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風力発電利用によるエネルギー転換パイロット事業調査

報　告　書

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風力発電利用によるエネルギー転換パイロット事業調査

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「共同実施（Joint Implementation）枠組の地球温暖化防止
パイロット・プロジェクとしてのエストニア・
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要約版

１．イントロダクション

国連気候変動枠組条約 （UN Framework Convention on Climate Change）締約国としてエストニアは、協定及び京都議定書によって設定された国際協力に対する責任を果たし、問題を解決しようとし続けてきました。地球温暖化防止は、温室効果ガス削減で最も大きな可能性を持っているエネルギー分野で最も効率的に行われます。1 つの大きなチャンスは、再生可能エネルギー資源の導入促進があります。エストニア共和国では、バイオマスおよび風力エネルギーが、まず一番初めに促進されるべき資源です。本調査で専念した事項は、地球温暖化防止の協力枠組の中で、風力発電の更なる普及の可能性についてであります。

パクリ半島ウインド・ファーム・フィージビリティ・スタディは、環境保護論者、気候に関する専門家、地理学者、電力技師、経済学者およびウインド・ファーム開発者などからなる熱意に満ちたチームによって調査され、エストニア持続可能な開発研究所（Estonian Institute for Sustainable Development）の調整の元で、風力エネルギー利用に関する様々な課題に対して取り組みました。

エストニアの北西部は、同国でも風力発電の実現可能性が最も高い地域のうちの 1 つと見なされています。今回の研究のためのテスト・サイトとしてパルディスキ市が選ばれました。 この地域は、電力技師、再生可能エネルギーの専門家、環境保護論者、自然保護論者、NGO、企業家などに大変興味を持たれています。

研究は、風力発電の可能性について対象地域全体に渡って注意深く調査されるように組織されました。風力タービン及びウインド・ファーム構築の際の様々な制限は環境影響評価の手法によって分析されました。そして、小規模な試験を異なる種類の発電機を仮定して行い、最終目標としてここで得られた知見をもっと大きな領域に対して利用するため、パイロットエリアを選定しました。費用便益計算は、研究の全ての段階において行われました。 オプションで選べる金融モデルは、そのために作られました。このように、一から積み上げていくボトムアップアプローチを用いて、最終的な目標を達成しました。

この後に続く部分は、フィージビリティ・スタディの内容を要約したものです。 多くの地図や図表が、分析の結果を定量的に計るために作成されました。しかしページ数の制約

から、ここではそれらのほんの一部しか掲載していません。数多くの独自の数値結果が得られましたが、これらはエストニアで風力エネルギー導入の一層の促進に役立つ大きな価値を持つでしょう。

２．パクリ（Pakri）半島－初めての大規模なウインド・ファームのためのテスト・サイト

エストニアは、温帯低気圧の活動が活発なバルト海の東部海岸に位置するため、比較的高い年間風速(4-8m/s)が得られる地域です。パクリ半島(40 km^2)は、エストニアの首都タリンから約 50km の位置にあります。半島は、エストニアの北の海岸に沿ったパクリ湾と Lahepera 湾の間にある、石灰質の海台上に位置しています。

パルディスキ（Paldiski）湾及び町に位置する旧ソ連の海軍基地(Soviet Naval Base)、およびそのまわりのパクリ半島は社会的・経済的発展の高い可能性を持っています。この地域の経済発展のための最も重要な要素は、良好な地理的位置、港湾、鉄道網、道路利用による容易なアクセス及び町の機能的なインフラです。長さ 2000m の滑走路がある軍用飛行場が、約 20km の距離に位置する Amari にあります。パクリ半島は、様々な便利な輸送機関によりアクセスが容易です。

パルディスキ港（Paldiski Harbour）は冬でも凍結しません。2 つの港、北部の港（深くすることが可能）および南部の港（Tallinn Port によって所有されており、それほど深くない）は年間約 20%の割合で増加する交通を扱います。より長い期間では、オイルターミナルが検討されています。1999 年以来、(スウェーデン)ストックホルム近郊の Kappelskar との間でフェリーが成功裏に運行しています。パルディスキの北部の港がさらに発展した場合、バルト海に入ることができる船をすべて扱うことが出来ます。

旧ソビエト連邦の海軍基地が町を去った後、経済の多くの重要なセクターは速い開発路線に移りました。現在、次の 10 年間を見据えた一般的な開発計画が存在し、以下に挙げられるものの開発が期待されています：港湾、金属工場、レクリエーションおよび観光事業、自然公園、ロジスティクス・センター、ウインド・ファーム建設。

強風エネルギーの潜在性、良好な地理的位置、既存の輸送ネットワーク、労働力の存在、および地元市当局(地方自治体)の支援は、パクリ半島および近隣の 2 つの島でのウインド・ファーム開発のための最も重要な利点です。

地方自治体-パルディスキ市当局は SEI タリンと協力して「グリーンパルディスキ」（Green Paldiski）というタイトルの、サステイナブル・ディベロプメント・プログラムを始めました。それは風力エネルギーおよびバイオマスの、より広い開発を含む包括的な再生可能エネルギーサブプログラムを目的としています。

発電に利用可能な風力の潜在量

エストニアの風況の一般的な特徴は、大気の循環および大西洋とユーラシア大陸上の季節変動によって決定されます。　しかし、風況に影響を及ぼす本当の重要な要素は、沿岸地域の風を支配する強い影響力をもつバルト海です。冬には、島の上および西部沿岸部の月平均風速は、7〜8.5 m/s に達し、内陸部では 4〜5 m/s に留まります。一番風の弱い夏は、沿岸部で平均風速 4〜6m/s で、エストニアの内陸部では、3〜3.5m/s 以内です。テスト・サイトであるパクリ半島は典型的な海岸で、風況も中から高程度のため、本調査ではエストニアの沿岸部の条件を代表するのに相応しいと考えます。

パクリ半島の地表高 10m における年間平均風速は、木々の生い茂った場所では 3.5-4.5m/s、内陸部の開けた場所では 4.5-5.5m/s、開けた沿岸部では 5-7m/s です。風力タービンのハブ高さ（地表高 80m）では、年間平均風速が 7-8m/s、沿岸部では 7.5-9m/s に達します。

パルディスキ地域での風力タービンの発電電力量の季節による偏りと、季節ごとのエネルギー消費パターンは密接な関係があります。最も高い発電電力量は、消費が最も大きい 10 月から 1 月（毎月の発電電力量は年間発電電力量の 10% 以上）にかけて出現します。最も低い発電電力量は、夏にかけての 5 月から 8 月にかけて出現します（詳細に関しては図 1 を参照）。

