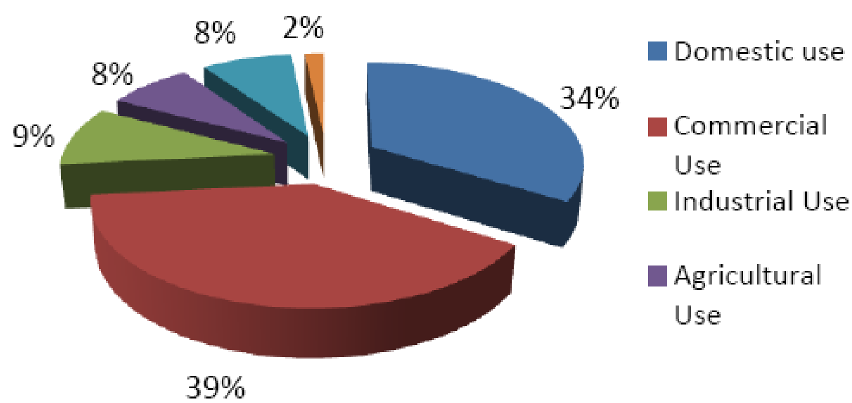
- Μοντέλα βελτιστοποίησης, τα οποία επιλέγουν την βέλτιστη οικονομικά και ενεργειακά διαθέσιμη λύση βασιζόμενα σε επιλεγμένους περιβαλλοντικούς και οικονομικούς περιορισμούς
- Μοντέλα προσομοίωσης, τα οποία απαιτούν αναλυτική περιγραφή του συστήματος, επιστρέφοντας εξίσου αναλυτικά αποτελέσματα
- Λογιστικά πλαίσια, τα οποία αποτελούν μια ευέλικτη και προσαρμόσιμη προσέγγιση στον ενεργειακό σχεδιασμό, χρησιμοποιώντας λογικές συσχετίσεις μεταξύ επιλεγόμενων από τον χρήστη παραμετροποιήσιμων παραμέτρων

Το ιδιόμορφο και ημιμονοπωλιακό ελληνικό σύστημα παραγωγής και διανομής ενέργειας καθιστά καταλληλότερα από τα παραπάνω τα «λογιστικά πλαίσια», καθώς μπορούν να προσαρμοστούν στο υπάρχον θεσμικό πλαίσιο αγοράς και πώλησης ηλεκτρισμού, καθώς και στην έλλειψη αναλυτικών στοιχείων, ειδικά στον τομέα της κατανάλωσης ηλεκτρικής ενέργειας.

Η εφαρμογή LEAP (Long range Energy Alternatives Planning system) αποτελεί ιδανικό μοντέλο αυτού του τύπου, που χρησιμοποιείται παγκοσμίως σε αντίστοιχες περιπτώσεις πολύπλοκων αυτόνομων συστημάτων όπως αυτό της Κρήτης. Ταυτόχρονα, χρησιμοποιείται και το πακέτο λογισμικού RETscreen International για την ανάλυση κύκλου ζωής των επιμέρους εφαρμογών ΑΠΕ.

Κεφάλαιο 3ο – Διαχείριση ζήτησης και δυναμικό εξοικονόμησης

Το τρίτο κεφάλαιο αφορά τον τομέα της διαχείρισης ζήτησης ηλεκτρικής ενέργειας (demand side management). Χρησιμοποιούνται στατιστικά στοιχεία που ανακοινώνονται ετησίως από τη Δημόσια Επιχείρηση Ηλεκτρισμού Α.Ε. (ΔΕΗ) σε συνδυασμό με αυτά της Εθνικής Στατιστικής Υπηρεσίας, από τα οποία προκύπτει η κατανομή της ζήτησης ανά Νομό και τομέα δραστηριότητας.



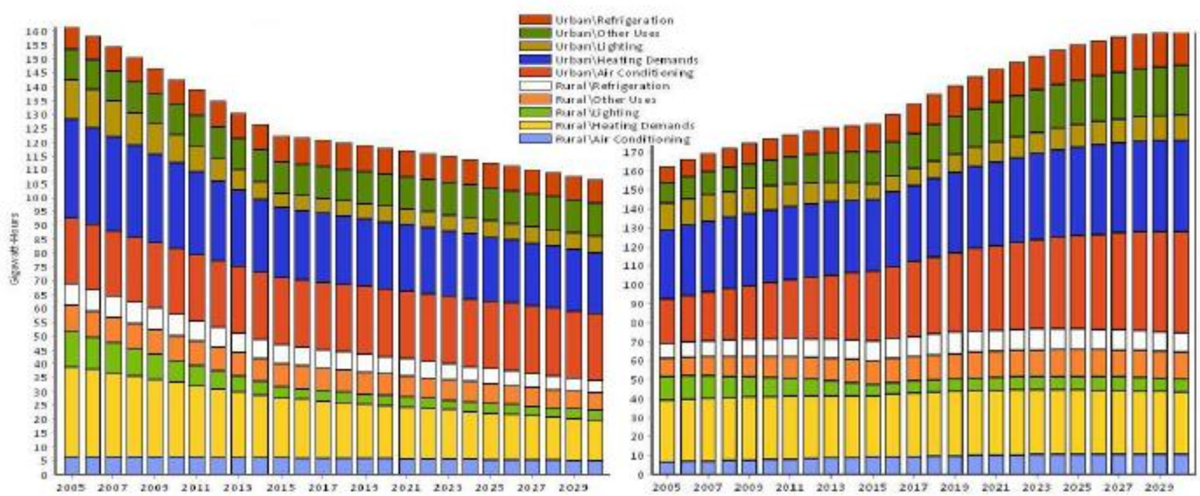
Γράφημα 2: Στατιστική κατανομή ζήτησης ενέργειας ανά τομέα δραστηριότητας

Η διαχείριση ζήτησης στόχο έχει την καλύτερη δυνατόν διαχείριση των διαθέσιμων πόρων μέσω α) εκμετάλλευσης του διαθέσιμου δυναμικού εξοικονόμησης που προκύπτει από βιβλιογραφική ανασκόπηση και τεκμηριωμένη ανάλυση και β) μείωση του συντελεστή φορτίου μέσω βελτιστοποίησης της κατανομής της ζήτησης.

Για να γίνει μια ρεαλιστική αποτίμηση του ενεργειακού (και κατά συνέπεια περιβαλλοντικού) οφέλους από τη διαχείριση ζήτησης, δημιουργούνται δύο σενάρια δράσης (*μερικής* και *εκτεταμένης* διαχείρισης), τα οποία αντιπαρατίθενται με την εξέλιξη της παρούσας κατάστασης εφόσον δεν ληφθούν μέτρα.

Κατά το σχηματισμό αυτών των σεναρίων πραγματοποιείται ενδελεχής ανάλυση του προφίλ ζήτησης για καθέναν από τους βασικούς τομείς δραστηριότητας (οικιακός, επαγγελματικός, βιομηχανικός, αγροτικός, δημόσιος) σε επιμέρους κατηγορίες χρήσης. Εκεί, αξιολογείται η παρούσα κατάσταση, αναλύεται η διαθέσιμη τεχνολογία και προτείνονται νέες πολιτικές ή εφαρμογή υπαρχουσών, προκειμένου να αξιοποιηθεί το δυναμικό εξοικονόμησης.

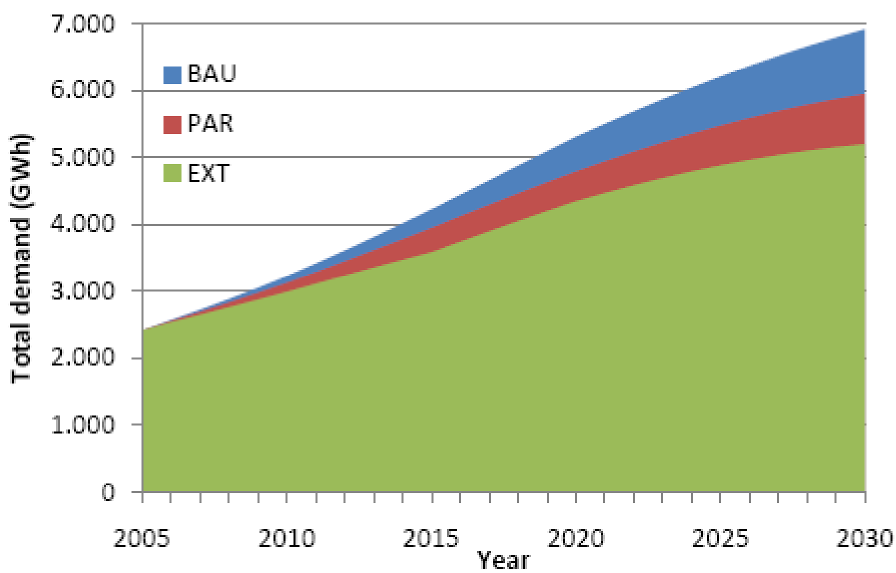
Επί παραδείγματι, στον τομέα των οικιακών καταναλωτών, υπολογίζονται οι ετήσιες ανάγκες του συνόλου των νοικοκυριών, με την υπόθεση πως ο αριθμός τους παραμένει σταθερός, για λόγους συγκρισιμότητας. Στο δεξί διάγραμμα παρουσιάζεται η υπολογιζόμενη ετήσια κατανάλωση του οικιακού τομέα, χωρισμένη και ανά κατηγορία χρήσης, όπως εξελίσσεται σύμφωνα με τους σημερινούς αύξησης δραστηριότητας και ποιότητας ζωής, καθώς και εξοικονόμησης ενέργειας. Στο αριστερό διάγραμμα αντιπαρατίθεται η υπολογιζόμενη ετήσια κατανάλωση, πάντα για σταθερό ρυθμό νοικοκυριών, εφόσον εφαρμοστούν οι πρακτικές εκτεταμένης διαχείρισης ζήτησης.



Γράφημα 3: Τα αποτελέσματα του LEAP για τη διαχείριση ζήτησης στα νοικοκυριά

Όπως γίνεται αντιληπτό, οι τρέχοντες ρυθμοί εξοικονόμησης δεν δύνανται να καλύψουν την αύξηση των απαιτήσεων - ανέσεων των ολοένα και πιο αναβαθμισμένων νοικοκυριών (δεξί γράφημα). Αντίθετα, εφόσον εφαρμοστεί το πρόγραμμα εξοικονόμησης (αριστερό γράφημα), όχι μόνο ισορροπείται η αύξηση δραστηριότητας ανά νοικοκυριό, αλλά πρακτικά προωθείται ουσιαστική εξοικονόμηση που ξεπερνά το 30% κατά το έτος 2030 σε σχέση με το έτος αναφοράς (2005).

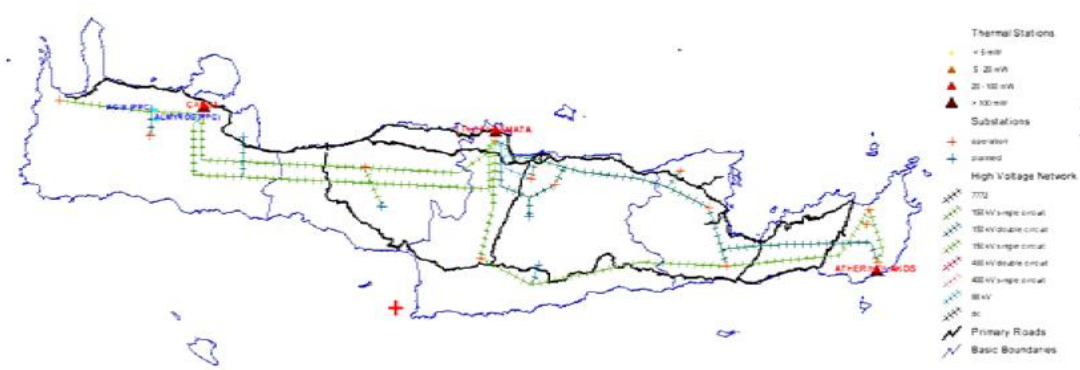
Τα ευρύτερα αποτελέσματα της προσομοίωσης εξοικονόμησης είναι απογοητευτικά για την παρούσα κατάσταση (τεράστιο ανεκμετάλλευτο δυναμικό) αλλά πολύ ενθαρρυντικά για το μέλλον (μεγάλη προοπτική μείωσης κατανάλωσης με απλά και εφαρμόσιμα μέτρα). Συγκεκριμένα, μέχρι το έτος 2030, μια εντατική πρακτική διαχείρισης μπορεί να εξοικονομήσει μέχρι και 8,5 χρόνια ενεργειακών αναγκών σύμφωνα με τις αυτές του έτους αναφοράς (2005).



Γράφημα 4: Ολική εξοικονόμηση ζήτησης για το σύστημα του Νησιού, για κάθε σενάριο

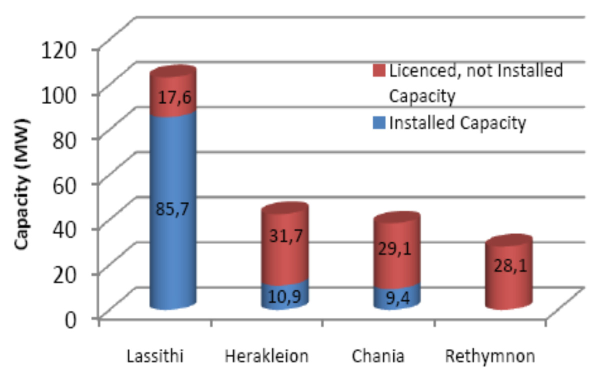
Κεφάλαιο 4ο – Ανάλυση του συστήματος παραγωγής και μεταφοράς του νησιού

Στο τέταρτο κεφάλαιο πραγματοποιείται καταγραφή των υπαρχουσών παραγωγικών μονάδων του νησιού. Οι συμβατικές μονάδες, των οποίων κύριος και διαχειριστής είναι η ΔΕΗ, αποτελούνται από μονάδες βάσης (ατμοστροβιλικές, ντίζελ και συνδυασμένου κύκλου), μεσαίου φορτίου (ντίζελ, συνδυασμένου κύκλου) και φορτίου αιχμής (αεριοστρόβιλοι). Συγκεκριμένα, αναλύεται η συμμετοχή της κάθε μονάδας στη διαδικασία ηλεκτροπαραγωγής, ο τρόπος λειτουργίας του συστήματος (χρονική ακολουθία εμπλοκής στο σύστημα), το χρησιμοποιούμενο μείγμα καυσίμων και οι αντιστοιχούσες εκπομπές, ενώ υπολογίζεται και το ανηγμένο κόστος λειτουργίας των βασικότερων μονάδων.



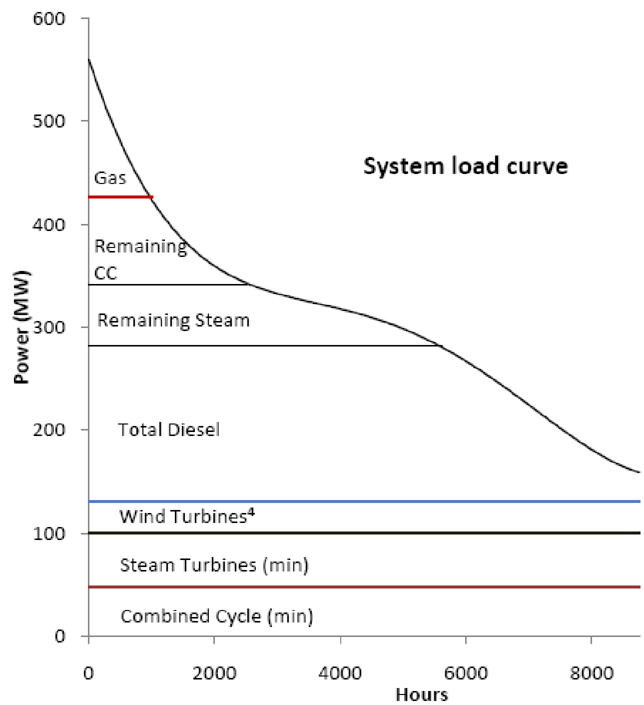
Εικόνα 2: Βασικές παραγωγικές μονάδες και δίκτυο μεταφοράς του νησιού

Ακολούθως, πραγματοποιείται αποτίμηση της συμμετοχής των ΑΠΕ στον ενεργειακό χάρτη της Κρήτης. Παρατηρείται η μονοδιάστατη συμμετοχή των αιολικών πάρκων, και ο υπερκορεσμός του Νομού Λασιθίου, ενώ εξηγείται και ο λόγος έλλειψης εφαρμογών εκμετάλλευσης των υπολοίπων ανανεώσιμων μορφών.



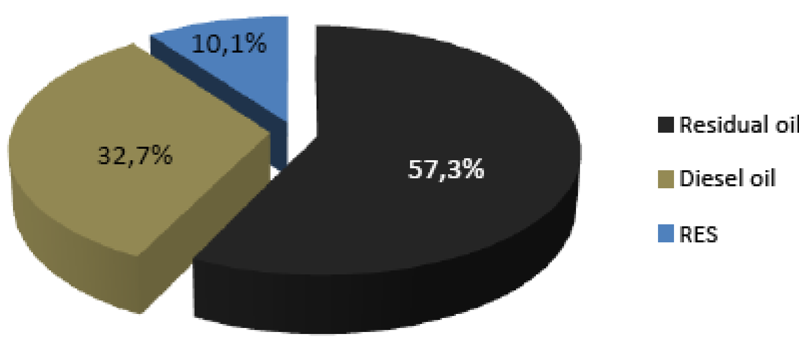
Γράφημα 5: Κατανομή αιολικών σταθμών ανά Νομό

Το παρακάτω διάγραμμα παρουσιάζει την καμπύλη φορτίου του συστήματος του νησιού. Η σειρά εμπλοκής των μονάδων ξεκινάει από τα χαμηλά (8.760 ώρες - μονάδες βάσης), καλύπτει την απορροφούμενη ενέργεια από τις ανεμογεννήτριες, συμπληρώνεται από της μονάδες μέσου φορτίου, ενώ στις ώρες αιχμής (< 1.000 ώρες), οι ανάγκες καλύπτονται αποκλειστικά από αεριοστρόβιλους.



Γράφημα 6: Καμπύλη φορτίου

Επιπλέον, στο διάγραμμα που ακολουθεί παρουσιάζεται προέλευση του ενεργειακού μείγματος. Παρατηρείται ότι για το έτος 2005, μόνο το 10% της ενέργειας παράγεται από ανανεώσιμες πηγές.



Γράφημα 7: Προέλευση ενεργειακού μείγματος

Κεφάλαιο 5ο – Σχέδιο διείσδυσης καθαρότερων πηγών ενεργείας

Στο πέμπτο και σημαντικότερο κεφάλαιο οργανώνεται το σχέδιο ανάπτυξης των ήπιων μορφών ενέργειας στο νησί. Αρχικά, ορίζονται οι προϋποθέσεις του βιώσιμου ενεργειακού σχεδιασμού που μεταξύ των άλλων περιλαμβάνουν:

- Εξασφάλιση των απαιτούμενων ποσοστών στρεφόμενης εφεδρείας και σεβασμός των τεχνικών ορίων διείσδυσης των μη ελεγχόμενων πηγών (ειδικά των αιολικών) προκειμένου να εξασφαλισθεί η ποιότητα και η σταθερότητα του δικτύου.
- Πρόταση για υιοθέτηση μόνο των οικονομικά βιώσιμων λύσεων σύμφωνα με την διαθέσιμη τεχνολογία και το τρέχον θεσμικό πλαίσιο ενισχύσεων των ενεργειακών επενδύσεων.
- Πιστή εφαρμογή της στρατηγικής ανάπτυξης συμβατικών σταθμών στο νησί όπως αυτές έχουν προγραμματιστεί από τη ΔΕΗ και το Υπουργείο Ανάπτυξης.

Το σχέδιο ανάπτυξης περιλαμβάνει μεταξύ άλλων:

- Δυναμική είσοδο του φυσικού αερίου στο ενεργειακό προφίλ του νησιού. Το φυσικό αέριο προβλέπεται να μειώσει τόσο τις εκπομπές αερίων του θερμοκηπίου όσο και τις επιπτώσεις στο τοπικό οικοσύστημα, ενώ η σωστή εφαρμογή του θα εξασφαλίσει και μείωση του κόστους ανά παραγόμενη μονάδα ενέργειας.
- Αύξηση του περιθωρίου διείσδυσης των αιολικών μέσω καλύτερης χωρικής κατανομής και εφαρμογής μεθόδων αποθήκευσης (αντλησιοταμιευτήρες) με ταυτόχρονα έλεγχο της βιωσιμότητας των νέων επενδύσεων και της σταθερότητας του συστήματος.

Εικόνα 3: Αιολικός χάρτης Κρήτης

- Ταχύτατη είσοδο της ηλιακά προερχόμενης ενέργειας στο σύστημα του νησιού σύμφωνα με το πρόγραμμα ανάπτυξης φωτοβολταϊκών σταθμών. Το ανεκμετάλλευτο έως σήμερα ηλιακό δυναμικό αποτελεί πλέον επενδυτικό κίνητρο για μικρές επιχειρήσεις βάσει των προβλεπόμενων ενισχύσεων.

Εικόνα 4: Ηλιακός χάρτης της Κρήτης

- Εκμετάλλευση των υπόλοιπων διαθέσιμων ανανεώσιμων πηγών μέσω των μικρών υδροηλεκτρικών έργων και της ηλεκτροπαραγωγής από βιομάζα.

Η προσομοίωση λειτουργίας των παραπάνω και η ανάλυση βιωσιμότητας τους πραγματοποιήθηκε με χρήση ενός επιπλέον υπολογιστικού πακέτου, του RETscreen International.

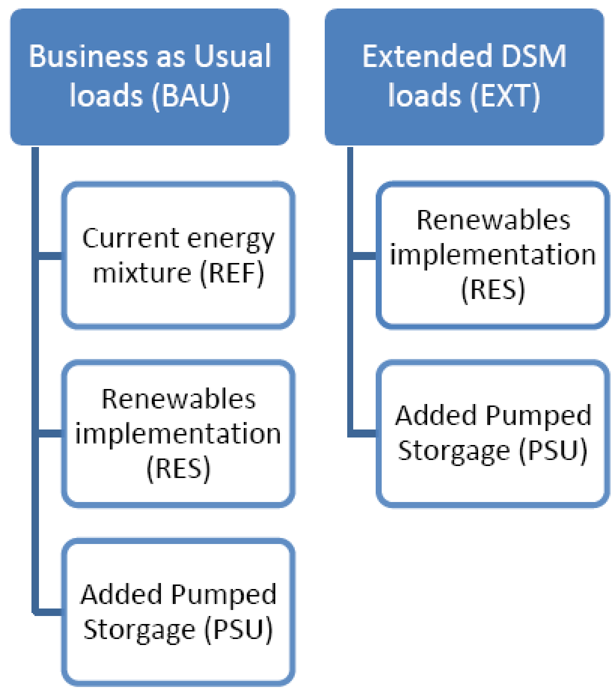
Κεφάλαιο 6ο – Αποτελέσματα προσομοίωσης

Στο τελευταίο κεφάλαιο πραγματοποιείται η διάρθρωση των σεναρίων παραγωγής ενέργειας και ο συνδυασμός αυτών με τα προαναφερθέντα σενάρια διαχείρισης ζήτησης.

Ως σημείο αναφοράς τίθεται η σημερινή κατάσταση, γραμμικά εξαρτημένη με την προβλεπόμενη αύξηση ζήτησης. Σε αυτή αντιπαρατίθενται δύο κεντρικά σενάρια διείσδυσης ΑΠΕ:

- Σενάριο ανάπτυξης ΑΠΕ και φυσικού αερίου, όπου εξαντλούνται τα περιθώρια διείσδυσης που θέτει η απρόσκοπτη λειτουργία του συστήματος. Η επιτυχία του συγκεκριμένου σχεδίου είναι εξασφαλισμένη μέσω των επενδυτικών κινήτρων (Αναπτυξιακός Νόμος και Νόμος για την παραγωγή ενέργειας από ΑΠΕ) και των θεσμικών διευκολύνσεων για μικρές και μεσαίες επενδύσεις.