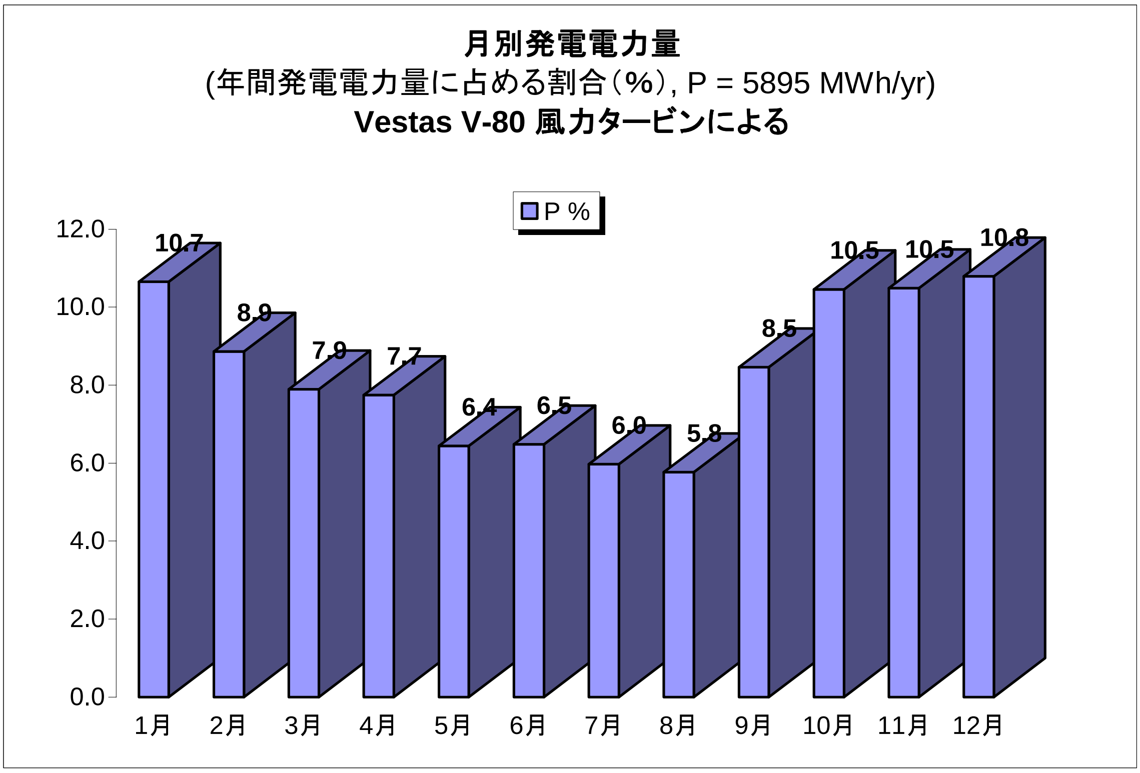

図1　ヴェスタ V-80 2MW 風力タービンによる月別発電電力量 (年間発電電力量 P=5895 MWh/yr　に占める%)。

ウインド・ファームの高いエネルギー効率、および風力タービンの適切な位置を確保するためにも、風力タービン建設可能なサイトを判断する際、環境影響アセスメント（以下 EIA）のほとんどの要素が適用されました。建設に関する制限の中で最も数が多いのは、パクリ景観保護区（崖、木の茂った・海岸の草地）、沿岸保護区およびオフ・ショア海岸保護区（鳥類重要生息地）などの地域です。他のいくつかの制限も考慮に入れる必要があります。騒音防止地区の要求が、地元から出されています。また、セーフティーゾーンが道路と送電線に沿うかたちで必要です。木の茂ったエリアおよび湿地も、ウインド・ファーム設計の際には、風力エネルギーへの負の影響および建設コストの上昇等の理由で制約を受けます。今回の評価では、これらのサイトは不適当なものと考えられています。

風力資源を技術的に可能な限り集中的に使おうと、EIA に基づいて異なる様々なエリアが選定されました。これらの選定されたエリアでは、自然の価値喪失、社会的・経済的混乱・矛盾などは全くありません。パルディスキ地域の風力タービン建設が可能なエリア、つまりパクリ半島および隣接する 2 つの島は、前述の様々な制限にも関わらず、1,134 ヘクタールもあります。ここで、制限がない利用可能な土地をすべて「グリーン電力」（green electricity）を生産する風力タービンの建設のために使用した場合、1.5～2.0MW クラスの風力タービンの最大設置数は 73 に達します（図 2 を参照)。潜在的な風力タービンおよびウインド・ファームの適切な 7 段階による分類は、以下の通りとなっています:

- 12 箇所の単独で風力タービンを用いるエリア、風力タービン合計 12 基
- 2 つの風力タービンを使用する 3 箇所のウインド・ファーム、風力タービン合計 6 基
- 3 つの風力タービンを使用する 1 箇所のウインド・ファーム、風力タービン合計 3 基
- 4 つの風力タービンを使用する 2 個所のウインド・ファーム、風力タービン合計 8 基
- 5 つの風力タービンを使用する 2 個所のウインド・ファーム、風力タービン合計 10 基
- 6 つの風力タービンを使用する 2 箇所のウインド・ファーム、風力タービン合計 12 基
- 7 つ以上の風力タービンを使用する 3 個所のウインド・ファーム、風力タービン合計 22 基

パルディスキ地域における風力タービンの最大数は、各々の定格出力を 1.5～2.5MW とした場合は 73 基です。様々な制限を考えると、最適な定格出力は 2.0MW です。

小さな風力タービン(850kW)を使用した場合、予測された年間発電電力量は、タービンに

よって異なり、半島内部の場合は 1 基当たり 1,750～2,500 MWh/yr、開けた沿岸部の場合は 1 基当たり 3,000 MWh/yr に達します。2MW の風力タービンが使用される場合、利用可能な風力エネルギーは、開けた内陸部では 1 基当たり 5,000 MWh/yr を超え、開けた沿岸部の場合 1 基当たり 6,000-8,000 MWh/yr になります。パルディスキ地区の合計年間発電電力量は、390 GWh にまで達するかもしれません！

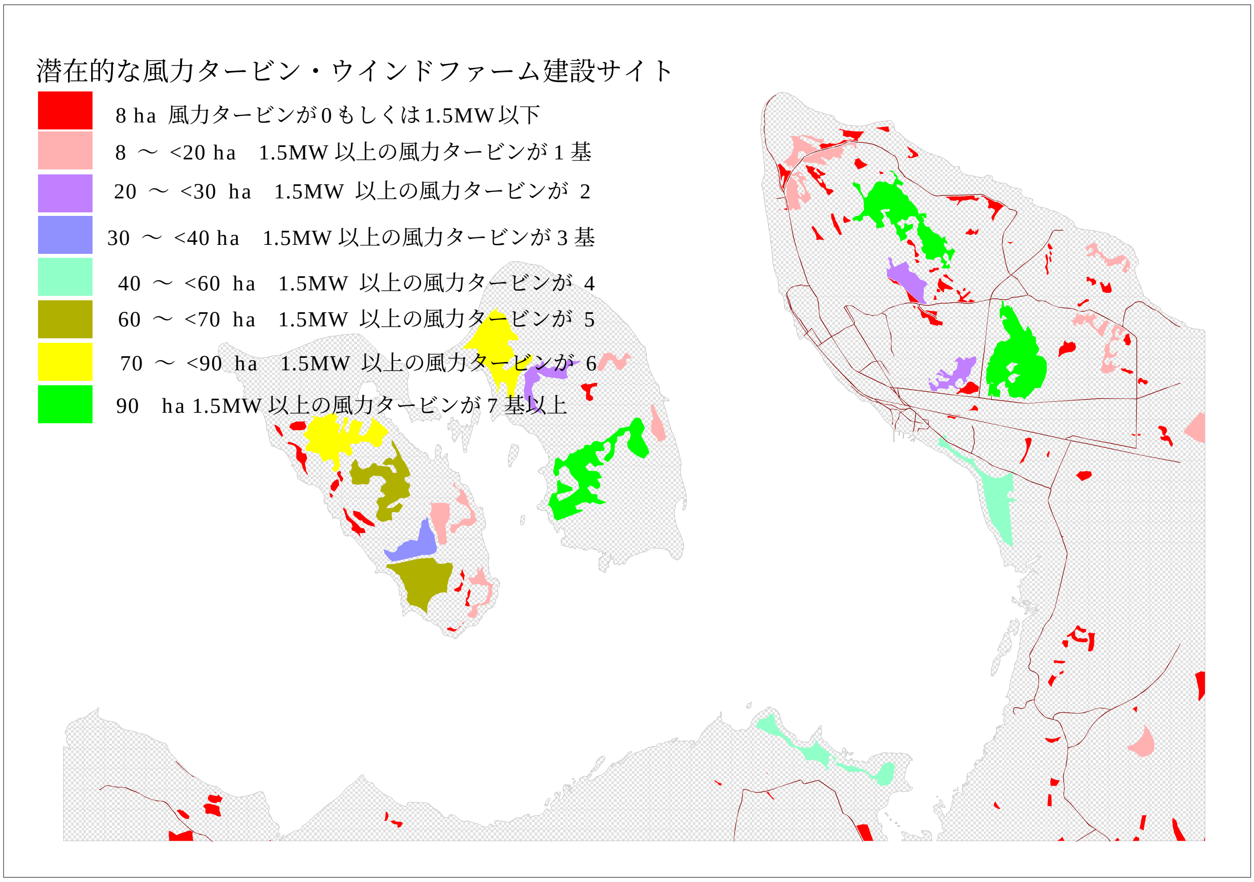

図 2　定格出力 1.5MW を超える風力タービンの最大設置可能数による潜在的なウインド・ファームのサイト。

３．風力タービンに関する技術的な課題

風力タービンの市場が非常に速く成長したのに伴い、技術も著しく発展しました。 例えば、主要な市場に導入されたタービンの平均発電容量は 1993 年には約 300kW でしたが、現在のそれは 1000～1500 kW です。現在の風力タービンは大容量、低騒音、グリッドとの良好な適合性及び長い耐用年数などの最先端技術の技術を兼ね備えています。風力タービンの機能はすべてマイクロプロセッサーベースの制御装置によってモニター・制御されます。 数多くのメーカーは、ソリッド・ステート・エネルギー変換器付きの直結式発電機を提供しています。高調波ひずみ発生が少なく、突入電流が発生せず、無効電力の調整が可能である出力が得られるということは、現代のインバーターが風力タービンをより小容量のグリッドにふさわしくしていることを意味します。また、技術の適用性および経済性も重要な要素です。

今回の調査では、デンマークの主要なメーカーであるヴェスタ社により製造され、実証済みである定格出力 2.0MW のヴェスタ V80 が選定されました。これはアクティブ・ヨー（首振り）システム、ピッチ制御及び 3 枚ブレード（翼）のローターを有するアップウインド（向い風）型で、特別なピッチ制御システムよって、常にブレードの向きを制御できます。

ヴェスタ・コンバータ・システム（Vestas Converter System、以下 VCS）は、タービンから安定して安定して電力を発生させます。VCS は、公称毎分回転数の 60%程度までの範囲で、可変速度運転を可能にします。VCS とピッチ・コントロールを兼ね備えることにより、ギアボックスおよび他の重要なコンポーネントへの負荷の低減、騒音の低減、及びエネルギー最適化を保証します。VCS は、発電機のローター回路中の電流を制御します。これは、無効電力の正確なコントロールを可能にします。ブレードはグラス・ファイバーで強化されたエポキシによって作られています。風力タービンの機能はすべてマイクロプロセッサーに基づいた制御装置によってモニターされコントロールされます。この変圧器を含むコントロールシステムはナセル（機関室）内に置かれます。ブレードのピッチ角変化は、油圧によって行い、95 度回転させることができます。この装置はさらに、ブレーキ装置にも油圧を供給します。ヴェスタはオプションとして、管状のタワーの中にサービスリフトをつけることも出来ます。

オプションで 2 種類の異なるハブ高さを選択でき、3 分割されたモジュールのタワー(67m)、あるいは 4 分割されたモジュールのタワー(78m)があります。ウインド・ファームに風力タービンを設置する際には、相互の間隔は少なくともローター直径の 5 倍の距離(400m)が必要です。風力タービンが主風向に対して垂直一列に設置される場合、風力タービン相互間の距離は少なくともローター直径の 4 倍(～320m)必要です。

風力タービンの基礎を構築するための地盤条件はパクリ半島においては良好です。ほとんどが石灰石であり、地下水の水位が高くない地域がほとんどを占めています。基礎をしっかりとしたものにするために、鋼製の補強材、調整ねじと電線管が必要であることがヴェスタによって予測されています。補強棒は、生産者もしくは適切なライセンスを保持する輸入業者によって運ばれます。

メーカーから立地サイトへのタービン翼、タワーおよび基礎部分の輸送は、国際インコタームズ 2000：DDU-on site（Delivery Duty Unpaid on site）に従って、パルディスキ南港（Paldiski South Port）を経由して行われます。港から立地サイトへの輸送は特別なトレーラーを使用して行われます。道路は、最小でも幅 5m が必要であり、軸荷重は 15 トン以上でなければなりません。カーブ半径の最小値も、47m のブレード用トレーラーに対応していなければなりません。港から立地サイト(～3 km)までは、良好な状態の道があります。風力タービンが建てられる立地サイト内では、道路を建設する必要があります。

パルディスキは、2 系統の 110kV 送電線(双方とも容量が約 70MW)を通じて主要な高電圧用のグリッドに接続されているため、グリッド接続が容易に行えます。32MW の変電所は立地エリア付近にあり、必要なのは 1,000m 足らずの 20kV 送電線です。パイロット・プロジェクトの風力タービンはこの変電所に接続することができます。テスト・サイト全体、つまりパクリ・ウインド・ファームの場合には、新しい 110/20kV 変電所が必要となります。接続グリッドによる年間の送電停止時間は、主要なグリッド所有者との契約によって取り決められます。

風力タービンの設置及び運転開始は、比較的短い期間に行う事が出来ます。組み立て・建設の時だけでなく、調整、試運転、最終的な引渡しに至る期間においても、実際の工事を行うチーム以外にも、高度の経験がある 1 人のスーパーバイザおよび数人の経験を積んだエンジニアが欠かせません。フィンランドのクレーン会社 Pekkaniska 株式会社は、タービン Liebherr 1600 LR/を組み立てるのに適した最大級のクレーンを保有しており、これは 100 トンの物を 130m の高さに持ち上げることが可能です。

運転と維持管理には、オンサイトでのサービス、消耗品の交換、修理、タービンの保険、用地のリース、諸管理業務などが含まれています。メンテナンスはタービンのメーカーに委託するという方法もあります。ギアボックス用オイル、ブレーキやクラッチ等の消耗品は、3 年の固定間隔で交換されます。ヨーシステムの一部特殊な部品は 5 年間隔で交換されます。

４．風力エネルギーに関する法的および制度的課題

エストニアは欧州連合（以下 EU）加盟を果たそうとしており、今後加盟出来る可能性は高いと考えられています。エネルギー分野に関する法令は、EU のそれにほとんど近いものに改定され、EU 加盟国においても適用出来る法令及び原則を採択しました。

4.1　再生可能エネルギーに対するEUのエネルギー政策

EUエネルギー政策の主要な優先事項は、エネルギー供給の安全保障、競争性、そして環境保護です。再生可能エネルギー資源（RES）の利用促進は、一次エネルギー供給に占めるこれらの割合を増加させることを目的としており、上述の全ての政策優先事項（目的）と適合し、同時に持続可能な開発の主な要素の1つです。再生可能エネルギー資源による電力生産の促進に関するEU指令（2001/77/EC）は2001年10月に施行され、共通の戦略および枠組みを作成することを目的としています。この新しい指令では、再生可能エネルギー資源による発電の割合が、EU加盟国の平均で1997年の13.9%から2010年には22.1%まで増加すると予測しています。

4.2　エストニアの状況

エストニアの環境及びエネルギー政策の戦略に関する公文書では、再生可能エネルギー資源のより広い使用が重要性を増している主要な原則として強調されています。しかしながら、今日までの実際の政策はここまで進んでおらず、講じられた立法措置は給電料金（家庭用の基本料金の90%）と購入義務だけです。さらに、これらの措置はどのような再生可能エネルギー資源に基づく発電にも適用でき、その全体量の上限は前年にエストニアにおいて消費された電力量の2%に制限されています。

エストニアのエネルギー関連の法律を再整理することが、政府によって決定されたことは、この調査との関連性があるため述べておくことは重要でしょう。計画によれば、現在のエネルギー法（Energy Act）は、電力市場法（Electricity Market Act）、ガスおよびヒートサプライ法（Gas and Heat Supply Act）、及び液体燃料法（Liquid Fuels Act）　の3つの新しい法律に置き換えられることになります。これらの新しい法律の準備は現在進行中です。従って、電力市場法の起草の過程においては、新しい電力の市場原理及び供給に関する情報（特に再生可能エネルギー資源による発電）が、まだ存在しない状態にあります。議会による法律の採択は2002年の後半になると予想されています。

4.3　主要な障壁

風力を含む再生可能エネルギー資源による電力生産のより広範囲でより広い開発への主な障害のうちの 1 つは、政府の曖昧なエネルギー計画です。この計

画は、主要な国内の化石燃料資源「オイルシェル」の利用を前提としたものであり、EU の新しい計画とは相容れないので、改定する必要があります。さらに、制度に関わる人材能力の問題は国レベルの基本的な障壁の 1 つです。 全ての管理層における制度の強化およびキャパシティー・ビルディングは、地域レベルを視点とした政策の支援によって達成することができるでしょう。

エストニアの風力エネルギーの広範囲な開発への直接的な障害の 1 つは、地域電力市場動向に関する潜在的な投資者の自信不足です。さらに、世界の投資機関に対する地域風力エネルギー開発者の自信不足もあります。風力エネルギー導入には比較的大きな投資が必要であり、したがって国際的な投資機関に関する知識の向上が急務です。しかし、ボンとマラケシュで話し合われた地球温暖化防止に関する政策は、エストニアにおける再生可能エネルギー資源の利用促進を支援するものです。特に、京都議定書の枠組みにおける気候変動枠組条約の附属書Ｉ締約国による共同実施 (Joint Implementation)の方向づけによって、風力発電の更なる導入の可能性が出て来るでしょう。

エストニアの電力分野における現在の構造は、新しい独立電気事業者にとって好都合ではありません。その理由としては、この分野は政府の公営企業（Eesti Energia AS）によって垂直に統合されており、発電・送電・配電・小売り、および輸出をも同時に担当しているからです。電力分野の改革および電力市場の自由化はまだ初期の段階にあります。