- Σενάριο εκτεταμένης ανάπτυξης ΑΠΕ, όπου εφαρμόζεται αντλησιοταμίευση με σκοπό τον εκμηδενισμό της απορριπτόμενης ανανεώσιμης ενέργειας από το διαχειριστή του δικτύου.

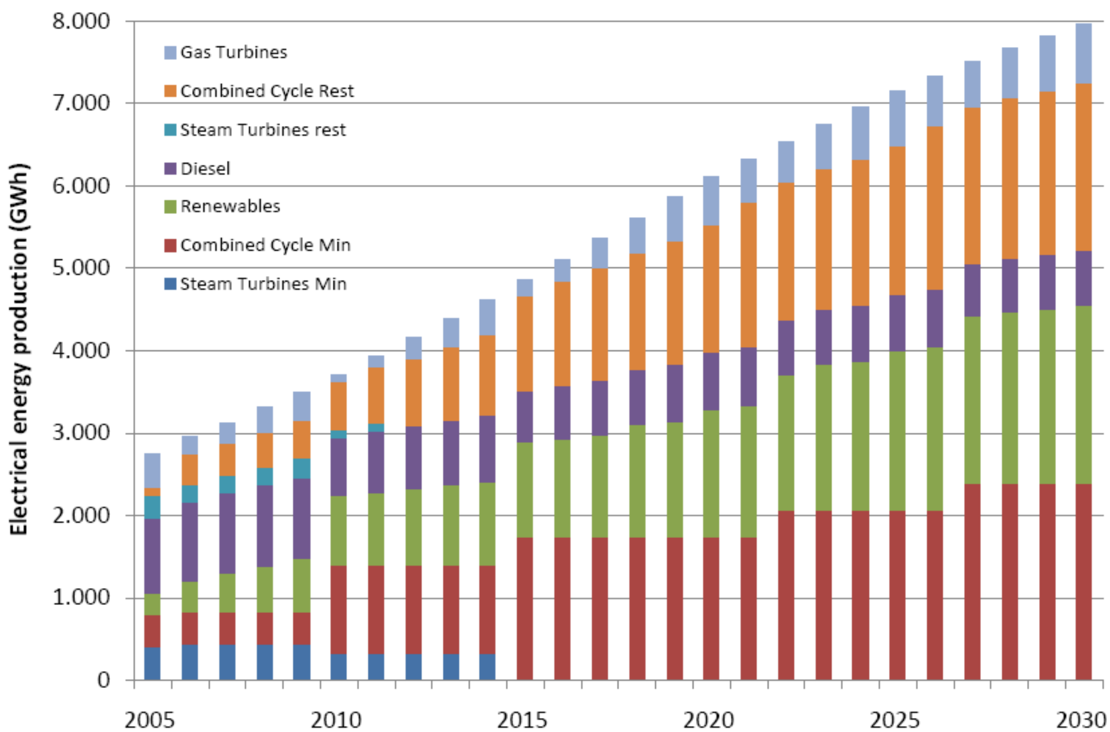


Εικόνα 5: Διάγραμμα δομής σεναρίων

Η προσομοίωση γίνεται μέσω του λογισμικού LEAP, σύμφωνα με τη μεθοδολογία που αναπτύχθηκε ως κατάλληλη για το ιδιόμορφο ενεργειακό καθεστώς του Νησιού. Η ανάλυση αποτελεσμάτων περιλαμβάνει, τόσο ενεργειακά ισοζύγια, όσο και υπολογισμό του περιβαλλοντικού οφέλους για κάθε συνδυασμό σεναρίων.

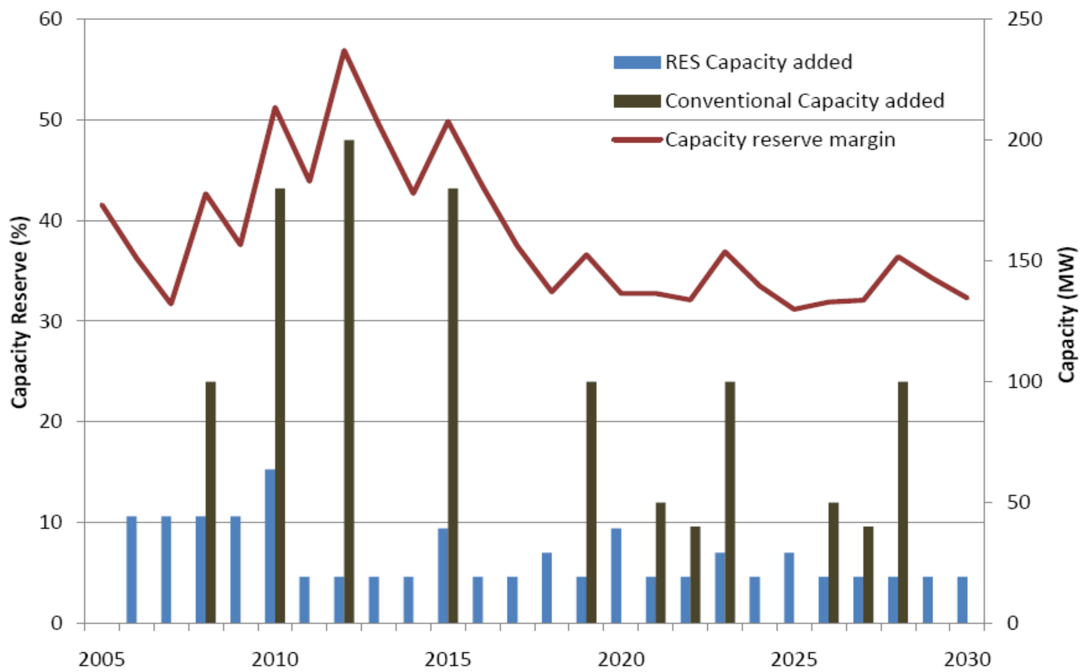
Ως αποτέλεσμα, υπολογίζονται τα ενεργειακά μείγματα όπως αυτά προκύπτουν από τη μοντελοποίηση, η συνεισφορά της κάθε ανανεώσιμης πηγής για κάθε σενάριο, οι απαιτούμενες εισαγωγές καυσίμων στο νησί και τέλος οι αντίστοιχες εκπομπές σε αέρια του θερμοκηπίου.

Το παρακάτω γράφημα παρουσιάζει τα αποτελέσματα της ανάλυσης ηλεκτροπαραγωγής για το τυπικό σενάριο ανάπτυξης ΑΠΕ, σε συνδυασμό με τα φορτία αναφοράς.

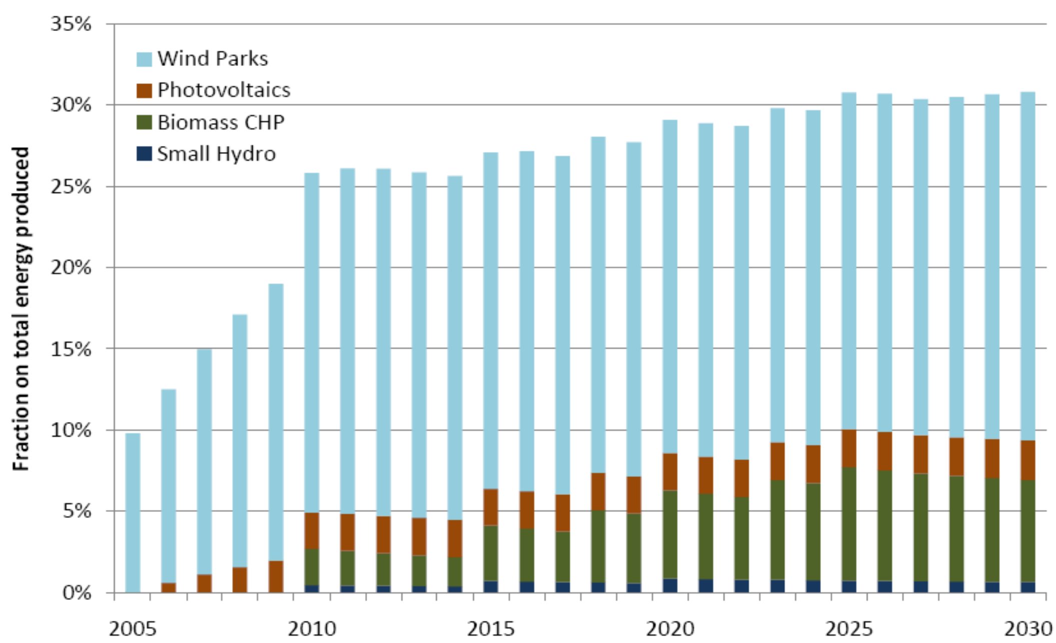


Γράφημα 8: Συμμετοχή ηλεκτροπαραγωγικών μονάδων στην κάλυψη των αναγκών

Όπως παρατηρείται στο ακόλουθο γράφημα, πραγματοποιούνται οι απαιτούμενες προσθήκες σε μονάδες, τόσο όταν καταργείται μια παλαιότερη, όσο και όταν αυξάνεται η ζήτηση του συστήματος. Ταυτόχρονα, διατηρείται ο συντελεστής στρεφόμενης εφεδρείας σε ποσοστά μεγαλύτερα του 30%.

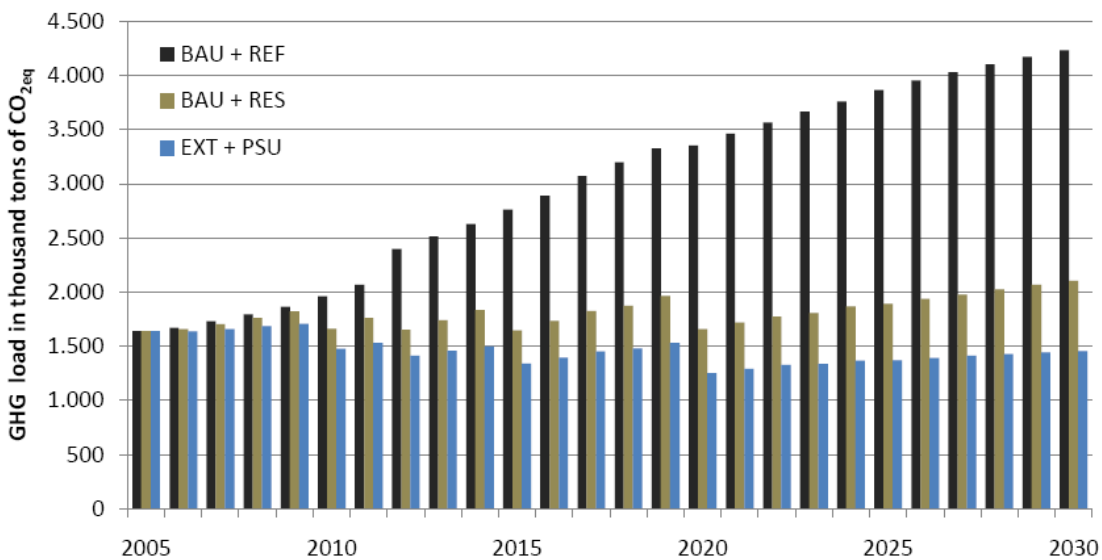


Γράφημα 9 & 10: Προσθήκη μονάδων, στρεφόμενη εφεδρεία και διείσδυση ΑΠΕ



Συνδυασμός των σεναρίων εκτεταμένης διαχείρισης ζήτησης και διείσδυσης ΑΠΕ δίνει πολύ θετικά αποτελέσματα, καθώς καταφέρνει να συγκρατήσει τις εκπομπές αερίων θερμοκηπίου για το τελικό έτος προσομοίωσης (2030) σε πολύ χαμηλά επίπεδα, χαμηλότερα ακόμα και από τους σημερινούς δείκτες.

Η προβλεπόμενη συνολική εξοικονόμηση για το έτος 2030 αγγίζει το 66%, η οποία αθροιστικά ισοδυναμεί με εξοικονόμηση 40 εκατομμυρίων τόνων ισοδύναμου CO_2 μέχρι το έτος αυτό, όπως φαίνεται στο ακόλουθο γράφημα.



Γράφημα 11: Εκπομπές αερίων θερμοκηπίου, όπως προκύπτουν από συνδυασμούς σεναρίων

Εν κατακλείδι, η περιβαλλοντική και οικονομική πίεση, σε συνδυασμό με την εφαρμοσιμότητα της υλοποίησης, καθιστά μονόδρομο την άμεση υιοθέτηση παρόμοιων βιώσιμων, ή και ακόμα πιο ριζοσπαστικών λύσεων, καθώς τα περιθώρια έχουν προ καιρού εξαντληθεί και το παγκόσμιο κλίμα έχει διαταραχθεί μόνιμα.

Summary

Crete, as one of the largest and most touristic islands of the Mediterranean, is facing abrupt population and economic growth tendencies that result in the incessant problem of inability to meet electrical energy demand increase.

Electrical energy planning for Crete is a complete and thorough evaluation of every single aspect of the island's present electrical energy status, together with examination of every possible future perspective.

In the **first chapter**, Crete is presented in numbers, showing the great economic development that the region is undergone during the previous years, combined with the anticipated increase in energy consumptions. The negative impacts on the island's native environment if sustainable development policies and renewable energy resources are not immediately adopted are considered.

The **second chapter** examines all available energy planning modeling software solutions and concludes to the most appropriate ones for this specific case study. *LEAP* proves a very capable tool of providing energy outlooks, integrated resource planning and greenhouse gas mitigation analysis though an intuitive, powerful and customizable user interface.

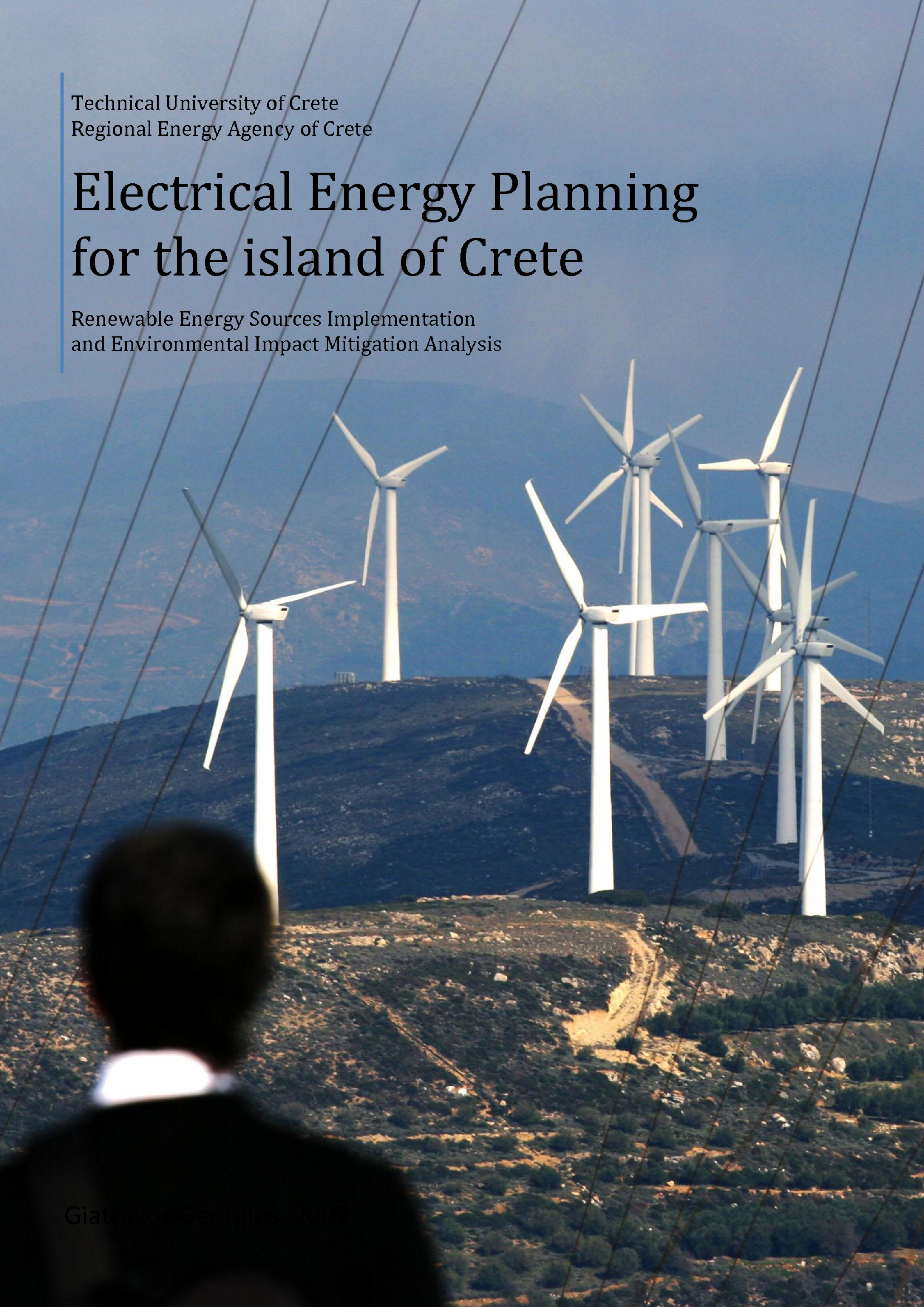
The **third chapter** can be described as the *demand side* chapter, as it deals with energy consumption in the island in the most analytical way. The lack of low-level statistical data on the island has led to the formation of custom methodologies based on various sources in order to output all data required for the simulation. Additionally, since demand restriction is one of the most important variables in energy planning schemes, two main demand side management scenarios where formed, offering realistic solutions that are available, or will be in future years.

In **chapter four**, the current electricity production technologies, including renewables and their contribution to the island's electrical network is mainly examined. Results from this chapter are used to form the plan's *reference*, *current accounts* scenario, against which all energy planning results (demand side management, RES implementation) will be compared with.

In the **fifth chapter**, the RES implementation plan is rigorously unfolded. Policies are set according to the government and EU directives, modeling methodology in analyzed, future conventional power plants and natural gas adoption are taken into account; and most importantly, renewable energy resources are fully exploited in the plan's RES scenarios, always taking into account all technical and legislative limitations.

Finally, in **chapter six**, modeling results are presented for the most important combination of scenarios. Analysis shows that even the most modest and realistic RES implementation scenario, combined with a partially successful demand restriction, could indeed mitigate the island's environmental burdening.

Regarding the feasibility and economic viability of the proposed renewable projects, it is safeguarded through the recent law for the development of RES, in conjunction with the 4^{th} Community Support Framework. This new reality drives the motivation of private capital with adequate incentives that ensure high investment return rates.



Technical University of Crete
Regional Energy Agency of Crete

Electrical Energy Planning for the island of Crete

Renewable Energy Sources Implementation and Environmental Impact Mitigation Analysis

Giatrakos Georgios, 2007

Table of Contents

1 General information regarding the island of Crete

1.1 The island of Crete

Crete is the fourth largest island in the Mediterranean with an area of 8.335 km2 (6,3% of the total area of Greece) and population that surpasses 600.000 residents (5,4% of the total population of Greece). Residents increase dramatically during summer months, as a result of the island's touristic development. Crete's permanent population is the second fastest growing between 13 Greek regions with an annual rate of 0,16%.

Crete is divided in four prefectures (Chania, Rethimnon, Heraklion and Lassithi), whose capitals are Heraklion, Chania, Rethimnon and Aghios Nikolaos respectively. All four cities include important infrastructures such as ports and airports. Official statistics on households and inhabitants for each prefecture in 2001 are shown on Table 1.

Table 1: Permanent residents and main households (1)

Prefecture	Primary households	Secondary Households	Permanent inhabitants[1]	Permanent inhabitants[2]
Heraklion	95.000	48.245	291.225	293.650
Lassithi	26.841	23.393	75.736	76.367
Rethymnon	25.694	17.150	78.957	79.615
Chania	48.252	26.133	148.450	149.686
Crete	**195.787**	**114.921**	**594.368**	**599.318**

Regarding its morphology, Crete can be characterized as a mountainous island, in which 60% of the total territory is 400m above sea level. Its complex morphology is proven ideal for wind applications, hosting hundreds of ideal locations for the installation of scale wind parks. On the contrary, the island's mountainous nature combined with limited water resources in the eastern part and a harsh geological infrastructure, offers quite narrow perspectives for agricultural alternatives such as energy crops cultivation.

Picture 1: Aerial overview of Crete

[1] Official 2001 population census values
[2] 2006 projection based on average population growth rate

1.2 Economy and energy overview

Extreme Gross Domestic Product growth rates witnessed over the previous decade (1995-2000), which almost doubled the Gross National Product growth average, will be considered a product of the lucrative European incentives that were largely adopted by Crete's numerous flexible investors.

Dramatic growth rates tend to adapt to the national rates after the year 2000 (2), as described in Table 2. This may result by the strict investment policy applied on the touristic sector as well as the decay in tourism since the beginning of the millennium. In any case, this study will disregard all economic data before 2000.

Table 2: GDP growth and forecasts in year 2000 prices

	Annual GDP (in Million €)						Linear Projections		Exponential Projections	
	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2015**	**2030**	**2015**	**2030**
Heraklion	3.967	4.179	4.665	4.911	5.367	5.660	9.175	14.476	11.939	36.049
Lassithi	1.009	1.096	1.121	1.205	1.284	1.355	2.015	3.019	2.412	5.733
Rethymno	1.103	1.107	1.171	1.243	1.415	1.492	2.293	3.582	2.844	7.650
Chania	1.955	2.045	2.146	2.318	2.543	2.683	4.080	6.277	5.179	13.956
Crete	**8.034**	**8.427**	**9.103**	**9.677**	**10.609**	**11.189**	**17.200**	**26.542**	**22.313**	**62.637**
Increment		4,66%	7,43%	5,93%	8,79%	5,18%			6,8%	
Greece	156.514	163.514	174.529	189.790	205.893	220.671				
Increment		4,28%	6,31%	8,04%	7,82%	6,70%				

Table 2 forecasts demand evolution using linear and exponential approach. It is considered safe to rely on linear projections for the following six to ten years; unfortunately, long term calculations must be disregarded (Figure 1). Similarly, exponential projections tend to be highly inaccurate in economic projections, as any future variations in the mean growth rates cause great deviations (Figure 2).

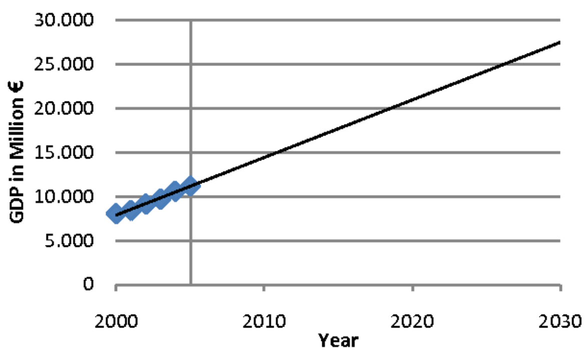


Figure 1: Linear projection for Crete's GDP in year 2000 prices

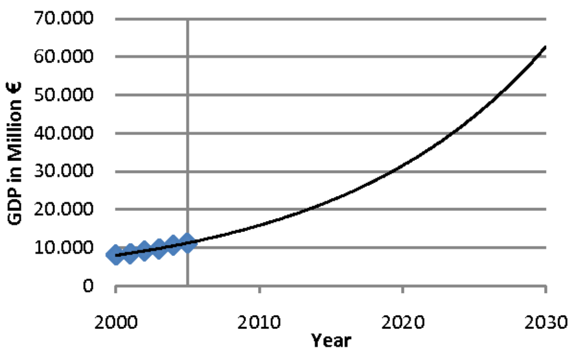


Figure 2: Exponential projection for Crete's GDP in year 2000 prices

In order to be realistic, a more complex methodology, namely logistic forecasting will be used. This "intermediate" means of predicting economy is proven more accurate especially for developing economies such as Crete's. Analysis will be conducted on the following chapters.

It can be clearly seen that Crete's economy is dominated by the tertiary sector, whose growth is based on seasonal activity. The services sector includes the touristic industry consisting of restaurants, commerce, transport and accommodation, as well as permanent residents' activity including public and private services, hospitals, universities, financing etc. Tourist overnights in Crete surpass 12.000.000 annually, counting for the Greece's 20% of total touristic activity. Total tertiary activity surpasses the ¾ of the regional GDP (3).