4.4 現在の発電及びその価格構成

エストニアにおいて、オイルシェル発電を行う主要な供給者は、電力会社 Eesti Energia AS です（2000 年に占める割合は 91%）。1991-2000 年の期間に、エストニアの電力消費は、ほぼ 1.3 倍の減少、輸出は 5 倍以上落ち込んでいます。国内消費の衰退は、エストニアにおける経済の構造変化と工業生産の落ち込みと関連があります。電力輸出の衰退は、主にロシアへの輸出の落ち込みによってもたらされており、2 番目に大きい輸出先であるラトビアは比較的安定しています。1996 年以来、毎年の発電電力量は約 7,500～8,000 GWh、国内消費は 5,500 GWh の水準で安定しました。1996～2000 年の間は、電力輸出はかなり不安定であり、毎年 400～1,000 GWh の変動がありました。電力需要の予測は、ネットの発電電力量で 2005 年では 7485 から 8,025 GWh の間（現在のレベル）、そして 2010 年には 7945 から 8,785 GWh の間（低い成長）となっています。国内消費の予測は、2005 年において 5,580～5,900 GWh、2010 年では 6,000～6,500 GWh となっています。

現在の電気価格水準（2001 年 1 月 1 日から有効）は、家庭用で 0.76 EEK/kWh（4.87 EUR/100 kWh）、中規模の産業用は 0.73 EEK/kWh（4.65 EUR/100 kWh）です（VAT を除く）。この水準は、特に産業消費者向けについて、例えば高度に発展した近隣の国々（フィンランド、スウェーデン）と比較した場合、比較的高いものであります。

Eesti Energia AS の年次報告のデータによれば、2000 年の Narva 発電所の発電単価（1 kWh のネット発電あたりの発電コスト）は、0.35 EEK/kWh（2.24 EUR/100 kWh）でした。エストニアは近隣の北欧諸国と比較して、環境汚染税の割合が低く、そのために化石燃料が再生可能エネルギーよりも優位な立場にあります。短期的計画によれば、CO_2 を含む汚染賦課金の増加のペースはかなり緩やかです。発電所での原価の中の環境コストは約 0.05 EEK/kWh（0.32 EUR/100 kWh）で、14.3%を占めます。家庭用基本料金では、環境コストが 6.6%を形成します。

オイルシェルによる発電は環境汚染が深刻ですが、政府による汚染賦課金やリソースペイメント（resource payment）を含む環境税システムはまだ初期の段階であり、1991 から始まった経済改革のために負担は低いレベルに設定されています（割合は今後増加する計画です)。オイルシェルによる発電をベースとした電力供給価格において、環境コストの割合を 2010 年までに著しく（約 2 倍）増加させることになるはずです。

オイルシェルによる電力供給価格は、北欧の国々における汚染賦課金が適用された場合、今日（2002 年）においても少なくとも 4.50～5.00 EUR/100kWh でしょう。更に他のいくつかの外部不経済、例えば地表水及び地下水の莫大な消費、土地、森林、泥炭およびそれらに伴う鉱物資源の喪失が考慮された場合、電力供給価格は更に上昇するでしょう。これらは明らかに風力エネルギーによる発電を有利にし、化石燃料による発電を適切な割合で廃止させるでしょう。これは前述のヨーロッパにおける再生可能エネルギー資源利用の拡充の指令とも整合を保っています。

５．パクリ半島ウインド・ファームの費用便益分析

5.1　パクリ半島ウインド・ファームへの投資

風力タービンの価格には、設計、製造、鋼製の基礎部分及び円錐管状形のタワーを備えた標準の風力タービンの供給が含まれています。タービンの価格には、5 回の保守点検訪問を含む 2 年間の保証、およびリモート・コントロール設備が含まれています。全ての価格に輸入税と VAT（付加価値税）が含まれていません。

風力タービン V52-850kW（65m）、V80-2000kW（67m）、V80-2000kW（78m）、S70-1500kW（65m）、および S70-1500kW（85m）を比較した結果、パクリ・ウインド・ファームのための最も適切な風力タービンが V80-2000kW（78m）であることが分かりました。
パクリ・ウインド・ファーム用の風力タービン V80（36 基）の合計金額は、5,700 万ユーロ（以下 EUR）です。

製造場所からパルディスキ（Paldiski）への風力タービン、タワーおよび基礎部分の輸送費は、国際インコタームズ 2000：DDU-on site（ Delivery Duty Unpaid on site）に従って算定されました。
風力タービン V80（36 基）の合計輸送費は 300 万 EUR です。

クライアントによって準備された基礎の上への風力タービンおよびタワーの建設は、サプライヤーによって行われます。建設コストに含まれる費用は、必要とされるクレーン、プロジェクト管理、組み立て・建設の時だけでなく、調整、試運転、最終的な引渡しに至るまでのすべての期間に渡り、資格があり経験に富む 1 人のスーパーバイザと数人のサービス・エンジニアがあります。
風力タービン V80（36 基）の総建設コストは、160 万 EUR です。

風力タービンの、鋼製円錐形タワー用の基礎建設コストには、地質調査、削掘、風力タービンサプライヤーの監督の下で行われるコンクリート・建設工事が含まれています。
V80 用の基礎（36 基分）の総コストは 140 万 EUR です。

風力タービンは既存の道路の付近に位置し、新しい道からは 100～400m の距離です。ウインド・ファーム・タワー1 基につき、8,500 EUR が平均的な道路建設コストです。パクリ・ウインド・ファームの道路建設コストは、約 30 万 EUR です。
用地買収コストは、現時点ではどれくらいの面積が、タービン・道路建設のために必要か明確ではないので、投資コストに含まれていません（ほとんどが国有地です）。グリッド接続および変電所の平均コストは、定格出力 1MW につき 64,000 EUR と試算されています。パイロット・プロジェクトについては、既存の変電所が利用できる場合、このコストがより低くなる可能性があります。パクリ・ウインド・ファームには、新しい 100～200MW の

変電所および新しい 100kV 送電線が必要です。

パクリ・ウインド・ファームのグリッド接続コストは約 460 万 EUR です。
パクリ・ウインド・ファームへの総投資額（Total investment costs、以下 TIN）は約 6,900 万 EUR です。
パルディスキ・パイロット・プロジェクトおよびパクリ・ウインド・ファームにおける（保険を含む）年間維持費は約 9.59 EUR/MWh です。
プロジェクト管理コストは投資額の 2%です。
土地リース代は、パクリ・ウインド・ファームの場合、約 64,000 EUR です。

5.2 風エネルギーベースの電気生産費

風力エネルギー発電のコストは、エストニアのオイルシェル電力価格、電気市場の自由化、およびエストニアの新しい再生可能エネルギー資源政策に依存するかもしれません。政府が利益指向の風力発電に力を入れることを決定した場合、給電価格は少なくとも 90 EEK あるいは 5.75 EUR/100 kWh である必要があります（ドイツでは、このレートが約 6 EUR/100 kWh です)。風力発電のグリッド接続のより高い購入代金は、風力エネルギー発電の成長を加速するでしょうが、同時に消費者の価格も増加させるでしょう。風力発電電力量が、総消費電力量の 10%未満にとどまるなら、消費者の電気価格の値上げは、毎年約 1～2%になるでしょう。別の戦略としては、電力価格及び風力発電コスト最小化する方法があります。この場合、資本の割合はより高く、そして利率はより低い必要があります。

パクリ半島ウインド・ファーム・フィージビリティ・スタディは、20 年の減価償却年数（インフレは考慮されていない）を用いて、3 つの風力エネルギー発電金融モデルを比較しました。3 つのオプションに関する簡潔な結果は以下に示されています。

A. 利益指向のオプション
1/3 TIN（Total Investment）は、毎年 8%の利率の資本（20 年間）;
2/3 TIN は、10 年間で返済の 6%の借入金;
11～20 年目は減価償却率が 8%;
電力給電価格は 5.75 EUR/100 kWh（20 年間)。
利益指向のパクリ・ウインド・ファームにおける風力発電（モデル A）のコストは、最初の 10 年間は 5.12 EUR/100 kWh、次の 10 年間は 4.80 EUR/100 kWh（含原価償却)。

B. 投資補助金付きの利益指向のオプション
1/3 TIN は、利率 0%の資本（国）;
2/3 TIN は、10 年間の 3%の借入金（補助金）;
11-20 年目にかけては 8%の原価償却率:
電力給電価格は 4.48 EUR/100 kWh（20 年間）;
年間の収益は年収の 10%以上。