Industry, which can be characterized as Crete's "secondary" sector, includes a variety of activities such as food industry, olive industry, plastics and quite importantly, electric energy production. The majority of industrial activity is based on the island's indigenous agricultural production, with the exception of the energy sector which relies in fossil fuel imports. Industrial activity counts for the 14% of the island's product, facing a decreasing tendency in recent years.

Finally, agriculture, which supports the island's industry, contributes by 8% in the regional GDP indicator. Agricultural activity maintains a growing tendency over the last couple of years (2%), despite the national annual decrease by 1,2%.

Table 3: GDP per prefecture and activity (3)

	2005 GDP per Prefecture (Million €)[3]					Fraction on Regional GDP (%)	2005 Growth rate
	Heraklion	Lassithi	Rethimnon	Chania	Crete		
Commercial Activity	3.735	893	903	1.741	**7.272**	64,99%	
Public Authorities	711	170	172	332	**1.385**	12,38%	
Services (tertiary)	4.446	1.064	1.075	2.072	**8.657**	77,36%	8,1%
Agricultural	438	139	205	241	**1.023**	9,14%	1,9%
Industry	776	152	212	369	**1.510**	13,49%	-3,8%
Total GDP	**5.660**	**1.355**	**1.492**	**2.683**	**11.190**	100,00%	5,8%

An interesting study is that of the correlation between electric energy requirements and economic growth. In order to safely compare the two growth indicators, the computed GDP growth rate must be delivered from deflated prices, as in Table 2.

For the needs of this study we will be using electricity demand data published by the Public Power Corporation SA, which despite the liberalization of the Greek energy market, still holds 100% shares on Crete's controllable production units, transmission and distribution network.

Table 4 summarizes electric demands in terms of produced energy and peak load for the previous ten periods (1995-2005). Graphing the raw PPC data clearly indexes an exponential growth of historical demand time series. Using exponential forecast methodology, electric demands tend to rise in the extreme rate of 6,0%; very similar to the rate in which economy develops (6,8%).

[3] Values refer to year 2000 prices

Taking a close look to exponential forecasts for year 2015 and 2030 in Table 4, it is rendered clear that electricity production growth rates (6%) must definitely be forced to decrease, especially after 2010, due to extreme environmental and economical pressure posed by the enormous demands.

Table 4: Annual escalation of energy production and peak load demand (2)

	Year	Energy Production		Peak Load Demand		Load Factor (%)
		GWh	Increment (%)	MW	Increment (%)	
Historical Production	1995	1.476	5,9	301,3	5,3	55,9
	1996	1.562	5,8	317,0	5,2	56,1
	1997	1.659	6,2	341,8	7,8	55,4
	1998	1.801	8,5	368,6	7,8	55,8
	1999	1.925	6,0	407,2	10,5	54
	2000	2.079	8,9	417,7	2,6	56,7
	2001	2.192	5,4	448,1	7,3	56,8
	2002	2.301	5,0	505,8	12,9	51,9
	2003	2.445	6,2	498,4	-1,5	56
	2004	2.545	4,1	529,2	6,2	54,7
	2005	2.654	4,3	560,3	5,9	54,1
Linear Forecast	2015	3.891		826		
	2030	5.724		1.226		
Exp. Forecast	2015	5.016	6,0%	1.088	6,3%	
	2030	12.451		2.831		

There are two ways of restraining this catastrophic increase in demands (Figure 3). One is by limiting economic growth, which would be considered unwise on a region where sustainable development is the target of European Committee's heavily funding policy; the other is by reducing energy intensities on developing activities in order to balance increased energy demands due to activity growth.

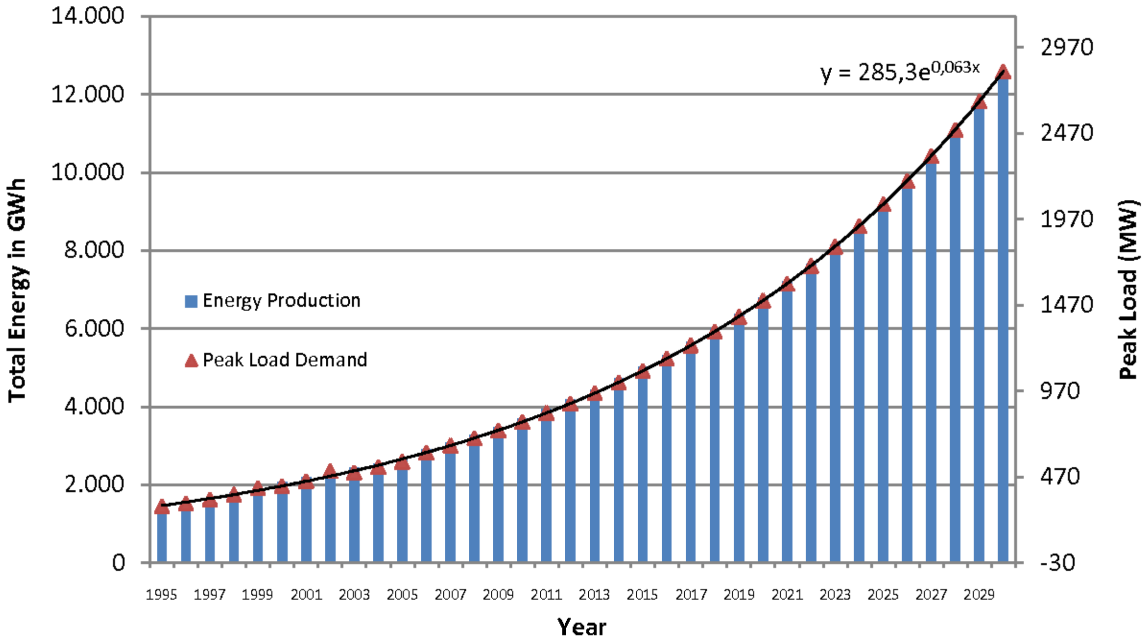


Figure 3: Projected electric demands based on current growth rates

Considering a positive reaction to economic incentives on energy saving measures applied by the EU, combined with the forthcoming increase in electricity pricing to follow the market liberalization, a more realistic "S curve" increase tendency will better serve our needs. This S curve, projected through logistic forecast methodology in Figure 4.

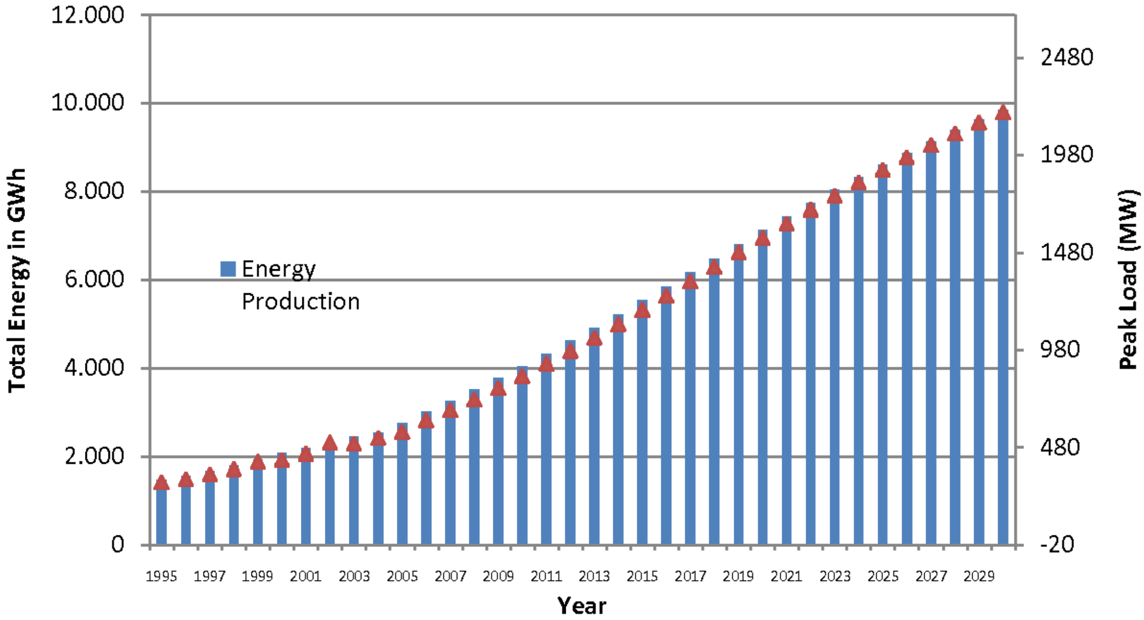


Figure 4: Logistic projection of future electric demands

In further chapters, we will be calculating actual final growth parametrically, using separate variables. Sectors, whose demands depend simply on economic growth, will follow the logistic forecast methodology, while others, depending on different variables (i.e. domestic sector) will follow their own, independent growth rates. Final energy projections will be exported by summing all different sector projections.

1.3 Crete's overall energy status

The island's electric energy demand is met mainly through the use of conventional fuels (up to 90% in 2005) (4) while, fortunately, a respectable part of the thermal needs is being satisfied by the utilization of biomass.

Picture 2: PPC conventional thermal station in Linoperamata – near one of the most touristic areas in North Heraklion

Crete's demanding electric system can be described by two parameters; extreme demand growth rates and low load factor. This is the cause of power inefficiency problems that the island experiences, provoked by the exceptionally high peak power loads caused by seasonal variations.

Crete's special and unique island environment and its subsequent touristic and services sectors development come in direct conflict with any additional environment pressure posed by the increase in fossil fuel use. Therefore, the island's public opinion reacts fiercely against the addition of new thermal plants due to their environmental impacts, while on the other hand, Renewable Energy Sources – based technologies tend to be positively assessed by the Cretan people.

Current available and applicable renewable technologies are unable to satisfy a significant part of the system's requirements, as its autonomous nature requires the major part of produced electricity as well as the total of the available reserve margin to be served from resource and production controlled units, such as fossil fuel based power plants.

For years there have been plans for the connection of the island's grid with the mainland's electrical grid. Such practice would allow full exploitation of the island's endogenous energy sources, such as solar and wind, while allowing the import of electricity from the mainland when natural reserves fall short. Unfortunately, due to difficulties caused by the strong undersea streams between Crete and Peloponnese, high depths and seismic activity, as well as the threat of security of supply in extreme conditions, the task has been abandoned (5).

1.4 Crete's existing RES infrastructure and the need for further exploitation

Since 1994, the private sector has been motivated by the law 2244/94 which allowed independent producers to invest in RES and sell the produced energy at 90% of the consumer's price per kWh. This law, together with the subsequent development laws (2234/94, 2601/98 and 3299/04), which supported private investment with subsidies that reached 45% of the invested capital, led in a substantial RES implementation of more than 100MW of installed capacity by the end of 2005.

Unfortunately, due to the nature of this specific law, which provided uniform energy credit regardless the exploited RES, only wind parks were realized (with the exception of a small amount of grid connected photovoltaic applications). The new RES law, 3468/06 simplifies and evolves the supportive legislative framework for renewables, especially in small applications and simultaneously supports the photovoltaic and solar thermal applications by increasing the energy credit up to 0,50 and 0,30 €/kWh respectively. Simultaneously, the updated investment law (3522/06) provides even higher incentives that reach 50% of the invested capital.

Picture 3: Traditional windmill in Sitia, Lassithi

It appears that the previously inexistent motives for the development of RES have become a reality, and Crete's most prominent sources (i.e. wind and solar) are soon to be fully exploited. Still there are few more potentially exploitable RES in Crete to be used for electricity generation; biomass, wave energy and small hydro are under consideration by researchers and private investors. In this study small hydro-electric as well as combined heat and power biomass plants will be investigated.

As renewables installed capacity increases, technical difficulties regarding their maximum penetration in the island's system arise. There are already high amounts of rejected energy from the currently functioning wind turbines, which are bound to get even higher as their contribution on the total capacity increases. Therefore, careful physical planning must be commissioned to ensure further RES development and to protect the interests of existing and future investors. For the above purposes, the Greek Regulatory Authority for Energy has applied strict methodologies for the licensing of new wind parks, and halted since 2003 the fast development of RES in Crete by characterizing the system "saturated".

This study is set to verify the technical difficulties regarding further RES implementation and offer a variety of scenarios in order to maximize RES contribution in order minimize Green House Gas emissions and make the island as autonomous as it is technically possible.

1.5 Main targets of the present work

The main objectives of the present work are summarized as following:

- Forecasting future needs with a reliable and intuitive methodology
- Offering demand restraint solutions that are available, or will be in near future
- Examining available modeling software solutions and using the most appropriate for this case study
- Determining, through the model's results on different load management scenarios, the effectiveness of the selected solutions in terms of energy requirements reduction
- Determining environmental impacts from the electric demand increase in future years and emissions mitigation resulting from the selected scenarios.
- Examining the current electricity production technologies and transmission network
- Examining the requirements for new power supplying units to satisfy the increasing demand
- Screening of available RES technologies by estimating resources, system integration potential, legislative and financial incentives
- Minimizing environmental impacts by migrating into cleaner controllable resources such as adoption of natural gas instead of fuel oil
- Exporting energy balances, fuel import requirements, emissions for each considered scenario
- Overall system technical evaluation in terms of stability and reserve
- Reviewing current legislative framework perspectives, incentives and future targets and proposing even stricter policies in order to achieve further environmental impact mitigation

2 Adopted methodology

Various approaches for energy planning and GHG mitigation assessment in the energy sector are offered by applying several available methodologies (6) such as optimization models, simulation models and accounting frameworks. For the purpose of this study, accounting framework software "LEAP" will be used, as it is considered most appropriate given the aspects of Crete's electric energy system as well as the available raw data.

2.1 Optimization models

Optimization models use mathematical programming to identify configurations of energy systems that minimize the total cost of providing energy services, based on various constraints (e.g. a CO2 emissions target). This kind of model selects among technologies based on their relative costs, resulting in allocation of all market share to the cheapest technology.

Therefore, in order to ensure realistic and trustworthy results, the model must be constrained to yield "reasonable" results in means of disaggregating demands into more homogenous groups, or by manually constraining market allocations. Other important parameters in optimization models are [a] that they typically assume that energy cost is the only factor in technology choice and [b] that they apply the questionable fundamental assumption of perfect competition (e.g., perfect competition, no monopolistic practices, no market power, no subsidies and all markets in equilibrium) (7). Trying to implement this method of analysis is in Crete's monopolistic and inflexible energy status can only lead to controversial outcomes.

2.2 Simulation models

Simulation models forecast the behavior of energy consumers and producers under various signals and constraints. Compared to optimization models they prove flexible to include non-price factors in analysis.

This methodology is considered more appropriate for energy planning in non-ideal energy communities such as the one under examination, as it is not limited by the assumption of the system's optimal behavior or that energy is the only factor affecting technology choice. On the opposite side, this methodology tends to be complex and data intensive and hard to parameterize. Additionally, future forecasts can be very sensitive to starting conditions and parameters.

Due to the fact that crucial parameters required for input are highly abstracted or poorly known, especially in Crete where disaggregated time series data is lacking, it is rendered clear that in order to fulfill the expectations of this work, a more flexible methodology is needed to be followed.

2.3 Accounting Frameworks

Accounting frameworks offer a physical description of an energy system, modeling for flows of energy based on simple engineering relationships. Rather than simulating decisions of energy consumers and producers, the user explicitly accounts for outcomes of those decisions.

Among their many advantages, accounting frameworks feature simple, transparent and flexible interface with lower data requirements than the previous methodologies. They are capable of examining issues that go beyond technology choice or are hard to specify their cost. They also flexibly operate regardless the amount of input in parameter completion. User may provide analytical data in categories where they are available, and aggregate categories using assumptions where not enough details exist.

2.4 Main software for the development of the study: LEAP

LEAP, the Long range Energy Alternatives Planning system is provided by the Stockholm Environment Institute, free of charge for academic use. It proves a very capable tool for strategic integrated energy and environment scenario studies, providing energy outlooks, integrated resource planning, greenhouse gas mitigation analysis, while offering a wide environmental impact inventory.

Its user interface is simple and transparent, based on the "accounting framework" methodology, offering a powerful yet friendly, scenario-based, integrated energy-environment model-building tool (7). Interestingly, it allows for spreadsheet-like "expressions" for the creation of powerful econometric and simulation models. Its flexible nature also allows for a variety of applications, from local to regional or national range for a medium to long term time base for unlimited number of periods.

Through the model's main, analysis view, the user is able to create custom scenarios with different data structures for the specific area of interest by simulating energy demand and energy conversion, specifying resources and costs, while modeling environmental parameters and impacts.

LEAP's results view examines the outcomes of scenarios in the form of charts and tables while the diagram view shows flows of energy in the area. Also, a very helpful feature of LEAP is the inclusion of the customizable "Technology and Environmental Database" which offers technology characteristics, costs, and environmental impacts of more than 1000 energy technologies.

2.5 Additional tools

While LEAP will be the prime IRP and environmental impact mitigation analysis model used for the development of scenarios included in this work, various additional energy planning tools will be used, especially for technology-specific calculations.

The most indispensable tool is the RETscreen International Clean Energy Project Analysis suite, an extremely advanced and analytical spreadsheet based tool capable of specifying the energy production, life-cycle costs and GHG emissions reductions from every renewable energy and energy efficient technology available.

RETscreen's nature is aimed primarily for project-level analysis of separate technologies and not for all round, regional-level integrated energy analyses, as LEAP is. Hence, it can only be used for screening options, before their inclusion in system-integrated assessments. RETscreen helps develop the technical, cost and performance variables required other models such as LEAP.

The RETscreen suite offers a variety of modules (RETs) such as wind, small hydro, photovoltaics, combined heat and power, solar water heating and others (8), most of which will be used in this study.

3 Analyzing the island's electric energy demands

3.1 Synopsis of the total energy demands

Power stations in Crete still operate 100% on liquid fuel oil, accounting for the 53% of the total fuel imports on the island. The remainder 47% is mainly used for transport (42%) and industry (5%) (5). In this study we will only be analyzing fuel transformation into electric energy; fuel consumption for the needs of transport will not be examined.

Similarly, an important fraction of the thermal energy demands in industry and households is satisfied by the all-important contribution of biomass, which will not be considered on the framework's energy balance scheme.

As referred in Paragraph 1.2, in 2005 more than 2.600GWh of electric energy where distributed though the transmission grid's main substations. Almost half of the produced energy was consumed for the needs of Heraklion, the largest and most populated prefecture of Crete. Another important fraction (25%) serves Chania, while Rethimnon and Lassithi share the remainder of the pie.

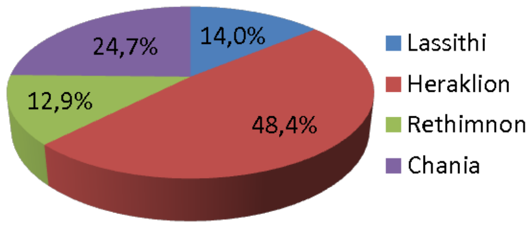


Figure 5: Fraction of energy requirements per prefecture

A breakdown of demands by category of use is presented on Table 5(9).

Table 5: Electric energy consumption by category of use for the year 2005

Prefecture	Domestic use	Commercial Use	Industrial Use	Agricultural Use	Public Authorities	Street Lighting	Total
Heraklion	392.879	467.619	134.358	85.041	89.354	14.737	**1.183.988**
Lassithi	110.096	130.198	12.165	49.631	21.588	9.540	**333.218**
Rethimnon	96.172	122.779	32.621	16.505	25.346	5.036	**298.459**
Chania	217.774	233.155	47.941	30.649	56.260	11.013	**596.792**
Crete total	**816.921**	**953.751**	**227.085**	**181.826**	**192.548**	**40.326**	**2.412.457**

The predominant amount of electricity is consumed by the domestic and commercial sector. Unfortunately, these sectors are the hardest to apply Demand Side Management (DSM) policies, since the level of adaptation of energy saving technologies depends mainly on self-motivation of individual consumers. On the other hand, self intrigued industries tend to apply DSM as it directly reflects on their profitability. In any case, it is a matter of

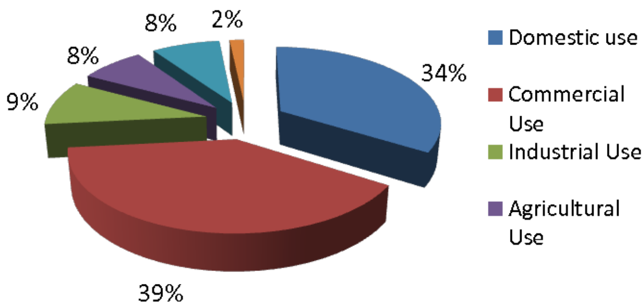


Figure 6: Electric energy consumption per category of use for the prefecture of Crete, 2005

regional policy, though the motivation from institutions such as the Regional Energy Agency of Crete, to implement DSM practices on public authorities or street lighting.

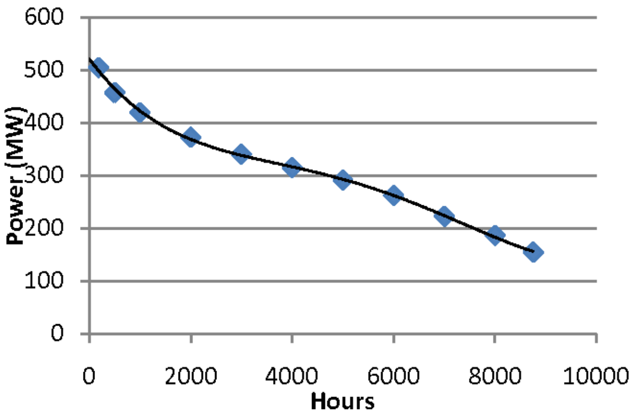


Figure 7: Electrical system load curve

One of the most important characteristic in an electric system is the load curve. It is a graph showing how the peak power demands on a system vary over the course of a year. In an accounting framework such as LEAP, the load curve can be imported exogenously or exported endogenously by separately specifying the load curves of each demand activity. In long term energy planning and mitigation analysis, disaggregating loads in activity branch level can be avoided, as the overall load factor is sufficient for process dispatch calculations.

Another important parameter acquired by the load curve is the load factor. The lesser the peak loads compared to the average load of a system the higher the load factor gets. Systems with low load factors such as Crete (54% in 2005) (4) tend to be demanding and more expensive to run, as peak load technologies must be employed more frequently. Simultaneously, in order to account with sudden increases in peak load compared to those of previous years, they require higher reserves on easy to dispatch technologies, such as gas turbines.

Increasing a system's load factor with extended and well-orchestrated DSM, by the means of peak shaving and daily load management is a common practice to reduce generation costs and environmental impacts, as in general, base load combined cycle units operate with higher efficiencies. In order to calculate the effect of DSM measures on the system's load factor, a custom assumption approach must be used, since historical data on load shapes per activity do not exist and would be impossible to quantify.

3.2 Scenario building on load forecasting

Restraining the extreme increase rate of electricity demands witnessed continuously in previous years is the key to ensure long term energy availability and sustainable development. In order to propose methods for restraining annual loads, correct methodology must be built on forecasting them. Using LEAP, we will be able to develop different scenarios of load unfolding, results of which will be used to predict annual minimum and maximum loads, in order to model the addition of further technologies for the production and transmission of electrical energy. Naturally, forecasting minimum loads will implicitly define further RES integration possibilities, while forecasting maximum loads will allow for planning of further controllable production units implementation.

3.2.1 Business as usual scenario

Business as usual (BAU) is the base case scenario that represents changes that are likely to occur in the future, in absence of any new policy measures. The aim of monitoring BAU is to make available reference values with which to compare actual Demand Side Management (DSM) scenarios. BAU will provide demands that will verify the accuracy of those logistically forecasted in Paragraph 1.2. Additionally, due to the absence of any DSM policy, load factors will remain unchanged in future years.

3.2.2 Demand side management

Two DSM scenarios will be formed, which are differentiated by the degree of DSM penetration. Both scenarios will exploit any energy saving potential in the various categories of use by adopting the available technologies. The most austere, extended DSM scenario will also try to comply with any existing EU targets in the categories in which they are set.

DSM needs the contribution of both committee incentives and private company agents for fast and successful implementation. Third Party Financing (TPF) is perceived as the most applicable mechanism to accomplish the target. It involves the provision of outsourced finance for capital investment in energy performance projects by any "third party", which is neither the end-energy user nor the energy supplier of the industrial or building site. The concept of TPF more usually refers to a specialized company, the Energy Service Company (ESCO) which provides a complete package of energy services for the implementation and operation of an energy performance project. ESCO's usually operate through energy performance contracting, a form of guarantee that reliefs the end-user from the risk that DSM involves when combined with traditional 'turnkey' equipment supply contracts (10).

3.3 Evaluation of different demand side options

In the following paragraphs, loads for each sector will be analyzed, either based on available historical data or on logical assumptions. Simultaneously, the available energy saving options on all primary energy consuming activities will be applied in the DSM scenarios, in order to estimate the final effects in demand per sector.

The demand modeling methodology used for calculating the evolution of demands per sector is final energy analysis (11). A typical approach is to disaggregate the available demand data structure, as previously seen in Paragraph 3.1, Table 5 into four levels representing sectors, subsectors, end-uses and devices and/or technologies. A demand tree structure example for Crete is shown in

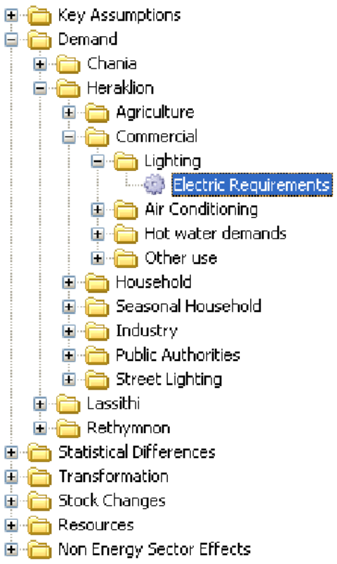


Figure 8: LEAP's tree, a hierarchical outline used to organize and edit the main data structures

Each sector or subsector is defined by the basic parameter activity level, which describes social and economic activity. When used in LEAP's demand analysis, activity levels are multiplied by energy intensities (the average energy consumption of some device or end-use per unit of activity) to yield overall levels of energy demand. The final energy analysis methodology is described by the simple function:

$$\boldsymbol{e = a \times i}$$

where e equals energy demand, a activity level and i final energy intensity.

3.4 Agriculture

The agricultural sector is divided into two subcategories, greenhouse and outdoor cultivations. Outdoor cultivations require electricity for water-pumping requirements, while a small fraction of greenhouse cultivations may require additional electricity for heating purposes. It is impossible to specify the exact requirements for heating, as there is not enough data on greenhouse cultivations; still it is possible to aggregate the requirements in a general electricity consuming end use, using the inverted final energy analysis procedure and calculating different energy intensities for each prefecture.

Table 6: Calculating energy intensities based on unrelated statistic data on agricutural activity

Prefecture	Areas of cultivated land ($x10^3$ ha)	Specific energy intensity (kWh/ha)	Total Annual Energy Demands (MWh)
Heraklion	2752,8	30,89	85.041
Lassithi	1069,2	46,42	49.631
Rethymnon	1242,1	13,29	16.505
Chania	1034,9	29,62	30.649
Crete	**6099,0**		**181.826**

Prefectures that account low (Rethimnon) and medium (Chania and Heraklion) energy intensities correspond apparently in fewer greenhouses than, for example, Lassithi which consumes 46kWh per cultivated hectare. Considering the fact that most outdoor cultivations less electricity due to reduced pumping and general requirements, DSM practices are destined to be more efficient on the latter, combined with the increasing contribution of fuel oil, biomass and solar electric heating (5). Hence a DSM “extended DSM” scenario will be formed, providing up to 30% savings until 2030 on the energy intensity values by decreasing aggregate consumptions proportionally, while “Partial DSM” scenario will forecast up 10% savings assuming only greenhouse intervention.

Table 7: 2030 Results of extended DSM assumptions in argicultural energy intensity

Prefecture	Estimated greenhouse saturation	Energy savings by year 2030	Specific energy intensity (kWh/ha)
Heraklion	66,6%	20,0%	24,72
Lassithi	100,0%	30,0%	32,49
Rethymnon	28,6%	8,6%	12,15
Chania	63,8%	19,1%	23,95

In any case, all scenarios will follow the key assumption that area of cultivated land grows correspondingly to the agricultural GDP indicator. The results of both DSM policies are presented in Figure 9; BAU is the abbreviation for “Business As Usual”, PAR for “Partial DSM” and EXT for “Extenended DSM”. As a conclusion, the proposed DSM policy may save up to 306GWh of energy until 2030; Load and environmental effects of this practice will be exposed and evaluated in later chapters.

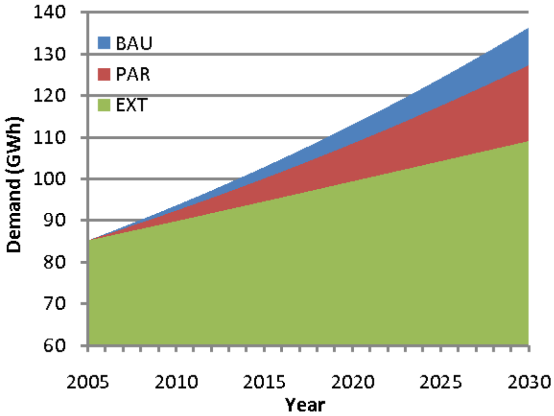


Figure 9: Annual demand reduction due to DSM application

3.5 Commercial Sector

3.5.1 Overview

The commercial sector is the most crucial of all in the rise of demand in following years. Not only it corresponds for almost 40% of the island's total electric demands, but it also grows in the fastest rate than all sectors, similarly to its GDP, as seen in Paragraph 1.2. The commercial sector comprises of the touristic, services and commerce activities, which can be described as seasonal, since they all grow during the summer months. This kind of activities also negatively affect the system's load factor, hence commercial DSM practice is considered utterly important for effective energy saving.

The unprecedented growth of over 8% in this sector in recent years is destined to decrease after the following 6 years, due to the inevitable saturation in tourism, as well as the expiration of the forthcoming fourth community support framework. We estimate that from 2011, Crete's development rates in this sector will adapt with the national rates (4%) (3), while after 2020 rates will decrease even more (3%). By these estimations, regional GDP forecasts will most probably follow the logistic projections described in Paragraph 1.2, rather than the exponential ones.

Business as usual scenario for the commercial sector will follow these activity development rates combined with no DSM program in consideration. Energy intensities will decrease slightly due to the expected upgrades in more energy efficient technologies, as old equipment is retired, combined with the additional new businesses that immediately purchase new equipment. The partial DSM and extensive DSM scenarios will apply measures for reducing energy intensities in the four main categories of use unfolded in Table 8.

Table 8: Commercial sector demands per category of use for the year 2005 (9)

Prefecture	Lighting electric demands (MWh)	Air-Conditioning demands (MWh)	Water heating demands (MWh)	Other use (MWh)	Total annual energy demands (MWh)
Heraklion	93.524	163.667	46.762	163.667	467.619
Lassithi	26.040	45.569	13.020	45.569	130.198
Rethymnon	24.556	42.973	12.278	42.973	122.779
Chania	46.631	81.604	23.316	81.604	233.155
Crete	**190.750**	**333.813**	**95.375**	**333.813**	**953.751**

3.5.2 Lighting

Energy saving is a crucial parameter for the viability of small businesses and gets even more important in lager ones such as luxurious hotels. This fact comes to aid the penetration of energy saving technologies among which, effective lighting is the easier and more efficient to apply, as lighting represents more than 20% of the total demands. Since the majority of commercial consumers have already adopted compact fluorescent lighting (CFL), further savings may occur by adaptation of natural lighting principles on future buildings, electronic ballasts in older applications that offer increased efficiency and light quality, as well as energy saving automation that will save power on non-used sectors of large buildings.

Combined application of the above measures may contribute in over 50% savings in commercial buildings (12). Realization of this target is considered quite optimistic, even in 2030 terms, although future applications are destined to offer even more savings than today's offerings. The main reason is that most of techniques are easy to apply in new or renovated buildings, but impossible to apply effectively in existing infrastructures. A more realistic target for extended DSM by the year 2030 is considered 40% reduction in energy intensity; intermediate values will be interpolated starting from 2005 (historical data). Still, strict legislative measures on new and existing commercial buildings should be applied by the government in order for the island to reach the moderately set target.

3.5.3 Air conditioning

Air conditioning accounts for the most determinant activity in the commercial sector, as sales of air conditioning units in Greece, and consequently Crete, are among the highest per capita in the European Union. Especially in seasonal-focused commercial sector, which operates at its highest during summer months, A/C demands may surpass 30% of the total demands. Simultaneously, a vast majority of businesses in Crete rely on A/Cs for both heating and cooling requirements.

Natural evolution in A/C technologies drives a transition to higher average Energy Efficiency Ratio (EER) per unit sold. EER is the ratio of the cooling-heating capacity [in Btu per hour] to the power input [in watts]. It also often described in watt per watt scale (13). A potential "strict" labeling scheme that would help consumers to easily seek for an efficient A/C unit is presented in Table 9. A unit whose efficiency equals today's average EER (about 9) should be labeled "G class" which means inefficient energy-wise; thus, a labeled "A class" A/C would output EER's of more than 13 (14).

Label Class Limits	EER/EERavg (%)
A starts over	150
B starts over	140-150
C starts over	130-140
D starts over	120-130
E starts over	110-120
F starts over	100-100
G starts below	100

Table 9: Proposed A/C efficiency labelling

Assuming that all A/C's sold in 2030 will be offering inverter technologies that output "A class" or better efficiencies, combined with the inevitable retirement of old, inefficient A/C's, it would be safe to forecast an average EER 13 efficiency for the operating A/C's after 25 years (BAU scenario). An optimistic DSM policy through labeling and advertisement could help for reaching the above target earlier; reaching EER 13 in 2020 and climbing to EER 15 in 2030 will form our PAR DSM scenario, while aggressively achieving EER 13 in 2015 and EER 15 by 2030 will indicate our EXT DSM scenario.

3.5.4 Water heating and other demands

Greece may be the EU's market leader in solar water heating systems, for reasons that are described later on (Paragraph 3.6), but the commercial sector is proven unable to follow this trend. The reasons are mainly due to lack of initiatives given for investing in solar thermal in the commercial sector (especially hotels and restaurants) and the criminal absence of legislation for the compulsory installation of solar thermal technologies in every new building. It's worth noting that a solar thermal system provides a pay-back period of initial capital of 7-8 years when no subsidies are given, which many investors consider long and instead choose to minimize the invested capital.

As reported, solar thermal sales in the tertiary sector was just a small slice of the pie till the year 2000, representing less than 1% of the total sales (15). Fortunately this proportion changed dramatically after

2000, in levels of 3-4%, possibly due to the incentives given by the development law. Hotels in Crete seem keener to adapt solar thermal technologies, but statistics are unavailable. Based on the national average demands for hot water on the commercial sector (10% of the total loads), as well the huge penetration potential combined with increasing sales, it would be safe to forecast 10% savings in 2030 (BAU scenario). Correspondingly, we assume 20% and 40% savings for the two DSM scenarios, depending on effectiveness on legislative measures taken by the society to exploit this extreme solar potential.

Finally, the additional electricity consumed by several other devices such as professional equipment, computers and televisions. Since it is impossible to disaggregate this category into consistent subcategories, we will simply be treating it as an end use. Regarding the scenarios, “other use” category will have to catch up with EU’s “20% savings until 2020” where 10% and 20% savings will be achieved from partial and extended DSM respectively and 5% savings will be the case in business as usual.

Table 10 summarizes the results of DSM practice on each scenario in terms of energy intensity. Methodology chosen uses the sector’s GDP as an activity level value, which is justified by the direct relation between electricity and economic development observed in Paragraph 1.2.

It is also important to notice that in both DSM scenarios, activity level (GDP) growth rates maintain the same values as those in the BAU scenario, based on the initial assumption that development will not be sacrificed in any way, even if energy shortages or environmental impacts occur. After all, economy tends to evolve together with technology, thus is able to balance itself by taking alternative courses of action when resource shortages occur.

Table 10: Summarizing scenario assumptions for the tertiary sector

Category of use	2005 intensities (in kWh/€ of GDP)	End year intensities (in kWh/€ of GDP)		
	Current Accounts	BAU	Partial DSM	Extended DSM
Lighting	~ 0,024	**Unchanged** 0,024	**20% savings by 2030** 0,0191	**40% savings by 2030** 0,0144
Air Conditing (Heating & cooling)	**EER 9** 0,042	**EER 13 by 2030** 0,0291	**EER 13 by 2020** 0,0252	**EER 13 by 2015** 0,0252
Hot Water	~ 0,012	**10% savings by 2030** 0,0108	**20% savings by 2030** 0,0096	**40% savings by 2030** 0,0072
Other use	~ 0,042	**5% savings by 2020** 0,0389	**10% savings by 2020** 0,0351	**20% savings by 2020** 0,0281

3.5.5 Results

Each of the two DSM scenarios will try to limit demand growths on the most crucial sector in Crete’s economy compared to the expected ones if no action is taken. In 2030, requirements will reach 3.700GWh, an increase of almost 300% compared to present values. If partial DSM policy is applied, demands will increase by 240%, reaching 3.300GWh per year and will totally save 5.600GWh by 2030, covering the island’s total demands for almost two years (in present rates).

Finally, if extended DSM is applied, the effects of development on energy demand will decrease even more, reaching just 2.700GWh in 2030, increasing only by 190% from today's levels. This will save 11.600GWh by 2030, which equals more than 4 times the annual energy demands according to current accounts. These energy savings reflect directly on the cumulative GHG emission savings, promoting the direct correlation between DSM and GHG emission mitigation.

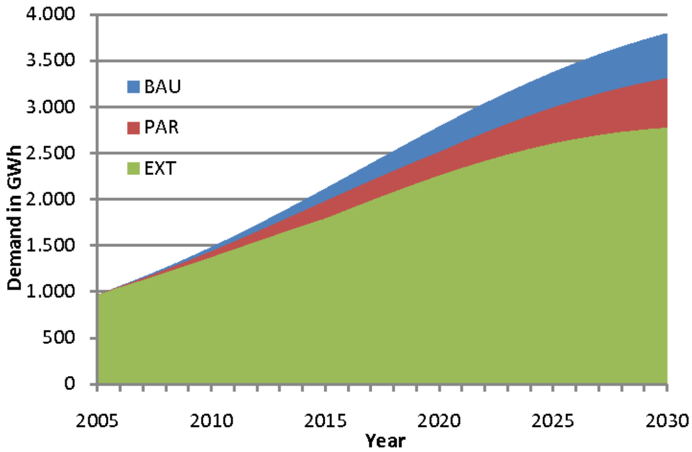


Figure 10: Scenario results on the commercial sector

3.6 Domestic sector

3.6.1 Introduction

Calculating future demands in Crete's domestic sector is probably the hardest task, as the unrelated variables of economic growth and population growth both affect building construction rates, whose technological characteristics, hence energy intensities vastly vary. A very arousing and intriguing controversy is that of the universal adoption of newer, more efficient technologies in new buildings, which simultaneously adopt even more new luxuries and as quality of life rises. These two opposing parameters are hard to quantify, as is the inflexible inhabitant that is unwilling to comprehend the importance of energy saving to the environment. In the meantime, due to PPC's extremely low electricity tariffs, no noticeable economic motive is given for the average consumer to adopt these energy saving measures.

As a method of driving consumers in endogenous DSM, PPC's tariffs increase noticeably as consumer's bill (in kWh) rises. Still, the prices are too low, compared to a household's various other expenses. For example a exchange of all incandescent lamps with CFL equivalents in an average household may cost just 40€, but saves up only 8€ annually on the electricity bill. Thus, although the investment pays up in just 5 years, the annually saved amount is indifferent and unable to motivate the environmentally insensitive consumer.

3.6.2 Distinguishing households

It may be impossible to define the level of consumption intensity between households with low and high incomes, but it is easy to distinguish household energy intensities by their classification as permanent or seasonal, urban or rural (1). Urbanization in Crete is fast, but still, urban areas keep up their population and development rates, possibly due to the secondary occupation of most Cretans with agriculture, as well as their strong family bondages. An overview of the domestic sector status in Crete, together with their corresponding energy requirements is unfolded in Table 11.

Table 11: Disaggregated domestic sector demands per category of use for the year 2005, based on the described methodology

URBAN HOUSEHOLDS - CURRENT ACCOUNTS

Prefecture	Number of urban electrified households	Percentage on Prefecture's total permanent households	Lighting electric demands (MWh)	Refrigeration electric demands (MWh)	Air-Conditioning (cooling) demands (MWh)	Electric heating demands (MWh)	Other use (MWh)	Total annual energy demands (MWh)	Percentage on total energy requirements (%)
Heraklion	59.850	63%	33.456	19.930	55.177	84.666	25.313	218.542	55,6%
Lassithi	11.614	43%	6.492	3.867	10.707	16.429	4.912	42.408	10,8%
Rethimnon	10.504	41%	5.872	3.498	9.684	14.859	4.443	38.355	9,8%
Chania	25.581	53%	14.300	8.518	23.584	36.188	10.819	93.409	23,8%
Crete	**107.549**		**60.120**	**35.814**	**99.152**	**152.142**	**45.487**	**392.714**	

RURAL HOUSEHOLDS - CURRENT ACCOUNTS

Prefecture	Number of rural electrified households	Percentage on total permanent households	Lighting electric demands (MWh)	Refrigeration electric demands (MWh)	Air-Conditioning (cooling) demands (MWh)	Electric heating demands (MWh)	Other use (MWh)	Total annual energy demands (MWh)	Percentage on total energy requirements (%)
Heraklion	35.150	37%	19.649	11.705	10.127	50.372	14.866	106.719	39,8%
Lassithi	15.227	57%	8.512	5.071	4.387	21.821	6.440	46.231	17,3%
Rethimnon	15.190	59%	8.491	5.058	4.376	21.768	6.424	46.118	17,2%
Chania	22.671	47%	12.673	7.549	6.532	32.489	9.588	68.831	25,7%
Crete	**88.238**		**49.325**	**29.383**	**25.421**	**126.450**	**37.319**	**267.899**	

SEASONAL HOUSEHOLDS - CURRENT ACCOUNTS

Prefecture	Number of seasonal electrified households	Percentage on total households	Lighting electric demands (MWh)	Refrigeration electric demands (MWh)	Air-Conditioning (cooling) demands (MWh)	Electric heating demands (MWh)	Other use (MWh)	Total annual energy demands (MWh)	Percentage on total energy requirements (%)
Heraklion	48.245	42%	6.742	8.033	38.918	6.825	5.101	65.619	42,0%
Lassithi	23.393	20%	3.269	3.895	18.871	3.309	2.473	31.818	20,4%
Rethimnon	17.150	15%	2.397	2.855	13.835	2.426	1.813	23.326	14,9%
Chania	26.133	23%	3.652	4.351	21.081	3.697	2.763	35.544	22,7%
Crete	**114.921**		**16.060**	**19.134**	**92.705**	**16.257**	**12.151**	**156.308**	

3.6.3 Lighting

As previously mentioned, 8€ of annual savings in electricity bill may be indifferent to the consumer, but the wasted 100.000MWh annually for domestic lighting through incandescent lighting in Crete contributes to global warming by 86.000 tons of CO_2 (16).

The domestic sector offers huge potential for energy savings in the lighting end use. Almost 80% of existing households are equipped exclusively with incandescent lamps. Migrating to 100% CFL lighting can be easily and quickly applied by the following proposed methods:

- Increasing the tariffs; this would decrease the pay back period of CFL lamps.
- Crediting the sales through electricity bills. This method has been applied successfully but in short scale during the past. According to this method, the consumer reduces initial costs by getting "free" lamps that are credited by the hardware store in his PPC account. The corresponding credit is being paid every two months, together with the reduced electricity bill.
- Even more simply, prohibiting further sales of incandescent lamps; this would simply ensure that every "dead" incandescent lamp would be exchanged with an efficient one. It can also be combined with the aforementioned crediting policy.

Quick implementation of the above measures provides a good start for environmental impact mitigation, as it is also an understandable method to drive the all important energy-awareness of the public.

Migrating to CFL lamps is not the only method of increasing lighting efficiencies on households; unfortunately we should not expect better overall results, since the modern, luxurious households that feature even more efficient lighting techniques also have increased requirements on *actual* light. Therefore, it's enough for the moment to rely on simple exchange methodology that will reduce lighting intensities by at least 70% on the average household. Simultaneously, household activity level will grow according to the 60% of the economic development rates, since houses get bigger and more demanding as average family income increase.

DSM targets for all three categories of households are summarized in Table 12. The target for partial DSM scenario is set for 2030, while in extended DSM efficient lighting will be 100% achieved by 2015.

Table 12: DSM targets for domestic lighting

			Partial DSM Scenario		Extended DSM Scenario	
Energy intensity (kWh/household)		**Current Accounts**	**2015**	**2030**	**2015**	**2030**
Existing	650	80%	50%	0%	0%	0%
Efficient	195	20%	50%	100%	100%	100%
Average (kWh/household)		**559**	**423**	**195**	**195**	**195**

For seasonal households, a custom parameter which will be named "intensity factor" will be applied. Different intensity factors will be implemented in LEAP's framework; each will specify the reduction of energy requirements compared to the average urban household, due to partial inhabitation.

For lighting, the seasonal intensity factor will be set to 0,25. For the following demand categories it will be set as follows: Refrigeration 0,5; Air Conditioning (cooling) 0,7; Electric Heating 0,1; Other use 0,25.

3.6.4 Refrigeration and Air Conditioning

Similarly to lighting, refrigeration also represents an important fraction of the island's domestic load, as it represents almost 10% of the load (17). Especially in seasonal households, refrigerators often operate continuously while residents visit the house just occasionally during the week.

Unfortunately, unlike lighting, interfering with home refrigeration is rendered from hard to impossible. Consumers will purchase new refrigerators, as the existing ones will reach the end of their lifecycle; but in order to drive them into buying most efficient ones, an informative campaign into energy saving and labeling, similar to the one proposed for air conditioning on the tertiary sector must be applied. Results of such campaign are presented, together with BAU predictions, in the following table.

Table 13: Energy intensities in refrigeration for each scenario

			Business as usual		Partial & Extended DSM Scenario	
Energy intensity (kWh/household)		Current Accounts	2015	2030	2015	2030
Existing	350	90%	80%	60%	60%	20%
Efficient	180	10%	20%	40%	40%	80%
Average (kWh/household)		**333**	**316**	**282**	**282**	**214**

Air Conditioning, on the other hand, varies in terms of integration between the three household categories. Urban households, due to higher temperatures in city environments have become oversaturated in A/C's as sales confirm (80%) (14), while rural households still use natural methods for cooling to an extent (25%). Impossible to quantify is the integration of room A/C's in seasonal households; we assume a saturation of 70% since they are used mainly in summer months. Intensity factors will be applied to the energy intensities presented in Table 14 accordingly. It is also important to mention that saturations will also increase accordingly to A/C sales rates.

As in refrigeration, the same actions will be taken in both DSM scenarios, as noticeable variations from the BAU predictions driven by retirement of old units and progress in average efficiency can prove very hard to implement.

Table 14: Energy intensities in room air-conditioning for each scenario

			Business as usual		Partial & Extended DSM Scenario	
Energy intensity (kWh/household)		Current Accounts	2015	2030	2015	2030
Existing (EER 9)	1200	90%	80%	60%	60%	20%
Efficient (EER 15)	720	10%	20%	40%	40%	80%
Average (kWh/household)		**333**	**316**	**282**	**282**	**214**

3.6.5 Electric heating

The RETscreen software was used to evaluate the average annual thermal needs of a Cretan household. The reverse methodology that we applied accounted for energy saving intensities, rather than energy consuming. Electric heating, was assumed as the worst heating option, while central, biomass and solar water heating reduce intensities by applying negative intensity values.