パクリ・ウインド・ファームにおけるモデル B の発電コストは、最初の 10 年間は 3.85 EUR/100 kWh、次の 10 年間は 3.75 EUR/100 kWh です（含原価償却）。

C. 非営利的な共同出資オプション

100% TIN は共同出資の資本;
電力給電価格は 2.56 EUR/100 kWh（20 年間）。
非営利的な風力エネルギー発電（モデル C）では、毎年の原価償却率が 4%です。原価償却率の合計は、TIN の 80%です。風力タービンの価格が下がってきていること、基礎およびタワーが少なくとも 40 年間風力タービンを保持できることを考えれば、それで十分です。パクリ･ウインド･ファームにおけるモデル C の発電コストは､たったの 2.42 EUR/100 kWh です。

費用対効果が最も高いオプションは C ですが、これは十分な投資力を持った人達の共同出資によってのみ達成できます｡したがってエストニアのより現実的な選択はオプション B であり、これは第 1 に政府が温暖化防止志向の再生可能エネルギー促進プロジェクトを行う、という仮定に基づいています。第 2 の仮定は、京都議定書で予見された地球温暖化防止のための共同実施に向けた国際協力への、国連気候変動枠組条約（UNFCCC）附属書 I 締約国の参加です。好条件の長期貸付金は実際に、このオプションの推進力および財政基盤を構成します。

６．住民参加およびキャパシティー・ビルディング

地域コミュニティーでは、パルディスキ地域の風力エネルギー計画に関する適切な情報が、投資プロジェクトの非常に初期の段階から必要です。適切なキャパシティー・ビルディングが前もって計画された場合、一般大衆、及び特に地域コミュニティーとの大きな争い及び誤解を回避することができます。プロジェクト開発者と地方自治体の間の綿密な連絡も重要です。

パクリ半島ウインド・ファーム・プロジェクトにおいて、住民参加およびキャパシティー・ビルディングを行うねらいとしては、以下のものが考えられます:

- 雇用の増加のような、有望な社会的かつ経済的な変革の促進、エストニア以外の人々の社会への融合、パルディスキ地域コミュニティーにおける課税ベース等の引き上げ;
- ウインド・ファーム・プロジェクトの計画に関して地元住民への情報提供;
- 技術、環境、経済の専門家だけでなく、政府および地方自治体の代表者への適切な情報の供給;
- 風力エネルギーに関する再生可能エネルギー資源の今後の可能性と利用促進を図るために、エストニアの一般大衆の再生可能エネルギー資源に関する知識向上;
- エストニアにおける、エストニアおよび EU エネルギー政策の実施の促進。

パクリ・ウインド・ファーム・プロジェクトに関する住民参加のためのターゲットグループは、風力発電利用にする利害に基づいて決定されます。ターゲットグループは、プロジェクトの中で計画された活動との関係で定義されます。ターゲットグループは以下のように分類できます:

- プロジェクト実施によって直接影響を及ぼされるグループ、つまりパルディスキ地域および関係自治体;
- 企業家、農民、地主、漁師、レクリエーションに来る人々、あるいはパルディスキ地域のビジネスなど、活動によって間接的に影響を受けるグループ。;
- 一般社会の人々、さらにプロジェクト実施エリアの自然と自然保護に関して自らの専門性を活かしたい、自然保護および環境保護の専門家、環境保護活動家（green movement）、エネルギーの専門家、NGO、教師、学生、学術的なスタッフ、ジャーナリストなど。;
- エストニアの一般大衆;
- フィンランド、スウェーデン、他のバルト三国およびロシアなどの近隣諸国の大衆。

パルディスキ町およびパクリ半島の地域コミュニティーの住民は、高い失業率、エストニア社会への併合、地元言語の理解の欠如に起因する問題などがあるとして、社会的に弱いグループとしばしば見なされます。このターゲットグ

ループは、キャパシティー・ビルディングおよび成人教育の視点から特別の注意を必要とします。このエリアの経済開発、例えばパルディスキ湾の拡張、新事業の設立、観光旅行およびレクリエーション事業の開始、ウインド・ファーム、あるいは風力タービン部品の生産の開始、さらに風力タービンの建設に関連する基礎・道路工事などは、ほぼ間違いなく多くの新しい雇用を創出し、地元住民に新しい可能性を与えます。

その他のいくつかのターゲットグループは、開発者との対立に発展してしまうかもしれませんので、特別の注意を必要とします。例えば自然保護論者および環境保護論者が考えられます。これらのグループの焦点には、鳥類重要生息地(Important Bird Areas)および景観保護地があります。初期の計画段階から、これらの様々なレベルのグループ、及び一般大衆への情報公開と住民参加により、最も高いレベルの住民参加「コンセンサス」を、適切な方法により得ることができます。この段階では、プロジェクト管理チーム以外の人々、プロジェクト開発者に彼らの助言および支援を与え、適切な方法の中で意志決定プロセスを支援することができます。

ウインド・パーク・プロジェクトへの望ましい形での住民参加プロセス及びキャパシティー・ビルディングには、異なる数々の方法があります。しかしながら、これらの選択は、ターゲットグループの特徴にも依存するので、人的資源、時間および財的資源についてもウインド・ファーム開発事業の中で先を見通すことが必要です。

７．結論

パクリ半島ウインド・ファーム・フィージビリティ・スタディは、数多くの重要な総合政策的、技術的かつ経済的な特性について結論を明らかにしました。

調査には、ボトム・アップ方法（つまり一から積み上げていくアプローチ）が用いられました。これは、単一の風力タービンに関する分析に始まり、タービン数及び定格出力などにいくつかのオプションを含む小規模なパイロット・プロジェクトを経て、最終的にパクリ半島全体に広げられたウインド・ファームまで扱うことを意味します。しかし、風力発電の可能性については、さらにより広範囲のエリアに対して調査を行いました。今回調査されたのはパルディスキ地域、つまり半島全体とそれに隣接する 2 つの島です。それは、この地域において潜在的に利用可能な、良質な風資源を戦略的アプローチによって有効に活用するために調査されました。しかしながら、今回のフィージビリティ・スタディでは、EIA に基づいて 36 の潜在的なサイトが選択されています。詳細な計算を行うために、定格出力 2.0MW の VESTAS80 風力タービンが選定され、3 つの異なる投資モデル A、B および C が用いられました。

モデル A は、6-8%の年利を用いた利益指向の風力エネルギーへの投資です。モデル B は、低い年利（3%）と、政府及び国際的な支援を受ける、中程度の利益指向投資です。そして最後のモデル C は、借入金・利子の支払いがない風力エネルギーへの共同出資の一つの例です。エストニアの現在の経済状況を最も現実的に反映しているものとして、モデル B が選定されました。モデル B に基づいた計算によれば、パクリ・ウインド・ファームにおける最初の 10 年間の年間コストは 3.75EUR/100kWh、次の 10 年間は 3.85 EUR/100kWh となっています。

本調査は、重要なエネルギー政策的および経済的な結論を明らかにします。それは、風力エネルギーによる発電は、オイルシェルによる発電のコストに、今現在でも匹敵することです。オイルシェルの発電コスト算出に際し、北欧諸国の汚染賦課金が適用された場合、驚くべき結果が得られます。それは、本調査で用いられたモデル B による風力発電のほうが、現在のオイルシェル発電と比較して、より大きなコスト削減が出来るでしょう。これは将来、環境税が政府によって導入されるに伴って、風力エネルギーの競争力が向上することを示しています。再生可能エネルギー資源普及のために行われる政府エネルギー戦略・政策の変更に伴い、競争力は更に向上するでしょう。オイルシェル発電価格について他の多くの外部不経済を適切に内部化した場合、再生可能エネルギー資源と化石燃料の発電原価の比較をすれば、興味深い結果が現われるかもしれません。

調査の結果から、政策一般のあり方についていくつかの提言及び結論が、政府と政策決定者のために作成されました。この報告書の執筆者達は近い将来、エストニアにおける風力エネルギー開発には、以下に示す支援的措置を講じる必要があると合意しました:

- 全国グリッド（送電または配電ネットワーク）へ接続される風力発電電力への固定給電料金の導入;
- 固定給電料金の十分に長い期間の据え置き設置（例えば、風力タービンの設置からの最初の10年間;
- エストニアの電力セクターの改革により垂直に統合された電力市場の独占を防止
- 発電、送電および配電をそれぞれ別の事業に分割

<u>中期的な措置</u>は、以下のものを含むべきです:

- 汚染賦課金の大幅な増加、その中でも特に CO_2 排出に関するもの
- 汚染賦課金の収入の一部を再生可能エネルギーの研究と開発に使用すること（例として、ウインド・ファームの設計、風力資源マップの作成、技術インフラの整備、グリッド接続の補助）