According to the results on RETscreen's Bioheat module, for a heating degree-day limit of 18°C, the average household requires 3.725kWh of energy annually, in order to maintain the desired room temperatures and satisfy hot water demands. Electric heaters provide 100% thermal efficiency, so the heating demands also correspond to 3.725kWh of electrical energy annually.

Urban and rural households differ mostly in terms of room heating options; this is why thermal scenarios will be considered separately for these two categories. Central heating, which is also combined with hot water, is found in more than 45% of the urban households, while only in the ¼ of rural households (9). Biomass heating is widely used in rural areas, but in the urban environment is only adopted in luxurious households. Finally, detailed data exists regarding solar water heating appliances (15); over 250 thousand m^2 of operational solar thermal systems are installed in the domestic sector, enough for supplying solar hot water in more than 105 thousand households, reaching a saturation fraction of 35%. We consider the same fraction for all three household categories.

Table 15: Energy intensities for domestic heating in urban and rural households, for each scenario

				Business as usual		Partial DSM Scenario		Extended DSM Scenario	
Urban households	**Energy intensity (kWh/household)**		**Current Accounts**	**2015**	**2030**	**2015**	**2030**	**2015**	**2030**
	Solar water heating	-1.008	35%	40%	45%	45%	50%	45%	55%
	Central heating & combined hot water	-2.717	45%	50%	55%	55%	60%	60%	60%
	Biomass & other non electric heating	-2.100	35%	35%	35%	35%	35%	35%	40%
	Average thermal requirements	3.725	100%	100%	100%	100%	100%	100%	100%
	Average (kWh/household)		**1.415**	**1.228**	**1.042**	**1.042**	**856**	**906**	**700**
Rural households	**Energy intensity (kWh/household)**		**Current Accounts**	**2015**	**2030**	**2015**	**2030**	**2015**	**2030**
	Solar water heating	-1.008	35%	35%	40%	40%	45%	45%	50%
	Central heating & combined hot water	-2.717	25%	30%	35%	30%	35%	35%	40%
	Biomass & other non electric heating	-2.100	60%	55%	50%	60%	60%	60%	60%
	Average thermal requirements	3.725	100%	100%	100%	100%	100%	100%	100%
	Average (kWh/household)		**1.415**	**1.402**	**1.321**	**1.247**	**1.061**	**1.061**	**874**

Further saving with improvements on the overall thermal efficiency of the average household could be studied, as there is a huge energy saving potential to be exploited (18). Unfortunately, this side option of DSM will not be studied, since it is easier to emphasize in retro-fit possibilities. Finally, in seasonal households, urban intensity values will be used, multiplied by a seasonal intensity factor of 0,1.

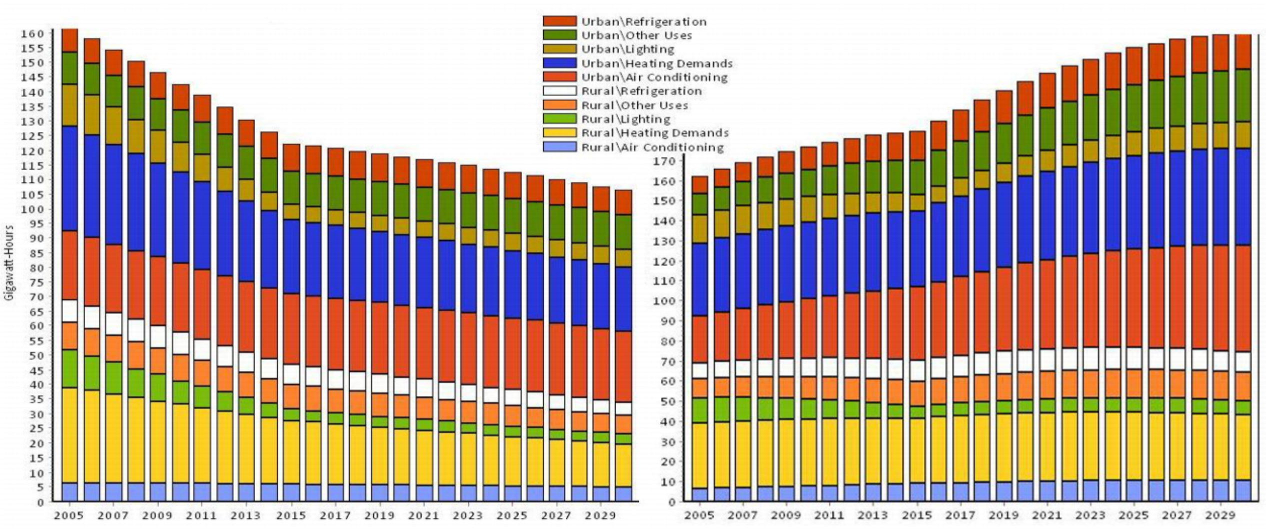
3.6.6 Other demands and results

The remaining electric needs in households derive from other electric devices such as washing machines, electric ovens and televisions. Similarly to the commercial sector, we will avoid disaggregation of this category into subcategories and we will simply form the two DSM scenarios to progressively catch up with EU's "20% savings until 2020".

Subsequently, after all loads have be distinguished and input in the framework, LEAP calculates the results of our DSM policy by projecting energy demands for each scenario in annual time-steps up until 2030. The two most important assumptions used by LEAP in order to accomplish the forecast are: [a] the end year urbanization value (that reflects for how many rural households have been reaching consumption characteristics of the average urban household) and [b] the activity level increase (which reflects the growth in quantity, size and comforts of the domestic sector).

Results in Figure 11 are ported directly from LEAP, in order to emphasize the framework's powerful graphing capabilities. The left graph is exported by a sub-scenario of extended DSM that assumes no increase in the number of urban households, in order to compare the DSM results annually, in terms of energy intensity; the right graph depicts just how successfully the extended DSM practice balances the forecasted increase of household activity.

Figure 11: LEAP's exported results. Extended DSM applied in constant and increasing household activity for the Chania Prefecture



In contrary to the commercial sector, where the requirements increased by over 300% in the BAU scenario, the domestic sector appears self-restrained, featuring increases of just 77%. This is caused primarily by the huge saving potential that the domestic sector offers, which together with the expected technological improvements balances the awkwardness in implementation of DSM due to the lack of motivation. Conclusively, DSM restrains growth even more to a mere 44%.

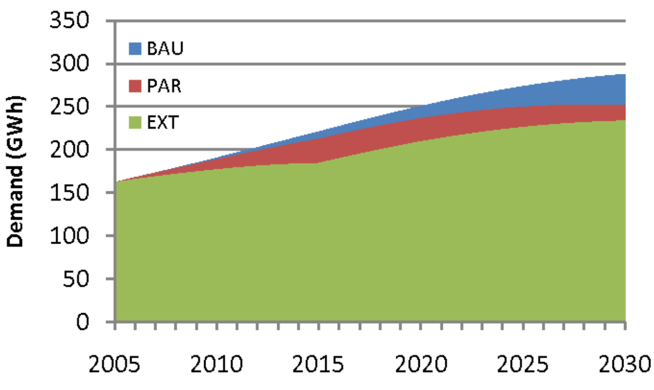


Figure 12: Aggregated demand forecasts for permanent households in Chania on each scenario

3.7 Industry

Industrial GDP and annual energy demands on each Prefecture provide us with energy intensities, using the inverted final energy analysis procedure that was previously described.

It appears that Heraklion industry is the most energy demanding (0,16 kWh/€ of GDP produced) in contradiction with Lassithi which consumes only 0,07 kWh/€ of GDP produced. These energy intensity values are exposed for statistic purposes only, such as to point out where DSM policies should be applied primarily.

Table 16: Calculating energy intensities based on statistic data for industrial activity

Prefecture	2005 GDP per Prefecture (M€)	Fraction on regional industrial GDP (%)	Calculated Specific energy intensity (kWh/€ of GDP)	DSM Specific energy intensity (kWh/€ of GDP)	Total Annual Energy Demands (MWh)
Heraklion	818	49,0%	0,16	0,12	134.358
Lassithi	180	10,8%	0,07	0,05	12.165
Rethimnon	249	14,9%	0,13	0,10	32.621
Chania	421	25,2%	0,11	0,09	47.941
Crete	**1668**	**13,1%**			**227.085**
		fraction on total GDP			

Industrial consumers are usually medium voltage customers which are offered discounted charges for low load factors and very low night tariffs. By these means, DSM is being conducted internally through the industry's logistic optimization for maximum profit. Potential for substantial energy savings in industries may be found in terms of Power Factor Correction (PFC), a technique of counteracting the undesirable effects of electric loads that create an overall power factor that is less than 1,0 (19). When an electric load has a power lower than 1,0, the apparent power delivered to the load is greater than the real power that the load consumes. Although this extra power is not actually consumed, it causes an increase in current though the transmission lines, which increases total losses.

Power factor correction equipment may be installed by individual electrical customers to reduce the costs charged to them by their electricity supplier. This is normally achieved by the addition of capacitors to the electrical network which compensate for the reactive power demand of the inductive load and thus reduce the burden on the supply. Simultaneously, PFC helps reducing overall system demands it the industrial sector by reducing the corresponding losses.

It is though impossible to determine real gains of PFC practice, which is considered some sort of DSM. For example, even if we assumed that the average industry has a power factor of 0,85, that is increased through PFC in 0,95 and we could specify the reduction in the grid's current since most industries use medium voltage (20kV) converters, we still could not specify energy savings due to loss reduction, as network characteristics regarding medium voltage transmission lines are unknown.

Therefore, in order to fill our DSM scenarios, partial and extended DSM, we assume general targets of 5% and 10% savings respectively until 2030, in terms of energy intensity.

3.8 Public authorities

Public authorities comprise mainly of buildings with offices, corridors and conference halls, which mainly demand lighting, air conditioning and electronic device operation (computers, printers etc.) loads. Public hospitals also consume large amounts of electricity for medical devices, aggregated in the "other use" category. The summary of electric needs per category of use, which resembles to that of the commercial sector, is presented on Table 17.

Table 17: Public services sector demands per category of use for the year 2005

Prefecture	Lighting demands (MWh)	Air-Conditioning demands (MWh)	Electronic Devices (MWh)	Other use (MWh)	2005 Public GDP per Prefecture (M€)	Total annual demands (MWh)
Heraklion	17.871	31.274	17.871	22.339	949	**89.354**
Lassithi	4.318	7.556	4.318	5.397	229	**21.588**
Rethimnon	5.069	8.871	5.069	6.337	269	**25.346**
Chania	11.252	19.691	11.252	14.065	597	**56.260**
Crete	**38.510**	**67.392**	**38.510**	**48.137**	**2.044**	**192.548**

The DSM options to be considered in our scenario-building are identical to those analyzed in the commercial sector in Paragraph 3.5. The main demarcation is that applying these measures should be considered easier in public authorities, if drastic, non bureaucratic regulations were applied by energy regulating authorities such as the Regional Energy Authority of Crete.

3.9 Street lighting

According to calculations based on the annual consumptions per Prefecture, a total of 70 thousand street lighting devices operate during the nights, from which 37% are sited in Heraklion, 27% in Chania, 24% in Lassithi and the remaining 12% in Rethimnon. The average device found in the region's streets uses Low Pressure Sodium (LPS) vapor technology. LPS lamps amps are the most efficient electrically powered light source, offering an efficiency of up to 200Lumens/Watt.

Table 18: Energy intensities in street lighting for each scenario

			Business as usual		Partial & Extended DSM Scenario	
Energy intensity (kWh/device)		**Current Accounts**	**2015**	**2030**	**2015**	**2030**
Existing	578	100%	70%	50%	50%	0%
Efficient	405	0%	30%	50%	50%	100%
Average (kWh/device)		**578**	**526**	**491**	**491**	**405**

Electronic communicating ballasts are dimming the lamps intelligently when less light level is required (middle of the night in industrial and commercial zones for instance). Moreover they consume 4 to 5Watts while usual magnetic ballast consume up to 20Watts. Moreover, such electronic ballast can usually identify failures in the lamp, on the electrical network and in the supply cabinet and communicate them through standardized protocols. Use of this type of ballasts may reduce electric demands by over 40% (20).

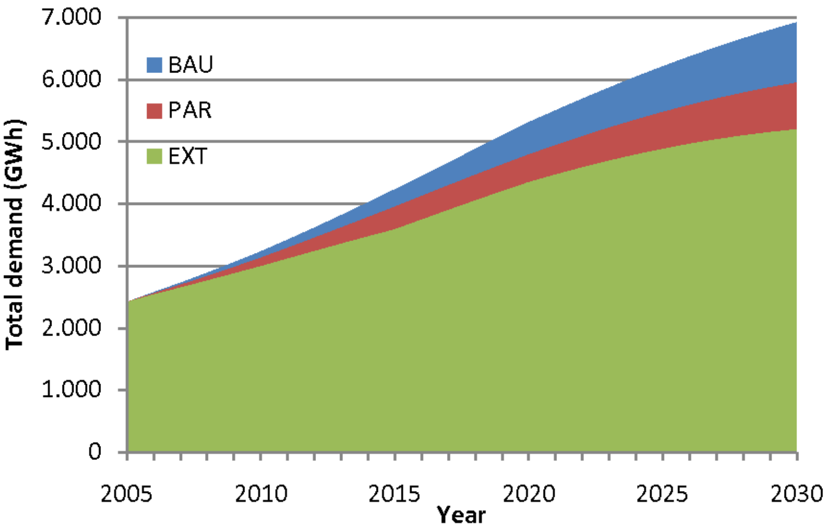
In extended DSM, the set target will be the integration of electronic ballasts on all existing devices until 2030, offering savings of 40%. In partial DSM, the 2030 target will be half the savings, as of 20%.

3.10 Results

LEAP's framework provides the possibility to export a range of custom results and graphs by analyzing demands on each scenario for the six main activity sectors. It is therefore easy to predict the cumulative benefits of our DSM policy, in comparison to the business as usual scenario, for the whole island of Crete, or individually for every Prefecture, category of use etc.

The following figure will sum up benefits in terms of electric energy savings for the entire island. In further chapters we will also analyze financial and environmental benefits which derive from these energy saving policies.

Figure 13: Crete's total demand evolution as calculated by LEAP



It appears that end-year demands are significantly lower than the logistic projection forecasted in Paragraph 1.2, Figure 4. According to LEAP's output, if no DSM practice is applied, demands will reach 6.900GWh which is 30% lower than logistically forecasted. This is justified by the inevitable introduction of energy saving technologies in the BAU scenario, which will happen due to the emphasis on efficiency given from researchers and manufacturers worldwide.

Demand side management restrains growths even further; only 5.100GWh will be consumed in 2030 according to the extended DSM scenario which will save an extra 27% of energy annually and a total of 21.000GWh until 2030, which counts for 8,5 years of system demands in present terms.

4 Analyzing the system's current transmission and generation structure

4.1 Transmission network in Crete

The transmission network of Crete is constructed by 150kV single and double circuit high voltage lines as well as 66kV medium-high voltage lines. The power is distributed into the medium voltage (20kV) grid by fifteen 150/20 kV substations.

High voltage grid is presented in Figure 14. It appears that the 600km of vigh voltage grid are efficiently covering the island's major cities and power plants, but still, most of the touristic and demanding areas, especially is Southern Chania, rely solely on the medium voltage lines.

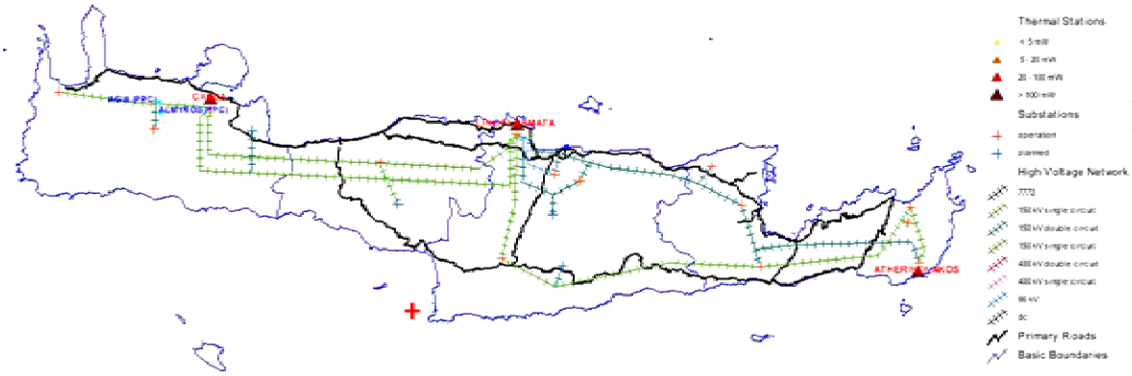


Figure 14: Crete's electric network structure, including high voltage transmission lines (21)

Crete's long and complicated medium voltage network is the main cause for high losses experienced in the island's system. Medium and low voltage cause losses equal to the 7,4% of the island's net energy production, while high voltage and substations only dissipate 1,7%. It is clear that a more sophisticated design of the system would save thousands of MWh annually.

Table 19: Electric losses in the island's system

	Total Energy (MWh)	Fraction of losses (%)
Net Energy Production	2.748.867	
Production Self-Consumption	95.352	3,47%
Net Energy Demands	2.653.515	
H.V. transmission and S.S. losses	47.373	1,72%
Distribution Total	2.615.573	
Distribution Losses	203.116	7,39%
Final Consumed Energy	2.412.457	

4.2 Existing main units

The major proportion of the electricity demand in Crete is currently fulfilled by fossil fuel based generators. A total of 26 units comprise PPC's conventional electrical generation system. Those 26 power units are shared between the three main power stations of the island.

The first and oldest power station is located at Linoperamata, 7 km west from the city of Heraklion. The Linoperamata station comprises of 14 units:

- Six residual oil-fired steam turbines, with a total installed capacity of 111,2MW
- Four internal combustion units, running on residual oil, with a total installed capacity of 49,2MW
- Five gas turbine units, which consume diesel oil, whose total capacity reaches 123,8MW

The second power station is located in Ksylokamara, 3 km from the centre of Chania. The station is mostly equipped with gas turbines which run exclusively on high quality diesel oil and is the first PPC station to gain an ISO 14000 certificate:

- Six gas turbine units with a total installed capacity of 221,6MW
- One combine cycle unit consisting of a steam turbine and two gas turbines with a total combined capacity of 133,4 MW

The third and most recent power station is located in Atherinolakkos, in the Lassithi prefecture and comprises of:

- Two identical two-stroke diesel combustion units, which run on residual oil, and contribute to a total capacity of 102 MW

Regarding the merit order of the above units, technologies are dispatched according to their efficiency, and therefore production costs.

In Crete the first units to enter the system are the steam turbines and the Combined Cycle (CC) at their technical minimums. This occurs as a result of the huge latency in the start up of a steam thermal unit. Once a steam turbine starts, it should be kept in its technical minimum in order to be able to output even more power when required.

As a result, steam turbines operate in very high capacity factors (i.e. 70% for the Linoperamata steam turbines). The reason that the capacity factor is not 100% is that because they always work at their technical minimum, but do not always reach their nominal maximum, since other, easy to dispatch processes, offer lower operating costs.

Table 20: Available power units in the island's system during the year 2005

Power Production Units	Capacity (MW)	Gross Production (MWh)
Steam Turbine & CC Units		
Linoperamata Steam (6 units)	111,2	685.323,7
Chania CC (3 units)	133,4	477.370,0
Total	111,2	685.323,7
Diesel Units		
Linoperamata (4 units)	49,2	260.357,0
Atherinolakkos (2 units)	102,0	649.334,7
Total	151,2	909.691,8
Gas Turbine Units		
Linoperamata (5 units)	123,8	111.929,6
Ksylokamara (6 units)	221,6	296.140,8
Total	478,8	408.070,4
Renewables Production		
Small Hydro-electric	0,6	832,0
Wind Parks	105,9	267.579,7
Photovoltaics	0,4	270,0
Total	106,5	268.411,7
Overall Total	847,7	2.748.867,5

Hence, the second technology to be dispatched in Crete's system are the two stroke diesel engines, which offer even lower consumptions and require lower quality fuel (especially compared to the Chania CC). Such examples of low cost applications are the two identical units in Atherinolakkos, which burn residual fuel oil costing only 0,052€/kWh, compared to the 0,071€/kWh of the Linoperamata steam turbines (4). This also justifies the high capacity factors in which diesel engines operate (more than 70%).

The ultimate units, which are to dispatch only in peak load conditions, are the gas turbines. Gas turbines only combust high quality fuel (diesel oil or natural gas) and output high flue gas temperatures, resulting in average thermal efficiencies and high production costs. For example, fuel cost in the gas Chania gas turbines surpasses 0,18€/kWh, which is more than twice as high as the consumer rates.

4.3 Wind energy

The majority of existing wind parks in Crete can be found in Lassithi, the Eastern prefecture of the region of Crete. Lassithi boasts numerous locations that experience average wind speeds exceeding 10 m/s. Other locations where wind speeds surpass 10m/s are shown in red in the following map (22).

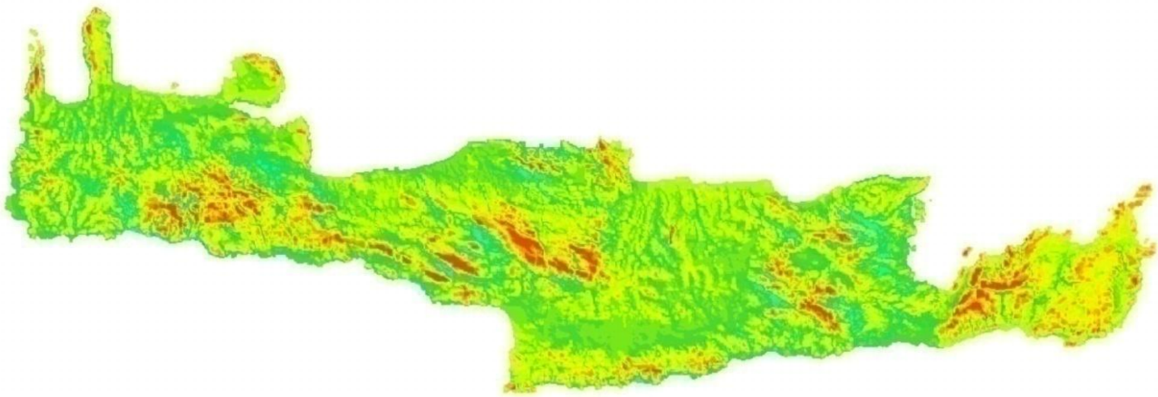


Figure 15: Wind map of Crete

PPC S.A. invested in five wind parks before 2000 in Itanos Municipality, Lassithi, with a total capacity of 16,8MW. Since the electricity market release with the law 2773/99, Regulatory Authority for Energy (RAE) operates as the ultimate independent energy administrative authority (23). In any case of new energy producing facility, RAE investigates the system's requirements for increase in capacity, as well as possibility for higher RES penetration, and licenses the investors accordingly.

After the market release, independent producers (according to the law 2244/94) have been licensed for an extra 195,5MW of wind capacity (24), from which only 89,1 MW are already functioning, together with the early ones belonging to PPC, accumulating a total of 105MW.

RAE's intentions in order to meet the EU 2010 target are met by the following policy measures (25):

- Realization of the licensed extra 106,5 MW, and in case of dropped projects, authorization of new wind farms to match up the licensed capacity (26)
- Denegation of new applications for the prefecture of Lassithi, allowing only wind turbine additions in existing parks
- High level of wind park efficiencies ensured by strict licensing evaluation procedures based only on validated wind potential for the exact site
- Careful spatial planning by scattering of installments in order to reduce rejected electricity due to similar meteorological conditions in minimum load periods

The following figure shows an overview of the wind power status in Crete. It clearly depicts RAE's intentions to promote investments in the rest of Crete, as Lassithi appears oversaturated on wind power.