<u>長期的な措置</u>は、以下のものを含むべきです:

- より長期的な時間の尺度で到達すべき目標は、全種類のエネルギー資源のあらゆる種類の外部不経済を内部化すること

今のエストニアでは、化石燃料および再生可能エネルギー資源に基づく発電価格の適切で公平な比較が求められています。エネルギー戦略を EU の新しい戦略の指示に従わせる必要が生じたことにより、風力エネルギーを含む地域の再生可能エネルギー資源の高い可能性に対し、政府はより多くの注意を払うようになるでしょう。これはまた、気候変動枠組条約の附属書 I 締約国として、および地球温暖化防止に協力するために京都議定書を署名した、エストニアの責任としての視点からも重要です。

パルディスキ地域の風力エネルギーによる年間当たりの発電電力量は、国内合計消費電力量のかなりのシェアを占めます。エストニアにおける年間電力消費量が 5,500GWh と仮定すると、今回のテスト・エリアにおける発電量のシェアは、およそ 3.5%に達します。

京都議定書の中で予見された地球温暖化防止および共同実施の視点から見て、削減される年間当たりの CO_2 はおよそ 25～30 万トンに達します。これは地球温暖化防止に寄与するかなりの削減量です。

２．　報告書要約（英文）

Executive Summary of the project " Pakri Peninsula wind farm feasibility study in Estonia as a climate change mitigation pilot project in the frame of Joint Implementation"

Executive Summary

of the project

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Introduction

Estonia as a Party to UN Framework Convention on Climate Change has been successful in following the responsibilities and challenges for international co-operation set by the convention and its' Kyoto Protocol. The climate change mitigation is most efficiently performed in energy sector which has the biggest potential in greenhouse gases mitigation. One of the major opportunities is included in active promotion of renewable energy sources wider introduction. For Estonian Republic biomass and wind energy are the major sources to be promoted in the first order. The present feasibility study is devoted to wind energy potential study with the aim of further implementation in the frame of international climate co-operation.

The Pakri Peninsula wind farm feasibility study which was performed by a team of environmentalists, climate experts, geographers, power engineering experts, economists, and wind farm developers brought together an enthusiastic team who worked under the coordination of the Estonian Institute for Sustainable Development on the most various issues connected to the wind energy use.

North-West region of Estonia is considered as one of the most feasible areas for wind energy production in Estonia. The test site for the present study is chosen Paldiski municipality. The area is of great interest to the power engineers, experts on renewable energy, environmentalists, nature conservationists, non-governmental organizations, entrepreneurs, etc.

The study was organised in a way that the wind energy potential was carefully studied for whole area. Various restrictions to the construction of wind turbines and wind farms were analysed with the tools of Environmental Impact Assessment. Further on the pilot area was selected out to exercise on small scale the different type of generators with the final aim to use this experience for much larger area. The cost-efficiency calculations followed all stages of the study. Optional financial models were worked out for that purpose. In so doing the final aim was reached in a so-called bottom up approach where step-wise movement from single to generic was performed.

In the following the concentrated content of the whole feasibility study is given. A number of geographical maps, also spreadsheets were created to quantify the results of the analysis. The limited volume of present summary made possible to include a few of them only. A number of original numeric results have been worked out, which will have significant value for further promotion of wind energy implementation in Estonia.

1. Pakri Peninsula – the test site for the first large-scale wind farm

Estonia is situated on the eastern coast of the Baltic Sea which is a region with intensive cyclonic activity and therefore with a relatively high mean annual wind speed (4-8 m/s). Pakri Peninsula (40 km^2) is located about 50 km from the capital of Estonia Tallinn. The peninsula is situated on the limestone plateau between the Pakri and Lahepera Bays along the Estonian northern coast.

The former Soviet Naval Base located in town and harbour of Paldiski and its surrounding Pakri Peninsula has a high potential for socio-economic development. The most important favouring factors for the economical development of the area are a favourable geographical position, ports, railway network, accessibility by roads and a functional infrastructure of the town. A military airfield is located at about 20 km distance at Ämari, with a runway of approximately 2000 m. Pakri Peninsula is easily accessible through various good transport links.

Paldiski Harbour is ice-free during winters. The two ports – North (deep-sea potential) and South (less deep, owned by Tallinn Port) are handling volumes of traffic increasing by about 20% a year. In longer run, an oil terminal is being discussed. A ferry link has been operating successfully to Kappelskär (Sweden) near Stockholm since 1999. Paldiski North Port could, if further developed, handle all vessels capable of entering the Baltic Sea.

After the former Soviet Naval Base had left the town a number of important sectors of economy have turned to fast development path. At present there exists the general development plan for next 10 years which foresees the following main lines: harbour development, metal works, recreation and tourism, nature park, logistics center, wind farms construction.

High wind energy potential, favourable geographical position, existing transportation network, availability of labour and the support of the local municipality (local government) are the most important advantages for the wind farms development in Pakri peninsula and at neighbouring two islands.

Local government - Paldiski Municipality has started in cooperation with SEI-Tallinn a Sustainable Development programme titled “Green Paldiski”, which is aimed to comprehensive sustainability and includes the renewable energy sub-programme on wider development of wind energy and biomass.

Available wind potential for power production

The general character of the Estonian wind regime is determined by atmospheric circulation and its seasonal variation over the Atlantic Ocean and Eurasia. However, very important factor affecting wind climate is the Baltic Sea itself, having strong influence on wind regime in coastal areas. In winter the monthly mean wind speed on islands and on the western coast reaches 7- 8.5 m/s, in the inland areas it remains between 4 -5 m/s. In summer, the season with lowest wind speed, wind is blowing in average 4-6 m/s in coastal areas and in the inland parts of Estonia it is up to 3 -3.5 m/s. The test site Pakri Peninsula is a typical coastal location with moderate to good wind condition and thereby it is very well suitable for feasibility study for wind farms that should represent Estonian coastal conditions.

Mean annual wind speed at 10 m above the ground level in Pakri Peninsula remains between 3.5-4.5 m/s at wooded sites, while open areas have wind speed of 4.5-5.5 m/s and open coastal locations 5-7 m/s. At wind turbine hub height (80 m above the ground level) mean annual wind speed reaches 7-8 m/s and the coastal locations 7.5-9 m/s.

Seasonal distribution of power production by wind turbines at Paldiski region is highly correlated with seasonal pattern of energy consumption. The highest energy yield is characteristic for period from October to January (more than 10% of annual energy production in every month) when the consumption is highest. The lowest energy yield is represented in summer from May to August (see for details in Fig 1).

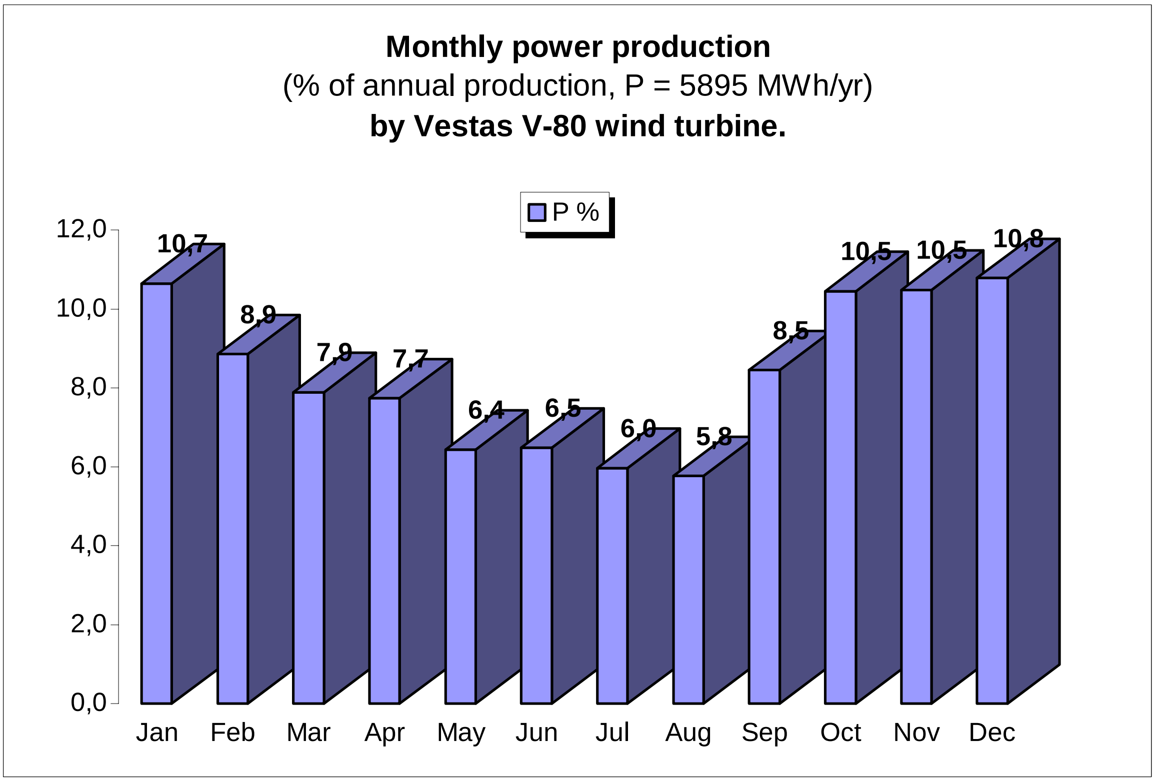

Figure 1. Monthly power production (% of annual production, P = 5895 MWh/yr) by Vestas V-80 2 MW wind turbine.