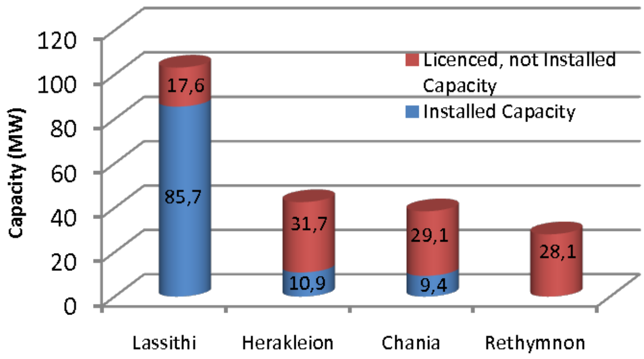


Figure 16: Operating and future wind power units

Further addition of wind turbines after the 2010 milestone will be modeled through LEAP's framework for each demand scenario separately, according to the increase in requirements. Technical difficulties will be explained and solutions for increased penetration will be proposed in the following paragraphs.

4.4 Other existing RES in Crete

4.4.1 Small hydro

According to the recent law 3468/06 for RES, a hydroelectric power plant (HEP) is classified as a small one, when its nominal power is less than 15MWe. This classification is not simply a matter of scale, as a Small HEP (SHEP) differentiates itself from a HEP in a significant number of characteristics, which simplify its construction and operation. The main difference between the two is that a HEP is designed to meet peak loads and is designed for large nominal power and the existence of a large water reservoir. On the contrary, a SHEP is designed to be cost effective in terms of installation and to operate on its natural - maximum load factor. SHEPs operate without the use of a large reservoir and thus do not affect natural environment.

In Crete, only two SHEPs operate in Almyros and Aghia, both constructed and owned by PPC S.A. Capacity and historical production data are summarized in Table 20. The reported average capacity factor for the two plants is 15,8%.

4.4.2 Photovoltaic

Very few photovoltaic installments (under 500kWp in total) were realized from independent producers under the law 2244/94, which unfortunately promoted selling of the produced energy to PPC at a very low price. Together with those private achievements, PPC constructed its own small demo stations in Sfakia and Gavdos which failed to reach their expected production due to bad technical implementation and insufficient maintenance. In any case, current photovoltaic share is dramatically low compared to the island's potential, as will be described in the following chapters.

4.5 Unit dispatch schedule

As mentioned in Paragraph 4.2 base load units should be kept in their technical minimum in order to operate efficiently all year round. Steam turbines in Linoperamata have a technical minimum in 47% of the units' rated power, while the Chania combined cycle operates in a minimum of 36% (27).

Further dispatch occurs by ascending production cost, simultaneously taking into account the load undertaking rate ability and the switching-on required time interval of the units.

SHEP, PV and Wind power must be absorbed in priority, directly after the base load units' minimum output. PV and SHEP are disregarded in present condition, since their contribution to the annual load duration curve is minimal. On the other hand, wind turbines contribute noticeably (9,7% of the annual demands). Unfortunately, the random nature of wind power raises the need for even more units to lye in standby, i.e. some of the diesel units in their technical minimum, which is in the 20% of their nominal power.

As load increases, reaching the annual average load (330MW in 2005), both steam turbines and diesel units operate in adequate capacity to satisfy the demands. Finally, gas turbines involve when demand peaks during summer months and major holidays.

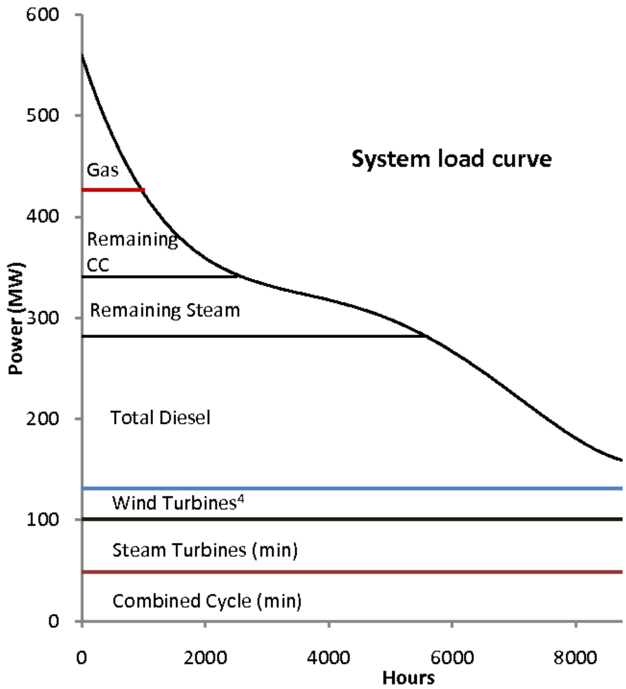


Figure 17: System annual duration curve – present situation

System annual load duration curve, the most representing figure for a system's load shape, energy mixture and process priority is described in Figure 17. Wind input in the graph is based on the reduced wind capacity factor due to excess electricity rejection during low demand periods. Thus, for this instance, wind turbine nominal capacity value is multiplied by its capacity factor and considered as a permanently operating unit, contributing on the base load demands of the system.

Although not depicted in the duration curve, a fraction of diesel engines also operate in their technical minimum for the previously described reasons. Their contribution varies in correlation with power demands. For example, in low consumption hours 7.000 - 8.760, where wind output may suddently cease, only one unit may be required in standby; on the other hand, in medium-high demand hours (i.e. 1500-3000 hours) all diesel units must be in standby. In any case, actual wind penetration of the system will be examined in the following chapters.

The remaining capacity of 211MW comprises the system's 37% reserve margin. This reserve margin for Crete's autonomous system is considered ideal, as just over 30% is sufficient for maximum stability and security.

[4] Wind turbines fragment does not represent actual capacity

4.6 Fuel mixture and emissions

An important indicator for the environmental aggravation of the island's ecosystem is the fuel resource mixture of the produced electricity. 57% of the totally produced energy comes from residual oil used in diesel and steam turbine units. Another 33% is produced by the "cleaner" diesel oil combusted in the gas turbines as well as combined cycle units. Finally, only 10,1% of the total energy is produced by RES, from which the majority (9,7%) originates from wind.

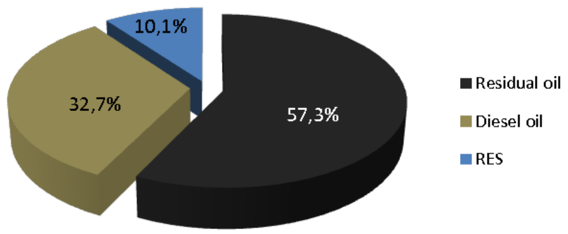


Figure 18: Fuel contribution into energy production

Fuel consumption varies though different units, even between those using the same fuel and pollution control techniques, as it the final value is determined by the specific unit's efficiency. In order to calculate actual emissions from each technology and specify RES implementation savings, we will have to rely on the effects caused by each fuel in terms of gas emissions per unit of thermal value consumed divided by the corresponding unit efficiency. SO_2 and NO_x values also take into account the emission control technologies that the plants are equipped with.

In average, residual oil, which is exclusively used in "base load" units, contributes similarly to diesel in CO_2 emissions, as seen in Table 21. On the opposite, diesel is proven cleaner in terms of SO_2 and NO_x, pollutants which mainly affect local environment and public health. This is the reason for which PPC S.A. is forced to discontinue the operation of the Linoperamata power station in Heraklion in the near future. On the contrary, the Chania station that is actually *in* the city, retains its ISO 14000 certificate for clean, emission controlled operation.

Table 21: Average emissions for the main pollutants in units of kg per TOE of energy consumed[5]

Fuel	CO_2 emissions (kg/TOE)	SO_2 emissions (kg/TOE)	NO_x emissions (kg/TOE)
Residual fuel oil	3.204,58	41,8 / 8,0[6]	7,1
Diesel oil	3.037,52	6,0	2,1

Given the demand growth forecasted by the model's calculations for each scenario and their corresponding emissions, the set target is to minimize those emissions by maximizing the RES contribution in the aforementioned resource mixture. With the help of our accounting framework modeling software (LEAP) and RES screening modules (RETscreen suite), we will be monitoring CO_2 and NO_x avoided emissions which will be estimated and presented for each RES technology, as well as the whole implementation scheme, in the following chapters.

[5] CO_2 values obtained from LEAP's Technology and Environmental Database; other values obtained from (5)
[6] Refers to low-sulfur residual fuel oil used in the near-city units

5 Migrating into cleaner energy sources and higher RES penetration

5.1 Energy policy development

This study will follow the national RES guidelines set by the Ministry of Development and RAE; the enthralling incentives given by the development law (3299/04) and RES law (3468/06) will ensure hard competition between private investors, resulting in even more mature and consistent implementations.

Additionally, we will also monitor the upcoming transition of PPC's conventional plants into cleaner energy resources such as Liquefied Natural Gas (LNG) and even more efficient technologies (i.e. advanced combined cycle units).

Finally, Pumped Storage Units (PSUs) will be proposed in a separate scenario in order to achieve an even higher wind penetration margin in the island's system and also increase its reserve margin. A summary of the main targets of the adopted energy policy in terms of power generation in this study follows.

- Direct increase (giving priority to RES) of production capacity in order to satisfy the additional energy demands in the following years
- Ensuring an adequate reserve margin, capable of dealing with suddenly increased peak loads, while simultaneously minimizing the recurring use of the reserve units (gas turbines)
- Installation of the new conventional power stations in locations that require minimum interventions to the existing high voltage grid, in order to avoid further losses and scenery aesthetic distortion
- Decentralizing the system by adding RES units in scattered locations, preferably near consumption areas, therefore reducing transmission losses and adding to local development in a sustainable way
- Full exploitation of the available natural resources in a profitable and environment-caring way; key resources for Crete which can be directly used through mature technologies are considered wind, solar, hydro and biomass

5.2 Expansion and alternative fuels for controllable resource units

5.2.1 Methodology approach

In the following subparagraphs we will be examining the evolution in Crete's thermal plants according to PPC and RAE targets, data which will be imported in LEAP's electricity generation process tree. New technologies and power stations will be inserted as exogenous capacity additions, while power upgrades through expanded units in existing stations will be inserted as endogenous additions. Endogenous additions will be deployed automatically by the model whenever it is considered necessary to increase capacity reserve margin.

LEAP also offers the option to mix feedstock fuels or replace one fuel with another during the unit's lifespan; using timestep expressions, we will be able to emulate transitions to LNG for each process according to our forecasts and assumptions. Importing LNG in Crete aims to eliminate SO_2, NO_x and flying ashes which deteriorate nearby environment. Still, unlike RES, in terms of thermal pollution and CO_2 emissions, LNG does not offer any important advantages over fuel oil.

5.2.2 The Atherinolakkos station

As planned in the unified generation license issued by RAE, another 93MW of gas turbines capacity remains to be added in the Atherinolakkos station; according to PPC S.A. plans, these units are expected to initiate operation in 2008 (23).

The license for a proposed 180MW combined cycle unit, which will cover a significant part of the island's base load, has been delayed due to harsh opposition from public opinion and environmental organizations against further aggravation of the local ecosystem. The plant is expected to operate at best after 2010, and is expected to offer high efficiencies, although low quality fuel is set to be used.

Migration to LNG is temporarily out of the question for the Atherinolakkos power station. It would be safe to consider LNG adaptation after 2020, since priority will be given to the near-city stations of Chania and Linoperamata.

5.2.3 The Linoperamata station

PPC intends to transfer all the existing gas turbine units to the upcoming Corakies station. Gas turbines will keep operating in order to cover peak loads using diesel oil, until the expected modifications to host LNG occur after 2012. The newest gas turbine was installed in 2003 (capacity 27,95MW) and PPC intends to keep replacing old units and adding new ones according to the indefinite emergency demand coverage license acquired by RAE, until the Corakies station finally starts operating.

Fortunately for the local environment, heavy oil-burning steam turbines and diesel engines will be discontinued by the estimated end of their lifecycle, as more efficient combined cycle units of even higher capacity will be operating in the upcoming Corakies and Atherinolakkos stations.

5.2.4 The Chania station

There are no plans for retirement of existing units and reduction of capacity on the Chania thermal station. On the opposite, PPC intends to replace units at the end of their lifespan and possibly add new gas and CC units to cope with increased demands, according to the aforementioned indefinite license.

Evolution of the plant is bound to persist at least until 2010, when the 300MW Corakies station is expected to be launched. Chania will adopt LNG quite possibly concurrently with Linoperamata, namely 2015.

5.2.5 The Corakies upcoming station

During the previous decade, the erection of a new thermal power station that would replace the degrading Linoperamata plant was heavily discussed. The Corakies location (in between Rethimnon and Heraklion) was finally selected as it combines some key advantages such as:

- It lies very close to the existing high voltage grid and therefore new network development is not required

- It is sited very close to the large consumption area of Heraklion city, compared to other proposed locations
- There is no direct visual contact with populated or touristic areas, although the archeological area of Pera Galini is relatively close

The area requires suffers from difficulties in the construction of the docking station due to steep depths, however, it is expected that the station will be completed and operating by 2010. This new station will boast a capacity of at least 350MW, which will comprise of combined cycle and gas turbine units.

In terms of fuel use, it is expected that the units will be using LNG, which is not expected to be imported earlier than 2010 due to the difficulties in the installation of an LNG terminal station in the island. Until LNG becomes available, Corakies units will operate with low-sulfur residual fuel oil.

5.2.6 LNG terminal facility

The long-awaited alternative to the use of fuel oil for power generation on the island of Crete, LNG, has been discussed for years as the ultimate importable resource that would solve the environmental burdening problem. A basic parameter of the LNG project's technical feasibility is the selection of an appropriate area for the installation of a liquefied natural gas terminal. For safety purposes, these installations should comply with several distance criteria from inhabited areas, as well as several other requirements concerning the vessel's mooring, etc (28). The location of the LNG terminal on the island of Crete also affects the cost of the entire project, since, among others, it determines the course and size of LNG transfer pipes.

DEPA, the public natural gas company of Greece prepared a site location study back in 1997, along with the aid of M.W. Kellogg Ltd. and the Development Organizations of Western and Eastern Crete (29). According to the feasibility studies that DEPA carried out the installation of the liquefied natural gas terminal at Corakies location to be the most economic amongst other proposed locations, since it lies closer to the existing PPC stations which will be the main consumers of LNG, as well as in the same location with the upcoming PPC Corakies plant.

A more recent study conducted by RAE and Advantica Ltd in 2004, proposes a complete implementation solution that would include LNG storage in 160.000m^3 tanks and transportation though ships which would not require a docking bay. The solution would provide up to 900 million m^3 of LNG annually, satisfying a total 900MW of installed capacity in combined-cycle based operation (30).

In terms of project viability, the same study reports that direct adaptation of LNG would be 15% cheaper in terms of overall running costs, at 78€/MWh produced from LNG versus 91,5€/MWh from fuel oil, in current (2006) prices. The same study characterizes the government and PPC co-decision to license the station operation temporarily in fuel oil absurd and unacceptable. The verdict is fair, since by those means, LNG adaptation may be postponed for long, as adequate capacity reserve will exist.

Summarizing the above, we will set 2012 as an optimistic yet achievable target for LNG adoption. In the following three years, the constructed pipelines are expected to supply LNG to Chania and Heraklion, and required modifications in equipment will allow all units to operate on LNG. Finally, after 2020, it is possible that Atherinolakkos will also be fueled by LNG.

5.3 Wind power, evolution

5.3.1 Feasibility and economic evaluation

The useful and intuitively designed RETscreen wind module will conduct our feasibility analysis on new wind energy applications in the island. For consistent start, we should specify two main parameters that will demarcate our investment review. At first, we should consider a minimum wind speed of 8,5m/s, as RAE does not license projects in locations that fall below this set target; a second, ultimate design parameter is the park's minimum capacity factor, which should be set according to RAE's minimal licensed level of 27,5%. As will be analyzed in the following paragraphs, there are several means of increasing the capacity factor, yet evaluation should only consider a worst case scenario in order to provide secure output.

Picture 4: Wind Park in Aghios Nikolaos, Lassithi

In fact, as will be proven in the module's sensitivity analysis overview, these two parameters are some of the most crucial in terms of IRR and year-to-positive indications. Fixed prices for production credit and credit escalation rate will be used as granted for autonomous systems by law 3468/06, while the funding scheme will follow track of the revised law 3299/04 with 50% subsidies and 25% debt ratio.

A wide-selling wind turbine featuring a healthy power curve to match the island's requirements of low speed cut-in and generous under-frequency tolerance was selected (Figure 19). Costs for a complete turnkey wind park, including wind turbine foundation and erection, road construction, transmission line, substation, control and Operation and Maintenance (O&M) building and transportation costs were calculated at 1400€/KW for mid-range installments in the 5-10MW scale.

Rejected electricity has been specified as 25% miscellaneous losses in the system characteristics field based on (31). System O&M costs are set at 0,025€ per KWh produced by the wind turbines, while incomes are calculated based on fixed price of 0,0846€ per KWh delivered to the system. Finally, production credit escalation rate has been set to 2,5% annually (80% of national inflation) and debt interest rate into 6,5% for 10 years as limited by the development law.

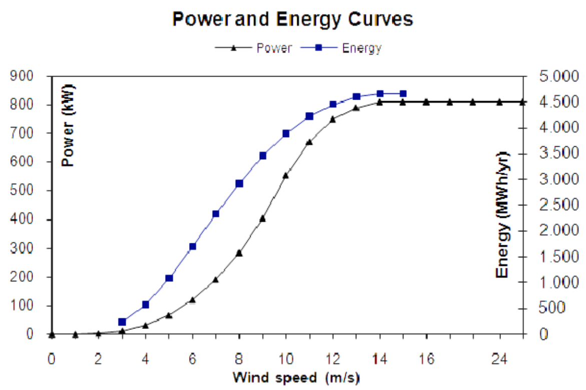


Figure 19: Wind turbine power and energy curves

Financial summary model output unveiled surprisingly rewarding results; Pre tax IRR of 21,0% and year-to-positive cash flow in 5,2 years can only be characterized as prosperous given that a worse-case scenario was considered. It is therefore certain that many, even more fruitful implementations will be achieved if [a] wind speeds surpass 9m/s, [b] much cheaper equipment is acquired, [c] O&M costs are shrinked down to optimal and most importantly [d] smaller amounts of electricity are rejected.

5.3.2 Wind penetration potential

Up until present times, no other RES except from wind energy has been noticeably applied to the Greek islands. This is the reason why the renewables penetration task has been treated for years solely regarding wind penetration. Prospects given by law 3468/06 for the exploitation of more RES, such as solar, render essential a differentiated approach for each technology, which will ensure maximum stability and will build strong GHG mitigation fundamentals.

Up to now, the implementation of more than 100MW of wind projects in Crete and licensing of another 100MW aroused several obstacles that have resulted in system saturation. An interesting controversy lies between PPC managers and environmentalists. Some of the former reckon that only controllable energy sources are network safe, while RES are equal to system instability; the latter oversimplify all technical difficulties in RES integration arguing for immediate migration to higher penetration margins.

The truth lies somewhere in between; it is very important to comprehend that not all RES are as unpredictable as wind. In fact, from all RES, only wind and wave sources (the latter will not be studied in the present work) are highly fluctuating and may cause system stability threats. For wind in specific, the amount of energy produced by a wind park may change suddenly as [a] wind's nature is very intermittent and even more importantly [b] wind speeds often surpass the turbine's maximum speed limits and result to sudden power cut offs.

Regulations on the determination of wind penetration potential in non-connected, autonomous islands are based on the following basic admissions:

- Technical minima of the incorporated conventional production units must never be breached; this measure ensures that no excess electricity resolving from polluting fossil fuels is produced.
- Total wind capacity must not exceed a certain fraction of the total controllable production units' capacity; this is limited to 30% for Crete in order to preserve the capability of compensating through conventional units for the frequency fluctuations due to sheer variations in wind power output.

From an environmental point of view, the set limit might be considered conservative, as results show that wind contribution in the annual energy mixture are still low, but studies carried out by RAE (32) show that limitations are rather reasonable.

The main argument behind limiting a system's hourly wind fraction is that frequency drops beyond safety limits when numerous wind turbines in a wind park, which operates on its apex, cut off concurrently. This drop in frequency, which sometimes is impossible to counterbalance fast enough if gas turbines are inoperative, often results in triggering frequency relays on all other operating wind turbines in near locations, resulting in partial or total system failure. From the above is concluded that the higher the wind participation in the hourly average energy mixture, the more sensitive the system gets. This tends to be solved from a new generation of turbines which offer lower frequency cut off relays, but still it is impossible to interfere with existing installments to solve this aspect of the problem.

In order to ensure quality of produced electricity with respect to conventional units' technical minima, contracts between PPC and independent wind power producers are limiting as of maximum hourly penetration of wind power to the system's demand. The contract limits total wind output to the 30% of the operating units' nominal capacity in hourly basis, giving PPC the authority of discarding excess wind power. As expected, the higher the wind penetration gets, the more electricity gets rejected during low consumption periods as is confirmed by recent studies (31), resulting in lower annual productions, hence incomes.

In order to preserve viability of existing and upcoming applications, a minimum overall wind capacity factor has been set at 27,5%, according to RAE (32). In 2005, Crete's wind production achieved a disappointing capacity factor of 28,8% which is set to decrease even below the set limits as licensed projects are brought to life. RAE intends to license future wind parks judging by the system's "viable capacity"; this indicator is set as the fraction of the island's average load that, if implemented though new wind parks, will result in the minimal capacity factor of 27,5%. For the moment, the anticipated applications will drop the overall capacity factor below the limit, and the system is bound to remain "saturated".


Picture 5: Wind Park in Sitia, Lassithi

It is therefore rendered clear that only an increase in the current overall capacity factor may allow further wind exploitation, as [a] the capacity factor is directly related to excess production and conventional units' technical minima which should be respected by regulation and [b] reduced profitability will drive back private capital motivation and slow down development speeds.

A simple tactic for increasing penetration is scattering wind parks between different locations in all of Crete's territories. Except from decreasing transmission losses and frequency drops, this decentralization approach utilizes the wide differentiation of wind conditions throughout the island, resulting in a more uniform allocation of wind output. Most of wind parks due for implementation within 2007 and 2008 are set in different, unexploited locations, away from Lassithi, as RAE licensed only expansions in existing parks for the specific prefecture (26). Analytical modeling could show if the new wind applications, especially in Chania and Rethimnon, will be able to keep the overall capacity factor in current levels or decrease it even further, but still, scattering of wind production *is* the desirable approach.

A second, more aggressive tactic is storage of the excess electricity through the means of Pumped Storage Units (PSU). A PSU operates by storing and producing electricity to supply high peak demands by moving water between reservoirs at different elevations. At low electrical demand periods, excess production capacity is used to pump water into the higher reservoir. When the demand peaks, water is released back into the lower reservoir through a turbine, generating electricity. Abandoned pits could be used as the lower reservoir, as the height difference between the two natural bodies of water are useable. Taking into account evaporation and conversion losses, approximately 80% of the electrical energy consumed for pumping the water into the elevated reservoir can be regained (33). The pumped storage technique is considered the most cost-effective means of storing large amounts of electrical energy on an operating basis, but high capital costs and the difficulties in reservation of a morphologically appropriate area are critical decisive factors.

Specific case studies for the system of Crete conducted by NTUA and PPC S.A. (34) have shown that the addition of a pumped storage unit that equals the island's wind capacity can drive to safe penetration of wind capacity to an hourly fraction of 36.4%, whereas current limit of 30% without a PSU is considered critical for the system's stability. The study concludes that even higher penetration margins would be possible with the adaptation of such storage possibilities.

According to a study conducted by NTUA and Regional Energy Agency of Crete (5), two sites were rated as appropriate for PSU installations. The first is located at Linoperamata, near the main thermal station of Heraklion, where the dump at Almyros spring is sited and the second is in Kourna, Rethimnon where the existing reservoir of water could be used as the lower reservoir of the final PSU plant. Some other sites in Crete are also studied, mainly from wind energy companies, which intend to install them in order to be able to increase wind penetration margins in the island. Determination of size, cost and economic viability of the plant are mainly depending on the location and the hydraulic head between the two reservoirs; the technical difficulties in finding and obtaining this location is the cause of delays in its implementation.

Pumped storage will be examined in LEAP as a separate, PSU scenario, allowing for higher wind penetration in terms of installed capacity and simultaneously, overall capacity factor increase due to excess energy utilization.