To ensure high energetic efficiency of wind farms and suitable location of wind turbines according to good practices, most of the elements of Environmental Impact Assessment (EIA) were applied when identifying possible sites for wind turbines. The highest number of building restrictions were set in the Pakri Landscape Protection area (cliff, wooded meadows and coastal meadows), coastal protection zone and off-shore areas (so called Important Bird Areas). Several other restrictions should be taken into consideration. Requirement on noise prevention zone is caused by local settlement. Generic safety zones are requested along roads and power lines. Wooded areas and wetlands also pose certain restrictions to design of wind farms due to negative effect on wind resources or high construction costs respectively. In the frame of present evaluation those sites are considered as unsuitable.

Acording to wind energy sources targeted use all over the suitable land as intensively as technically possible, different areas were selected based on EIA. These selected areas possess no conflicts in sense of natural values or social and economical regulations. Despite of all above-mentioned restrictions there are still 1134 hectares suitable land for building wind turbines in Paldiski region, i.e. in Pakri Peninsula and two neighbouring islands. In conditions, where all free-of-restrictions available land will be used for construction of wind turbines to produce “green electricity” the maximum number of 1.5 to 2.0 MW class wind turbines reaches 73 (see Fig 2). Potential wind turbines’ and wind farms’ specification by size to 7 suitable plots allows the following ranking:

- areas for 12 stand alone wind turbines, total <= 12 wind turbines,
- areas for 2 wind turbines in 3 wind farms, total <= 6 wind turbines,
- areas for 3 wind turbines in 1 wind farm, total <= 3 wind turbines,
- areas for 4 wind turbines in 2 wind farms, total <= 8 wind turbines,
- areas for 5 wind turbines in 2 wind farms, total <= 10 wind turbines,
- areas for 6 wind turbines in 2 wind farms, total <= 12 wind turbines,
- areas for 7 or more wind turbines in 3 wind farms, total <= 22 wind turbines.

Total maximum number of wind turbines for Paldiski region equals to 73 units with capacity 1.5 to 2,5 MW each. The optimal rated power considering various restrictions is 2.0 MW.

The estimated annual power production in case of using small wind turbines (850 kW) varies per unit between 1750-2500 MWh/yr in the inner part of the peninsula and reaches 3000 MWh/yr in open coastal areas. In case the 2 MW wind turbines are used, the available wind energy enables to produce more than 5000 MWh/yr per unit in open inland areas and 6000-8000 MWh/yr in open coastal regions. The total yearly power production in Paldiski area may reach to 390 GWh!

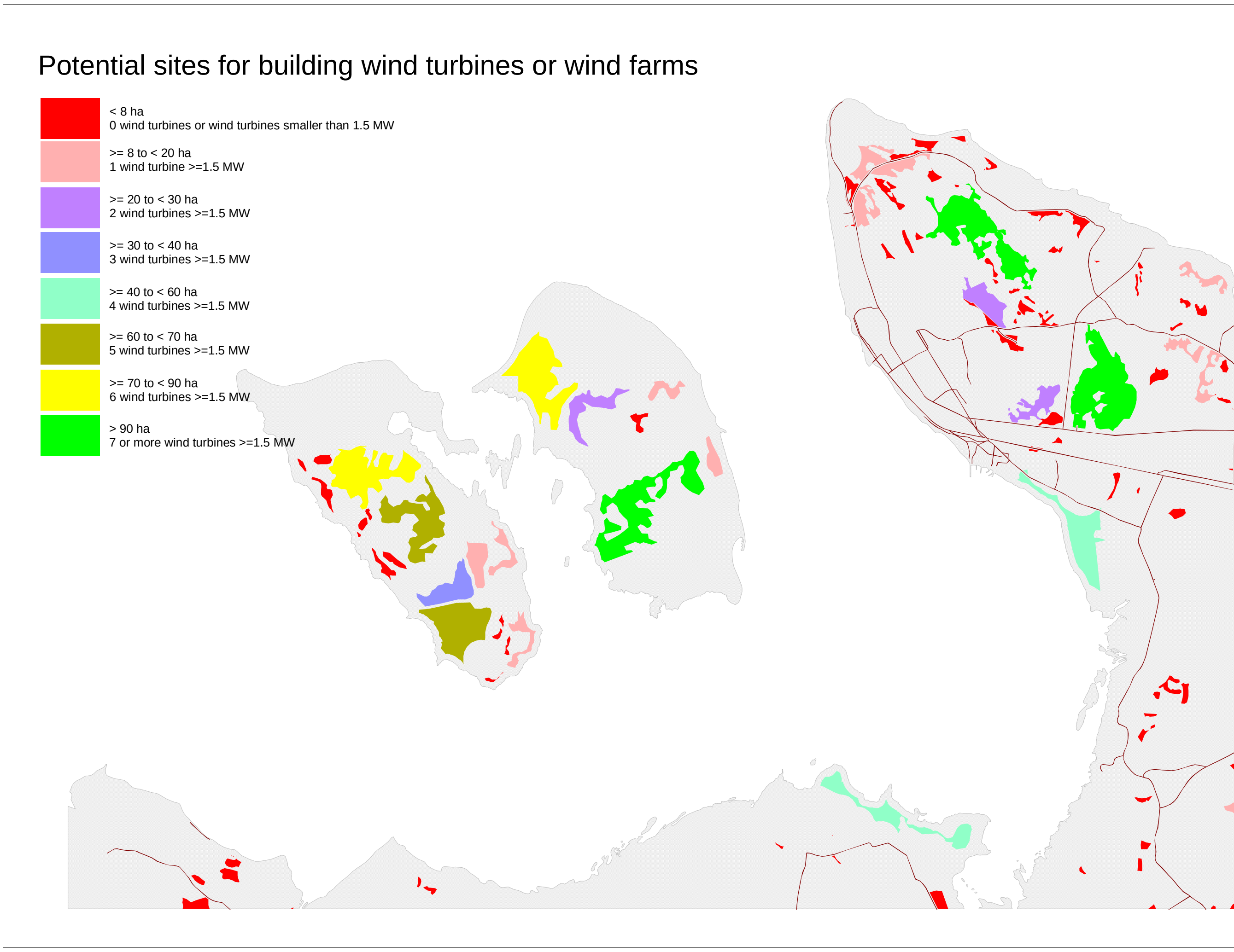

Figure 2. Potential sites for wind farms according to maximum possible number of wind turbines with rated power more than 1.5 MW.

2. Wind turbines related technical issues

As the markets for wind turbines have grown very fast the technology has developed significantly. In 1993, for example, the average size of turbines installed in the leading markets was around 300 kW, today it is 1000 …1500 kW. Modern wind turbines features state-of-the-art technology with major properties, such as high energy yields, silent operation, superior grid compatibility and long service life. All functions of the wind turbine are monitored and controlled by microprocessor based control units. A number of manufactures offer direct-drive generators with solid-state energy converters. The low content of harmonic distortion, absence of inrush currents, and adjustable reactive power supply mean these modern inverters make wind turbines particularly suitable for weaker grids. Also high technical availability and economic efficiency are important factors.

For the present feasibility study well proven *Vestas V80* with 2.0 MW rated power wind turbine from leading Danish manufacture Vestas was chosen. It has the pitch regulated upwind turbine with active yaw and a rotor with three blades, the special pitch regulating system allows the blades direction constant regulation.