5.4 Solar power, revolution

5.4.1 Feasibility and economic evaluation

Similarly to the wind energy feasibility sturdy, RETscreen PV module will be conducting analysis on possible photovoltaic installments set to rapidly change the island's energy outlook. "Revolution" refers to the generous 100MWp proclaimed until 2010, 49 of which will be licensed within 2007. In fact, incentives for small (20kWp) and medium (100kWp) applications given by law 3468/06, combined with development law subsidies have already turned photovoltaic investments very popular indeed.

Crete offers excellent solar dynamic throughout its territory; solar data for the island is acquired by the Photovoltaic Geographical Information System (PVGIS) created by the Institute for Environment and Sustainability of the European Commission's Joint Research Centre (35). The PVGIS database is the only reliable and scientifically consistent means of estimating photovoltaic application efficiency, anywhere within Europe. The model's algorithm estimates beam, diffuse and reflected irradiation on horizontal or inclined surfaces. Its computation also accounts for sky obstruction by local terrain features such as hills or mountains, calculated from the digital elevation model.

Picture 6: Crete's solar map as provided by PVGIS

PVGIS calculates more than 4,8 kWh/m^2/day of average solar irradiation at optimal angle (28°) for the largest part of Crete, which equals to 1.600kWh per kWp of fixed crystalline silicon modules including ambient temperature losses. System losses, which derive from cabling and inverters, have been estimated at 18%. Resulting from calculations, a PV system capacity factor of 15,1% is expected by fixed panel setup at 28°, while optional two-axis tracking systems are capable of increasing it to 19,6%

In terms of scale, a medium range non-tracked PV park will be examined, as investment interest peaks at 100kWp. This is basically caused by three important variables that this specific installed capacity offers: [a] high production credit at 0,50€/KWh, [b] possibility of connecting at low voltage distribution lines and [c] ease of authorization by facilitated licensing procedures. Costs for a complete turnkey PV park of 100kWp, including modules, mounting structures, inverters, land formation and other essentials are estimated around 6.000€/KWp based on current prices. O&M costs will been accounted for, but are minimal compared to the ones for wind turbines.

Financial summary model output, using the same funding scheme seen previously in wind parks, unveiled even more astonishing results. Pre tax IRR of 29,0% and year-to-positive cash flow in 3,4 years are even more intriguing than the corresponding wind indicators. It seems unquestionable that immense interest will be shown by private investors which will be attracted by the profitability and ease of implementation of PV systems; therefore all set targets for solar penetration in the island will be easily accomplished.

5.4.2 Penetration potential

Photovoltaics found their operation in solar energy, which offers two significant advantages in comparison to wind applications:

- Solar energy typically keeps pace with electricity demands; solar stations deliver energy to the grid during medium and high load hours. This allows for the solar output to be directly consumed by nearby end users.
- Solar energy resource, for the greatest part of the year, does not vary distinctly during the day. An island's total solar output is even steadier if photovoltaic stations have been diligently scattered in numerous locations.

Picture 7: Typical, medium scale PV Park

In order to achieve decentralization, law 3468/06 promotes the installation of hundreds of small parks (rated capacity below 150kWp). Production control by output limitations of such units is impossible and is consider unnecessary altogether. This will allow the operation of solar units in their maximum capacity factor, therefore bypassing the utilization parameter when dealing with maximum penetration.

RAE's reports (32) showed that photovoltaic adaptation up to 15% of the average system load interferes minimally with the obtained wind capacity factor, reducing it only by 0,5 – 1%. Therefore it is concluded that such level of photovoltaics integration, which equals the 8,1% of the system's hourly peak, is considered technically safe.

According to the same source, total RES maximum hourly penetration limit should increase up to 35% after the addition of PV units in wind-saturated islands. This policy will ensure that the operating units' technical minima will not be breached on a 99% probability.

For 2007, RAE and the Ministry of Development have proclaimed a total of 49MW on PV licenses, which correspond to the 15% of the estimated year 2006 average loads. RAE intends to keep licensing PV parks accordingly, as system loads increase during following years. According to LEAP's business as usual demand calculations, the adopted policy will give rise to a total capacity of 140MWp up to 2030.

We consider the set target very realistic and it may well be surpassed; although realization of such number of PV installments is bound to face several impediments at least until 2010, solar technologies are destined to become even more affordable and efficient during the next decades. Adding to their value is also the ease of system integration and the island's fantastic solar potential, which offers the highest capacity factors across Europe.

5.5 Small hydro

Unlike solar technologies, law 3468/06 for RES did not provide any additional production credit for hydro produced electricity, yet it simplifies licensing procedures by granting "application exempts" for applications smaller than 40kWe. Unfortunately, given the island's total needs, only considerably sized SHEPs can noticeably contribute to its energy status.

An important number of sites are suitable for exploitation in the scale of 500kWe – 10MWe. In all such places, the SHEPs will operate mainly in the autumn and winter months because during spring and summer months, water is mainly used for irrigation. These potential SHEPs are small in size and require relatively small amount of capital and thus they can possibly be undertaken by local authorities (5). Private investors have shown little interest in the past, possibly due to the low obtainable capacity factors. This is not expected to change drastically, as feasibility investigation is costly compared to the overall project budget, thus investors tend towards wind and solar applications.

For the needs of our model, we will examine a total of 30MWe of SHEPs until 2030. Economic analysis cannot be investigated as obtained capacity factors may vary dramatically between locations and historical hydraulic data for credible locations cannot be obtained.

5.6 Biomass

5.6.1 Technological overview

Biomass burning combined heat and power (CHP) systems could play an important role in global warming mitigation. Among the potentially CO_2 - neutral and less polluting energy alternatives that are being seriously considered for large scale implementation, biomass offers [a] controllable base-load electrical power depending on annual biomass supply, and [b] possibility to be converted into liquid transportation fuels; therefore, it could become a key part of the solution (36). Several plans have been formulated to exploit this renewable potential, suggesting that biomass residues can substitute a large part of conventional fuels. Most of these technologies are mature and can be embodied in the Cretan energy system, contribute in the local - regional development and create new jobs (37).

Exploitation of biomass will be based [a] on the island's major agricultural residues such as olive kernel, citrus fruits and grapes, [b] tree branches and [c] forestry biomass. Accurate resource statistics about the cellulosic agricultural byproducts recovery potential are aggregate, partly because substantial amounts are exploited informally, but also because the method of utilization varies greatly between areas. Application of biomass-to-energy systems has to face various challenges in Crete, especially when combined with remote domestic heating. In order to implement a large scale CHP application, ensuring the uninterrupted resource availability via contracting and finding a strategic location near a populated area is compulsory (36).

Studies regarding the island's endogenous biomass potential have shown that, even with low source retrieval factors of agricultural residues, installments of the 10MWe scale are possible only near agricultural areas such as Heraklio's Messara. Intense exploitation of all sources beyond residues with increased retrieval factors may result up to 60MWe in different locations around Crete (5). We will set this target to be accomplished in 2025; implementation will be concluded in 10MWe steps starting from 2010.

5.6.2 Feasibility and economic evaluation

Regarding the essential feasibility analysis, it would be interesting to specify the marginal average resource price that would ensure an investment IRR of 15%. We would also like to examine household heating from this 10MWe CHP plant in order to specify the marginal heating rates that should be applied to maintain the project's viability and reduce local heating emissions. RETscreen was used to conduct this examination, although this specific approach was rather controversial it terms of model use. Possibility of applying a combined cycle unit exists, in order to increase process heat rates, by using a biomass gasification system (38). In order to simplify simulation, CC will not be examined as heat sufficient recovery will occur through remote heating for an important part of the year (November to April) as seen in Table 22.

Table 22: Annual heating degree-days below 18°C

Month	°C-d <18°C
January	183
February	174
March	158
April	60
May	0
June	0
July	0
August	0
September	0
October	0
November	48
December	143

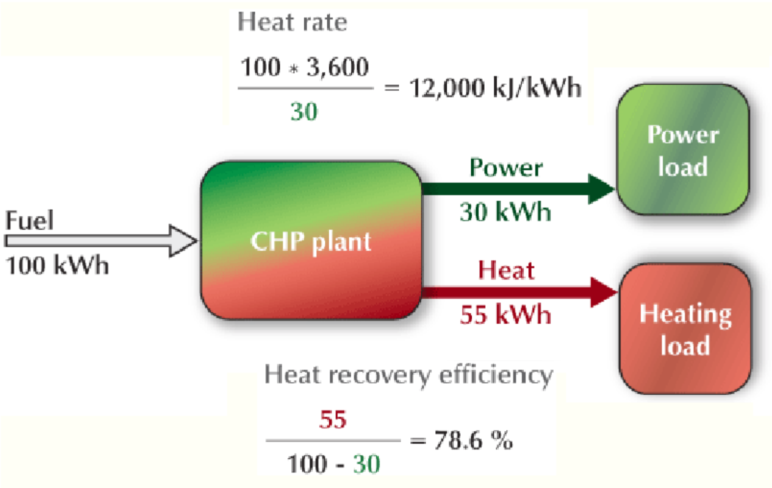


Figure 20: RETscreen's CHP Plant Heat Rate & Heat Recovery Efficiency Calculator

Examined fuel mixture consists of oil industry residues (50%), mixed softwood (30%) and fruit waste (20%). Mixture is to be provided in a homogenized, dried form and to offer a constant thermal value in order to achieve production stability. In order for the plant to operate as a base load unit in maximum power with 95% availability (hence 95% capacity factor), a hefty 77.000 tons of the proposed biomass mixture are required annually, as the system's heat rate hardly surpasses 20%.

The fist target was to specify the average marginal resource price that would ensure project viability; RETscreen's technology database contributed in the calculation of the facility's initial and annual costs, while production credit and funding scheme are following current legislation. It appears that our biomass mixture must be obtained at less than 84€/t. This price should include all collection, transportation, storage and processing costs that may occur.

The second target is to develop a remote heating network that will drive the plant not only to provide CO_2 neutral electricity, but [a] cover the heating needs of a nearby buildings in an economic and sustainable way, [b] increase its profitability by selling remote heating services and [c] recover heat loads produced by the plant (Figure 20), saving even more CO_2 emissions caused by building fossil fuel-based building heating.

Assuming that the biomass plant is set close to a district where households exists, we can modify the steam turbine's steam flow and backpressure values during winter months and in order to acquire high output temperatures. The installation of a remote heating network could be easily applied in densely populated districts where central heating is already available. It could also be combined with further end-use energy saving measures such as better piping insulation etc.

Resulting from Table 22, 765 heating degree-days below 18°C are required for the capital of Crete, Heraklion. Arising from the above, a poorly insulated Cretan household requires 6.653kWh of thermal energy annually to cover its space and water heating demands, corresponding in 660L of diesel oil costing about 400€ in year 2006 prices. If remote heating is considered for 1.000 households and energy saving measures are applied, a net peak heating load of 5MW is required. In order to achieve the required thermal output and retain the 10MW electrical output simultaneously, increase in biomass consumption during the winter months occurs due to increased steam flow requirements, together with the addition of a medium-to-peak load biomass burner.

Marginal heating rates

6 Modeling and implementation results

6.1 Scenario formation on power generation

For reference purposes, we will be examining our RES implementation policy using the load status forecasted on the BAU scenario. A RES scenario will be created, inherited by the BAU scenario, which will allow us to compare implementation results with forecasts that use the current energy mixture.

The RES scenario will apply all RES penetration and LNG adaptation plans described in Chapter 5. The plans are in accordance with European Committee's directives, Greek government's environmental targets, RAE's remote network and national security regulations and moreover, both legislative framework and financial incentives exist for unobstructed and beneficial implementation. Furthermore, the same RES policy will be applied on BAU, refined by adding pumped storage hydroelectricity namely PSU scenario.

Finally, the RES and PSU scenarios will also be applied in extended DSM load status forecasted on the EXT scenario; this will incorporate the most aggressive GHG mitigation course of action that this study has to offer.

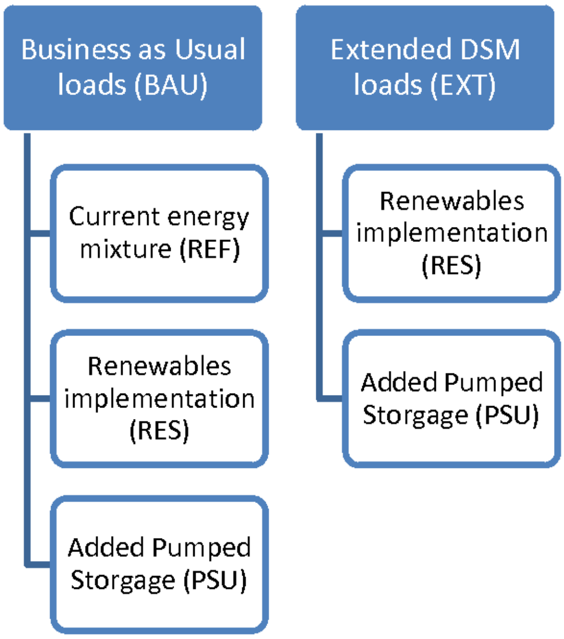


Figure 21: Scenario relationship schematic

6.2 Electricity generation simulation

This paragraph intends to shed light on the methodologies followed to model current and future system behavior in LEAP's transformation branch. Accounting framework modeling offers flexibility in data input, which will be exploited in order to intuitively simulate the island's electricity generation unfolding. All engaged processes and criteria will be in respect of the energy policy development analyzed in Chapter 5.

6.2.1 Endogenous and exogenous capacities

Exogenous capacity values reflect existing capacity as well as planned capacity additions and retirements. New power plants, such as Corakies and new technologies, such as combined cycle in the Atherinolakkos plant, will be set implicitly in a user-defined period. New controllable RES plants, such as biomass CHP, or low-contribution applications such as SHEPs, will also be applied exogenously, as their set capacity could not interfere with system safety limits.

Endogenous capacity values are calculated internally by LEAP in order to maintain a minimum planning reserve margin. Existing thermal plan unit expansions will be set as endogenous potential leaving the model to judge the launch period. RES unit additions will also appear only as endogenously calculated capacity.

6.2.2 Planning reserve margin and capacity credit

It is considered ideal to maintain a high reserve margin in an isolated grid, since designing peak capacity based on hourly load monitoring is insufficient considering instantaneous load variations. A reserve margin of at least 30% ensures power quality during peak load hours.

Capacity credit is the main parameter used for calculating endogenous capacity additions. The capacity value is defined as the fraction of the rated capacity considered firm for the purposes of calculating the system reserve margin (11). For thermal power plants the value is normally 100%. Lower values of 30% are used for intermittent sources such as wind and hydro, reflecting their lower average availability. Photovoltaics, output of which is considered to peak during increased-consumption hours, get an 80% capacity credit.

6.2.3 Dispatch rules and maximum availability

The majority of processes are dispatched hierarchically, according to their merit order. Processes with the lowest value merit order are dispatched first (base load units) and those with the highest merit order are dispatched last (peak load, reserve units). Processes with equal merit order are dispatched together in proportion to their available capacity.

- Steam and combined cycle, as well as the proposed biomass plant operate as base load units and therefore are granted merit order “1”. Implicitly for these units, only their technical minimums have priority over renewables
- All RES production is granted “2”, while PSU hydro gets “3” as it operates on excess renewable electricity
- Diesel units, which offer lower productions costs are ordered “4”
- The “rest” of steam turbines and CC gets a dispatch priority number “5”, due to high fuel costs compared to diesel units
- Finally, peak load gas turbines are granted “6”

Maximum availability is the LEAP expression for describing a process capacity factor. It is the ratio of the maximum energy annually produced to what would have been produced if the process ran at full capacity.

- In the case of RES technologies, maximum availability reflects the overall capacity factor; for example, 28,8% in wind and 15,1% in PV, as mentioned in Paragraphs 5.3.2 and 5.4.1
- In the case of a PSU unit, maximum availability will be estimated by the excess RES power produced annually, in reference to the unit’s capacity
- In the case of the existing thermal plants, maximum availability derives from PPC’s utilization figures, which are dispatched in ascending order of their overall running costs, also taking into account undisclosed system stability parameters
- In the case of upgrades on existing units into burning LNG, the same maximum availability values will be retained, since process efficiencies and therefore relative running costs will remain unchanged
- Finally, in the case of new thermal plants and endogenous additions, full maximum availability rates will be given, since they will incorporate higher efficiencies and emission saving measures

6.2.4 Unit efficiency and fuel mixtures

Unit efficiency is the percentage ratio of energy outputs to feedstock energy inputs in each process. Efficiency data can also be specified as a heat rate - the rate of feedstock fuel required per unit of energy produced. The heat rate is the amount of energy input (in kJ or Btu) from the fuel required to produce 1 kWh of electricity.

For hydro and renewable electricity generation systems 100% efficiency will be used, while for conventional units we will refer to both the RETscreen and LEAP database heat rates in conjunction with the available PPC data. Finally, fuel energy contents are entered in net form (lower heating values).

Table 23: Unit efficiency and fuel energy content

Process	Heat rates (kJ/kWh)	Efficiency (%)
Steam turbines	11.500	31,0
Combined Cycle	7.000	51,5
Diesel	8.000	45,0
Gas turbines	8.500	42,5
RES	~	100,0

Fuel	Energy content
Diesel	8.514 kCal/L
Residual oil	9.766 kCal/kg
LNG	5.015 kCal/L

6.2.5 Generation process overview

Table 24: Electricity generation processes - all variables – RES & PSU scenario

	Efficiency (%)	Exogenous capacity up to 2030 (MW)	Endogenous capacity margin	First simulation year	LNG introduct. year	Merit Order	Maximum Availability (%)	Capacity Credit (%)
COR Gas Turbines	42,5	200,0	300,0	2010	2012	6	50	100
CHA Gas Turbines	42,5	221,6	100,0	2006	2015	6	25	100
LIN Gas Turbines	42,5	123,8	~	2006	2015	6	25	100
COR CC rest	51,5	100,0	300,0	2010	2012	5	95	100
ATH CC rest	51,5	100,0	~	2010	2020	5	90	100
CHA CC rest	51,5	85,4	~	2006	2015	5	90	100
LIN ST rest	30,0	58,9	~	2006	~	5	70	100
ATH Diesel	45,0	102,0	~	2006	2020	4	85	100
LIN Diesel	40,0	49,2	~	2006	~	4	70	100
Pumped Storage	80,0	~	limited[7]	2010	~	3	100	100
Photovoltaics	100,0	0,2	limited[8]	2006	~	2	16	80
Wind Parks	100,0	105,9	limited[7]	2006	~	2	29	30
Small Hydro	100,0	30,0	~	2006	~	2	20	30
Biomass CHP	22,5	60,0	~	2010	~	1	95	100
COR CC min	51,5	80,0	240,0	2010	2012	1	95	100
ATH CC min	51,5	80,0	~	2010	2020	1	95	100
CHA CC min	51,5	48,0	~	2006	2015	1	95	100
LIN ST min	31,0	52,3	~	2006	~	1	95	100

[7] Defined by corresponding wind penetration
[8] Defined by RES penetration limitations

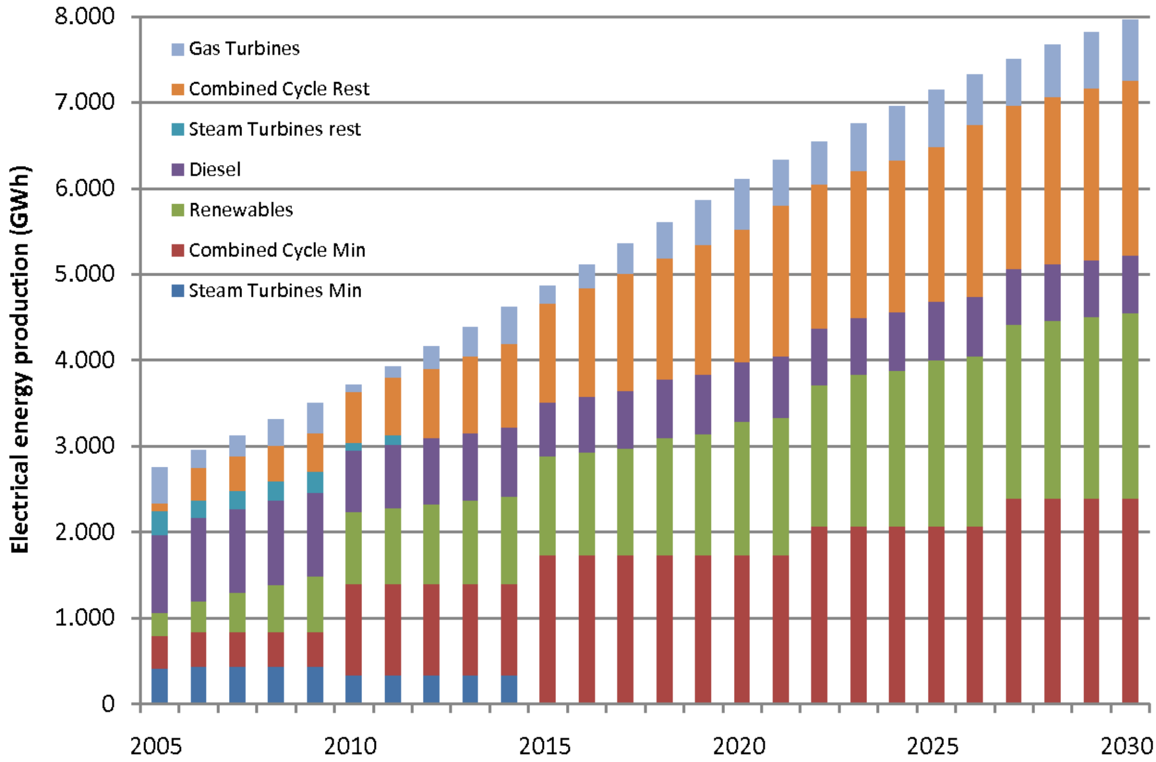


Figure 22: Energy generation annual outputs for the BAU + RES scenario

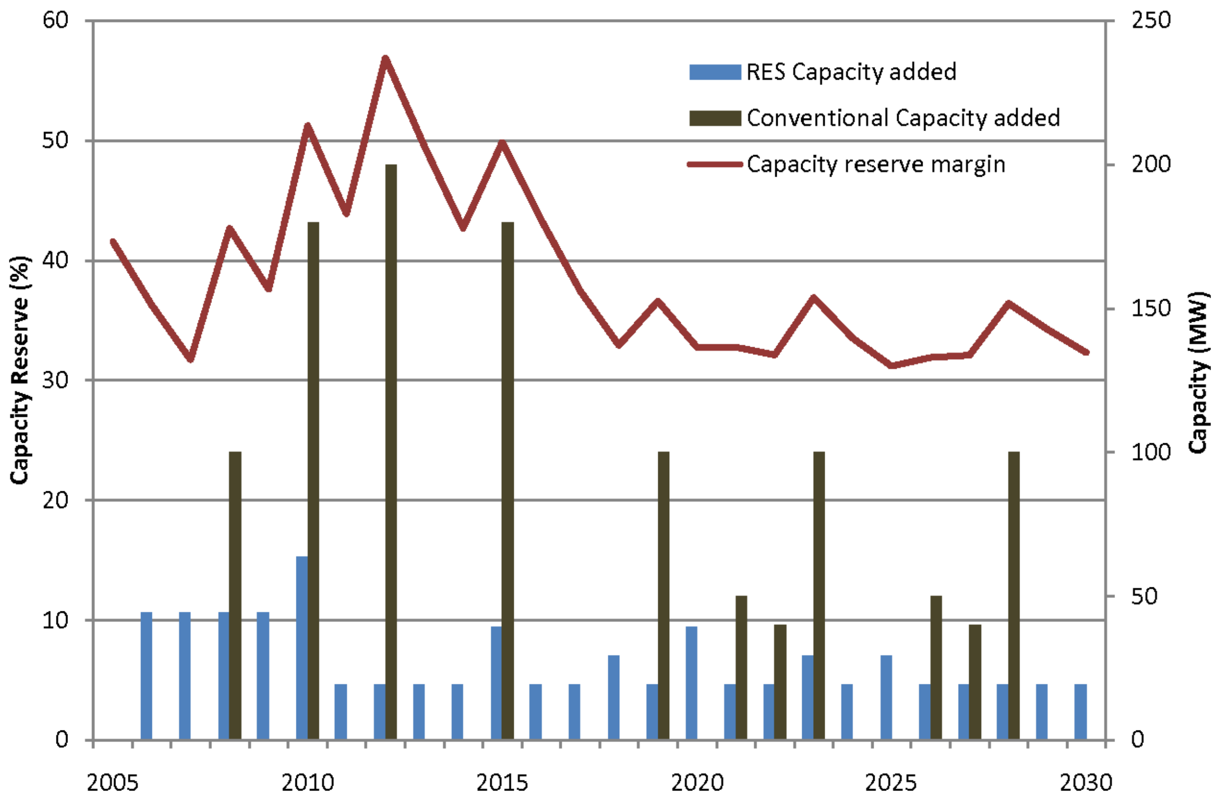


Figure 23: RES and thermal capacity additions and corresponding reserve margin for the BAU + RES scenario

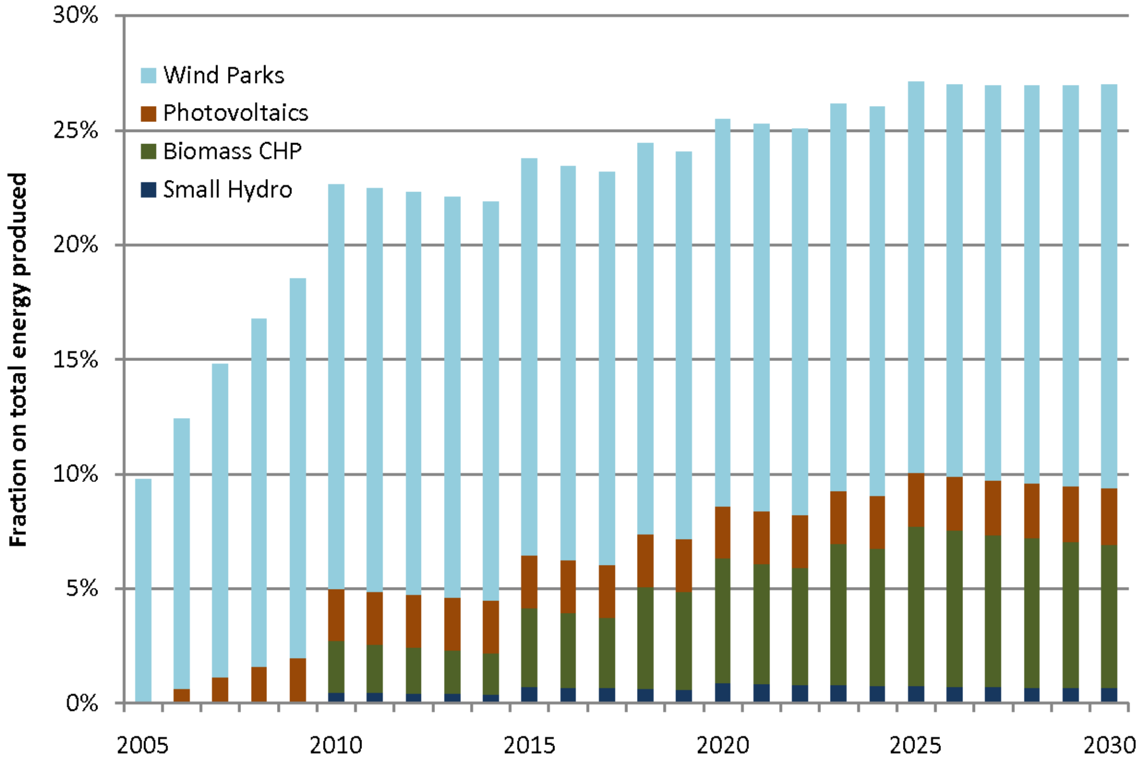


Figure 24: Renewable energy delivered annually for the BAU + RES scenario

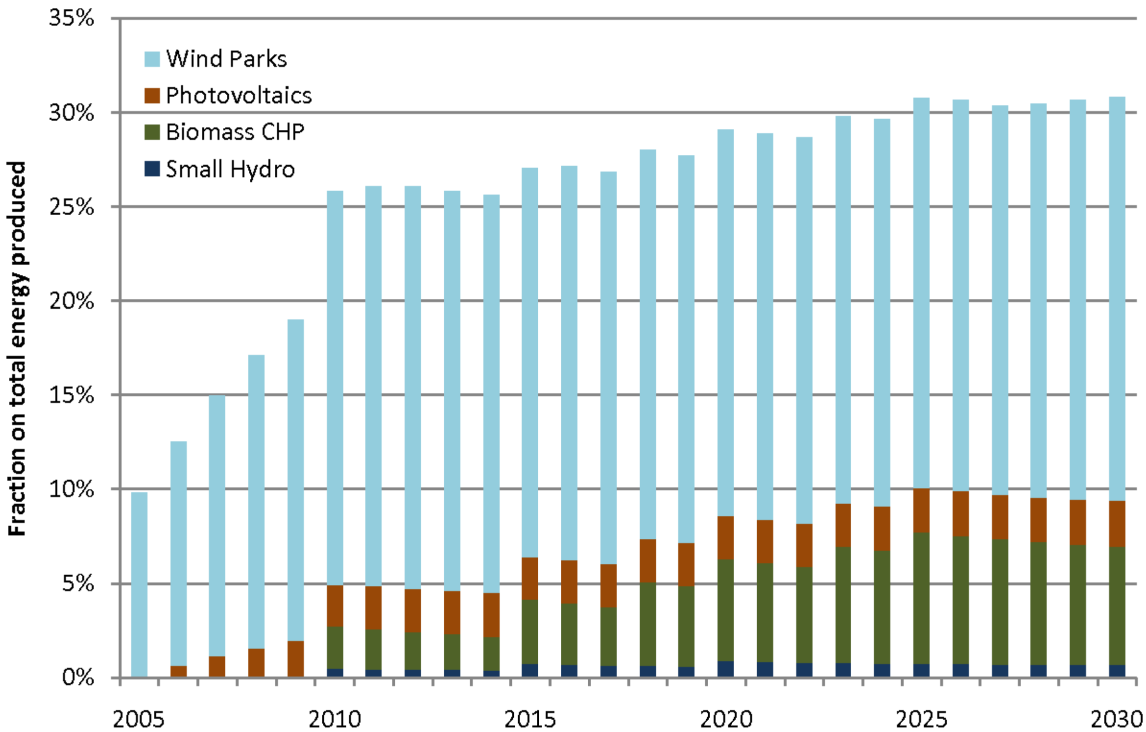


Figure 25: Renewable energy delivered annually for the BAU + PSU scenario

6.3 GHG mitigation results

6.3.1 Fuel consumption

In order to successfully compare between scenarios, we will be screening fuel consumption in terms energy content. Energy contents and composition of the used fuels are represented in Table 25 (39) (40).

Table 25: Fuel energy contents and chemical composition (w/w)

Fuel	Net Energy Content	Energy Units per Physical Unit	Net/Gross Heating Value Ratio	Carbon Content	Sulfur Content	Nitrogen Content	Ash Content
Diesel Oil	8514	Kcal/L	0,95	86,5	0,4	0,59	0
Natural Gas	5015	Kcal/L	0,875	73,4	0,01	0,03	0
Residual Fuel Oil	9766	Kcal/Kg	0,95	84,4	2	1	0,075

Fuel consumptions for the three most representative scenarios are exported in Tons of Oil Equivalent units in Figures 25 to 27. The EXT+PSU scenario is an extended DSM load scenario combined with PSU scenario's generation scheme, created for comparison purposes.

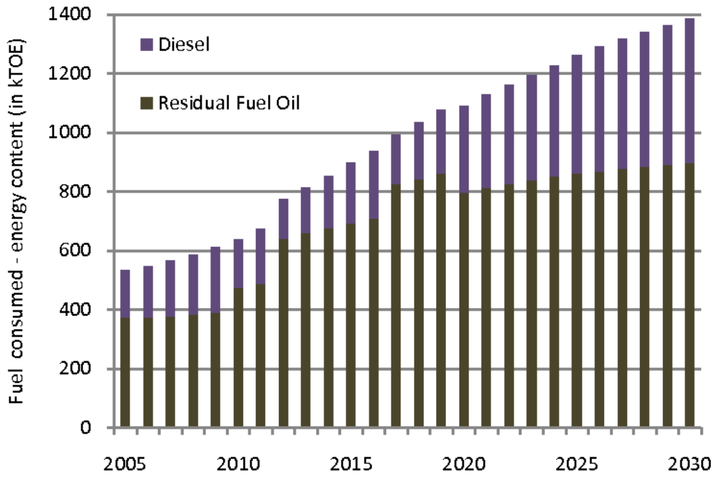


Figure 26: Fuel consumption in terms of energy content – BAU +REF scenario

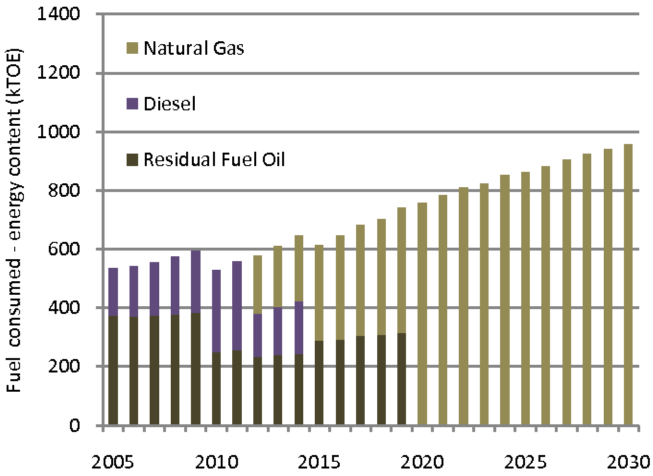


Figure 27: Fuel consumption in terms of energy content – BAU + PSU scenario

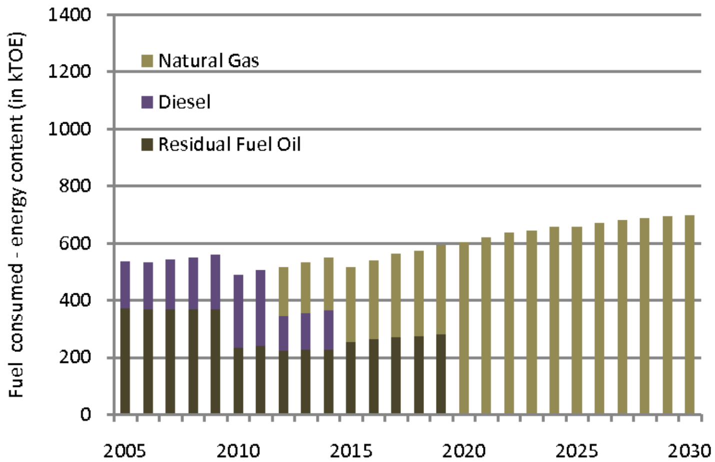


Figure 27: Fuel consumption in terms of energy content – EXT +PSU scenario

Observed drops in fuel consumption for 2010 and 2015 correspond to the implementation of higher efficiency units and discontinuation of the older Linoperamata units. As seen in the provided figures, the applied measures were proven quite drastic in terms of reducing the amount of fuel energy required. Especially in case of the extended DSM and maximum RES penetration (EXT+PSU) scenario, fuel requirements appear to be almost constant up until 2030.

6.3.2 Environmental loading

In an attempt to designate each fuel's contribution to the global warming phenomenon, the GHG emission factor will be used. This aids in calculating the tons of CO_2 – equivalent pollution potential per unit of fuel energy content. For the used fuels, emission factors are presented in Table 26.

Table 26: Fuel global warming potential résumé

Fuel	CO_2 emission factor $kgCO_2/TOE$	CH_4 emission factor[9] $kgCO_{2eq}/TOE$	N_2O emission factor[10] kg_{2eq}/TOE	GHG emission factor tCO_{2eq}/TOE
Natural gas	2066,20	0,152	0,0379	2,081
Diesel Oil	2902,57	0,079	0,0791	2,928
Residual Fuel Oil	3102,66	0,120	0,0797	3,129

According to LEAP's final output, implementing RES and cleaner fuels though the described planning in the RES scenario will save 50% of annual emissions by 2030, cumulatively saving more than 30 million tons of CO_{2eq} during this 24 year period.

Further load shaving actions such as extended DSM, as described in the EXT scenario, combined with maximized RES penetration, as in PSU scenario, results in even higher GHG savings of 66% annually. These correspond to 40 million tons of CO_{2eq} savings from 2006 to 2030.

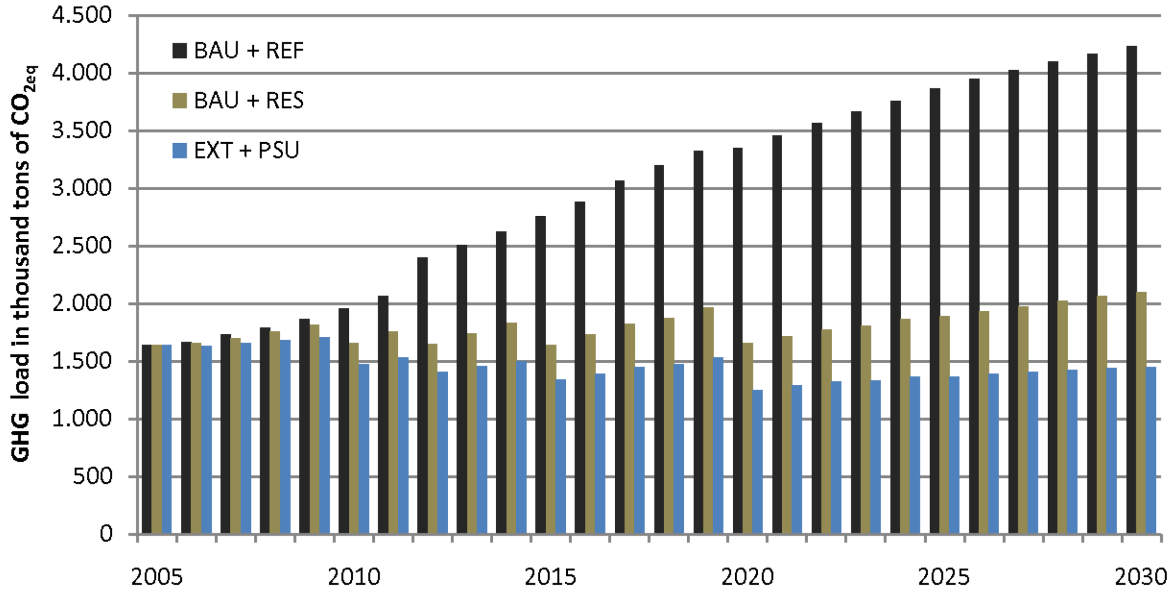


Figure 28: Greenhouse gas emissions summary for every major scenario

[9] 1t of CH_4 equals 21t of CO_2 in global warming potential (IPCC 1996)
[10] 1t of N_2O equals 310t of CO_2 in global warming potential (IPCC 1996)

REFERENCES

1. **General Secretariat Of National Satistical Service Of Greece.** *2001 Population Census.* 2001.

2. —. *2005 Gross Domestic Product Report.* 2006.

3. **Greek Ministry of Economy and Finance.** *Regional Accounts for the 2003-2005 period.* 2006.

4. **Public Power Corporation, Devision of Islands.** *Annual Report fot the island of Crete.* 2005.

5. **Regional Energy Agency of Crete, National Technical University of Athens.** *Renewable Energy Sources in Crete, An Implementation Plan.* 1998.

6. **United Nations Framework Convention on Climate Change.** *Module 5.1 - Mitigation Methods and Tools in the Energy Sector.* 2006.

7. **Heaps, Charlie.** *Integrated Energy-Environment Modeling and LEAP.* s.l. : SEI-Boston and Tellus Institute, 2002.

8. **Natural Resources Canada.** *www.retscreen.net.* [Online] 2007.

9. **General Secretariat Of National Satistical Service Of Greece.** *Electric energy consumption by great geographic area, region and department and by category of use:2005.* 2005.

10. **Centre for Renewable Energy Sources.** *IEA DSM TASK X - Performance Contracting.* s.l. : CRES, 2004.

11. **Stockholm Environment Institute.** *Leap User Guide.* 2000-2006.

12. **Lampropoulou, Eleni.** *Building Lighting and Energy Saving.* s.l. : CRES, 2007.

13. *Managing the Growth of the Demand for Cooling in Urban Areas and Mitigating the Urban Heat Island Effect.* **Carlos Lopes et. al.** s.l. : University of Seville, 2003.

14. **Various.** *Energy Efficiency in Room Air Conditioners.* s.l. : Directorate General for Energy (DGXVII), Commission of the European Communities, 1999.

15. **CRES - Department of Energy Information Systems.** *Collection of Statistical Data on Solar Energy Applications in Greece.* 2001.

16. **(CRES), Centre for Renewable Energy Sources.** www.cres.gr. [Online] 2006.

17. **Intelligent Energy Europe.** http://ec.europa.eu/energy/intelligent/projects/save_en.htm. [Online] 2007.

18. **Lytras, Konstantinos.** *Policy measures for the improvement of energy efficiency in buildings.* s.l. : CRES, 2007.

19. **Tony R. Kuphaldt.** http://www.ibiblio.org/obp/electricCircuits/AC/AC_11.html#xtocid88951. *Lessons in Electric Circuits.* [Online] 2007.

20. Wikipedia - Street light. *http://en.wikipedia.org/wiki/Street_light.* [Online] 2007.

21. **National Information System for Energy.** http://195.251.42.2/website/GIS.htm. [Online] September 2006.

22. **D. Chistakis et. al.** *Wind map of Crete.* 2002.

23. **(RAE), Regulatory Authority for Energy.** www.rae.gr. [Online] 2006.

24. **RAE.** *Archive of RAE's positive assessments on power production license claims.* 2006.

25. **Ministry of Development - Directorate General for Energy.** *3rd National Report regarding the penetration level of Renewable Energy Sources up to the year 2010.* 2005.

26. **RAE.** *Additional authorization for new wind powered units in the island of Crete.* 2003.

27. **Katsaprakis D., Christakis D.** *On the Wind Power Penetration in the Island of Crete.* 2003.

28. *Integrated Resounce Planning for the island of Crete.* **SAVE-DGXVII, Various -.** 1998.

29. **DEPA.** *Conclusions from the 1997 study of DEPA for Natural Gas import in Crete.* 2004.

30. **Pantelis Kapros.** *Long term energy planning for Crete and introduction propostal for LNG.* s.l. : National Technical University of Athens, 2006.

31. **J.K. Kaldelis et al.** *Income loss due to wind energy rejected by the Crete island electrical network - the present situation.* 2003.

32. **RAE.** *Methodology for the verification of RES development margins on saturated networks.* 2007.

33. **Wikipedia.** Pumped-storage hydroelectricity. [Online] 2007.

34. *Secure increase of wind penetration in islands by the use of Pumped Storage Units - the Crete case.* **D.P. Georgiadis et al.** Athens : s.n., 2002.

35. **European Commission's Joint Research Centre, Institute for Environment and Sustainability.** PVGIS: Geographical Assessment of Solar Energy Resource and Photovoltaic Technology. *http://re.jrc.ec.europa.eu/pvgis/.* [Online] 2007.

36. *Energy exploitation of agricultural residues in Crete.* **D. Vamvuka and T.D. Tsoutsos.** 2001.

37. *Potential of Biomass in Greece. Present situation.* **Tsoutsos T., O.S. Umealu and E.G. Koukios.** 1991.

38. *A Small Scale Biomass Fueled Gas Turbine Power Plant.* **C.R. Purvis and J.D. Craig.** Madison, WI USA : BioEnergy '98 - The Eighth Biennial National Bioenergy Conference, October 4-8, 1998.

39. **IEA - International Energy Agency.** [Online] 1999.

40. **Intergovernmental Panel on Climate Change.** *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 3: Reference Manual.* 1996.

Appendix – Notes & Explanations

Chapter 1.1

Primary Households correspond to **Permanent** Households. Permanent households include both urban and rural households used *primarily* (i.e. as main residence) by Crete's *permanent inhabitants*.

Secondary Households correspond to **Seasonal** Households. These are used *occasionally* (i.e. weekends, holidays) from both Crete's permanent inhabitants **and** seasonal inhabitants.

From Chapter 1.1 onward, households are being addressed to as *permanent* and *seasonal*.

Chapter 1.2

In **table 2**, GDP rates for each prefecture, as well as **table 3**, disaggregation/categorization between levels of economic activity (from primary to tertiary sector) were seeded from the website www.economics.gr, which facilitates user access to the Ministry's of Economy and Finance statistic database.

Raw data was referring to year 1994 prices, therefore final values were post-processed in order to match the year 2000 reference standard set implicitly for simulation accuracy purposes.

Chapter 3.5.3

Areas of cultivated land were acquired from the **General Secretariat of National Satistical Service of Greece** website www.statistics.gr.

Chapter 3.5.3

Product labeling is a *dynamic* and *evolving* classification of consumer electronics that aids the consumers into easily choosing the most economic model that their money could buy.

By dynamic and evolving we imply that a product classified today as A or A+ may be classified as C after a couple of years, as technology dramatically *evolves*.

This is the main reason why, labeling policy targets must **not be set** according to the performance ratio of today's "A-labeled" device (i.e. EER), but instead, the average label rate of the total of devices sold annually should be headed closer to the specific year's corresponding (i.e. concurrent) "A-label".

Methodology described in this specific chapter follows the above logic by simply estimating (assuming) the advance of technology in parallel with the proposed labeling policy.

Chapter 3.5.4

In **Table 10** "end year intensities" do not always refer to the simulation end year (2030). Better described as "target year intensities", they vary depending on the ease of measure implementation. Year 2020 is often used as it is commonly encountered in EU directives.

Chapter 3.6.2

Table 11 "Disaggregated domestic sector demands per category of use for the year 2005, based on the described methodology" is based on the methodology described on the *following* chapters 3.6.3 – 3.6.6 and therefore would be best examined *after* studying those specific chapters.

Chapter 3.6.3

In the final paragraph on page 23 "*For seasonal households, a custom parameter which will be named "**intensity factor**" will be applied*", a new term is being introduced.

In the following paragraphs the same term is mentioned as "**seasonal intensity factor**" or "**seasonal factor**" and is always used to *"specify the reduction of energy requirements compared to the average urban household, due to partial inhabitation".*

Chapter 3.6.3

In order to calculate **current and DSM lighting mixtures**, a custom methodology has been formed:

[a] The average household was considered as a 80m^2 building flat apartment, with poor natural lighting potential.

[b] Lighting requirements in *lumens* were calculated, based on the above assumptions and the available literature.

[c] Based on the annual electrical energy consumption per household for lighting demands, in combination with each lamp technology's efficiency (for simplification purposes only incandescent and CFL were considered), the current technology mixture was calculated.

[d] Finally, based on the described DSM methodology, future target technology mixtures were set for 2015 and 2030 as seen in Table 12.

Chapter 3.6.5

In the second paragraph is stated *"According to the results on RETscreen's Bioheat module, for a heating degree-day limit of 18$_o$C, the average household requires 3.725kWh of energy annually, in order to maintain the desired room temperatures and satisfy hot water demands".*

For the calculation of the thermal requirements, two basic assumptions were used in combination with the island's average meteorological data: [a] the average household heated area is considered 80m^2 and [b] the insulation of the average Cretan household is characterized as "poor" (still, quite optimistic assessment) in RETscreen's insulation level ratings scheme.

Chapter 5.5

The 30MWe target for SHEPs is a very optimistic assumption which is set as an attempt to diversify the island's RES production by increasing the hydro contribution in noticeable amounts.

A more realistic estimate for year 2030 is just 6MWe, which would still be considered as success if they could be finally exploited.

Chapter 5.6.1

Similarly to the SHEPs, the biomass potential of 60MWe could be described as overestimated. According to sources from the Regional Energy Agency of Crete, more recent researches on the subject have concluded in a maximum biomass potential of 40MWe.