Vestas Converter System (VCS), ensures steady and stable electric power from the turbine. VCS enables variable speed operation in range of approx. 60% of nominal rotations per minute. VCS together with the pitch control ensures energy optimization, low noise and reduction of loads on the gearbox and other vital components. VCS controls the current in the rotor circuit in the generator. This gives precise control of the reactive power. The blades are made of glass fibre reinforced epoxy. All functions of the wind turbine are monitored and controlled by microprocessor-based control units. This control system – including the transformer – is placed in the nacelle. Changes in the pitch of the blades are activated by a hydraulic system, which enables the blades to rotate 95 degrees. This system also supplies the pressure for the brake system. As an option, Vestas offers a service lift in the tubular tower.

Optional two different hub heights are available – 3-parted, modular tower (67m) or 4-parted, modular tower (78m). The wind turbines can be placed in wind farms with a distance of at least 5 rotor diameters (400 m) between the wind turbines. If the wind turbines are placed in one row perpendicular of the predominant wind direction, the distance between the wind turbines must, at least be 4 rotor diameters (~320m).

The soil conditions for building the foundations for wind turbines are good in Pakri peninsula. Mostly limestone basis with not high ground water level is dominating. For ensuring the foundations steel section with stiffenings, regulation screws and wiring tubes are foreseen by the Vestas. The reinforcement bars are delivered by the producer or importer holding relevant certifying license.

Shipping of the wind turbines, towers and foundation sections from place of manufacture to site will be performed via Paldiski South port according to international Incoterms 2000: DDU-on site (Delivery Duty Unpaid on site). Transportation from port to the site will be performed using special trailer. The road must be minimum 5m width and load capacity per axle should never be less that 15 tons per axle. Road minimum bend radius must correspond requirements of 47 m long blade trailer. From port until the site (~3 km) exists good road. Inside of the area were wind turbines are being built the roads must be constructed.

Grid connection is eased as Paldiski town is connected to main high voltage grid through two 110 kV lines, both able to transfer about 70 MW of capacity. The 32 MW transformer station is situated just nearby of feasibility study area, less than 1000 m of 20 kV lines/cables must be installed. The pilot project wind turbines could be connected to this transformer. For the whole test site, i.e. Pakri wind farm a new 110/20 kV transformer is needed. The time of interruptions per year caused from grid connection will be fixed in the contract with main grid owner.

The wind turbine can be mounted and started-up in relatively short time. Beside the construction team one highly qualified supervisor and several experienced service engineers are needed in assembling and erection phase as well as in the period of tuning, testing and final commissioning. Finnish crane company *Pekkaniska Ltd* has the biggest crane suitable for assembling of turbines *Liebherr 1600 LR/1*, capable to lift a 100-tonne item to 130 m height.

Operation and maintenance include service on site, consumables, repair, turbine insurance, lease of the land for site, administration, etc. Maintenance could be agreed with turbine manufacture. Consumables, such as oil for gearboxes, brakes and clutches are replaced at fixed intervals of three years. Particular details of the yaw system are replaced at intervals of five years.

3. Legal and institutional issues in relation to wind energy

Estonia is a country in accession to European Union (EU) and has potentially good possibilities for acceptation of membership during next coming years. In energy sector the legislative basis has been mostly approximated to that of EU, which means, country has adopted basic legal acts and principles which are valid in EU Member Countries.

Energy policy in European Union towards renewables

The main priorities of the EU energy policy are security of energy supplies, competitiveness and environmental protection. Promotion of renewable energy sources (RES), aimed at increasing their share in the primary energy supply is compatible with all abovementioned policy priorities (objectives), being at the same time one of major elements of sustainable development. The enforced in October 2001 EU Directive on promotion of RES based electricity production (2001/77/EC) is aimed to create a common strategy and framework. The new Directive foresees increasing the share of electricity generated from RES in the EU as an average of Member States from 13.9 % in 1997 to 22.1 % by 2010.

Situation in Estonia

In strategical documents of Estonian environmental and energy policy the wider use of RES is emphasised as a key principle having growing importance. However, the actual policy has been more modest up today as the only measures provided in legislation are the feed-in tariff rate (90% of households' basic tariff) together with the purchase obligation. Moreover, these measures can be applied to electricity generated based on any RES and the total volume of it is restricted with the upper limit of 2% of electricity consumption of previous year in Estonia.

It is hereby important to point out in connection of present feasibility study that it has been decided by the Government to rearrange the energy-related legislation in Estonia. According to the plan the current *Energy Act* shall be replaced by three new acts: *Electricity Market Act*, *Gas and Heat Supply Act* and *Liquid Fuels Act*. The preparation of these new acts is in progress. Hence, the process of drafting of the *Electricity Market Act* is still in the phase in which no information on principles and provisions of the new electricity market, especially on RES based electricity, are not yet available. The adoption of the act by Parliament is foreseen in the second half of 2002.

Main barriers

One of the major barriers to more extensive and wider development of RES (incl. wind) based electricity production is the vague state of national energy strategy, which needs upgrading as it is still oriented towards the utilisation of the main local fossil fuel resource – oil shale and therefore does not match yet with the new strategic directions of the European Union.

Also, institutional capability is one of the basic barriers at state level. Institutional enhancement and capacity building at all administrative levels could be still reached with the help of well-targeted policies at local level.

One of the direct barriers to extensive development of wind energy in Estonia is the lack of confidence in local electricity market conditions for the potential investors. Also, lack of confidence of local wind energy developers in world financing opportunities. Wind energy implementation is connected with relatively high investment need, therefore the knowledge on international financing institutions is urgently needed to be improved. Still, recently emphasized climate change mitigation policies, raised on international climate negotiations in Bonn and Marrakesh, do assist the RES promotion policies also in Estonia. In particular, those oriented to the Joint Implementation in UN FCCC Annex I countries in frame of Kyoto Protocol will give more possibilities for introducing wind energy extensive use in country.

The present structure of Estonia's electricity sector is not favourable for new independent power plants as the sector is dominated by a state owned public limited company (*Eesti Energia AS*), which is a vertically integrated company being at the same time in charge of generation, transmission, distribution and sales as well as of exports of electricity. Total restructuring of electricity sector and liberalisation of electricity market are still in an initial phase.

Present electricity production and its' price formation

The main producer of the oil shale based electricity (which formed 91% in 2000) dominating in Estonia is the power company *Eesti Energia AS*. During the period 1991-2000 the electricity consumption in Estonia has declined nearly 1.3 times and exports more than 5 times. The decline of inland consumption is connected with the general structural changes in economy and decline of industrial production in Estonia. The decline of electricity export is mainly caused by decline of export to Russia, demand by our second export partner – Latvia has been relatively stable. Since 1996 the annual electricity net production has stabilised around 7500 - 8000 GWh and inland consumption on the level 5500 GWh. Electricity export has been quite unstable changing from 400 to 1000 GWh per year in the period 1996-2000. Forecasts of the electricity demand foresee the electricity net production in 2005 in interval 7485 - 8025 GWh (actually the present level) and in 2010 in interval 7945 - 8785 GWh (little growth). For the inland consumption the respective forecasts are 5580 - 5900 GWh (2005) and 6000 - 6500 GWh (2010).

The present electricity price level (in force from 01.01.2001) is 0.76 EEK/kWh (4.87 EUR/100 kWh) for households and 0.73 EEK/kWh (4.65 EUR/100 kWh) for medium size industrial users (excl. VAT). These levels are relatively high, especially for industrial consumers if compared for example with developed neighbouring countries (Finland, Sweden).

According to the data of the annual report of *Eesti Energia AS* the producer price (production costs per 1 kWh of net production) in Narva Power Plants in 2000 was 0.35 EEK/kWh (2.24 EUR/100 kWh). In Estonia the rates of environmental pollution charges are relatively low compared to neighbouring Nordic countries, therefore the fossil fuels still have preferable status over renewable energy sources. The planned pace of increase of pollution charges, incl. CO_2, for near-term is quite modest. The environmental costs in the producer price were about 0.05 EEK/kWh (0.32 EUR/100 kWh) which is 14.3%. In the households basic tariff the environmental costs form 6.6 %.

Considering that oil shale based electricity production is highly polluting and development of national system of environmental taxation including pollution charges and resource payments is at very initial stage yet due to huge economic changes beginning from 1991 the charge rates were set at low level (the rates are planned to increase now). The share of environmental costs in oil shale based electricity producer price can be significantly increased (approximately doubled) by 2010.

The oil shale based electricity producer price would be actually at least 4.50 – 5.00 EUR/100kWh already today (in 2002) in case the pollution charge rates available in Nordic countries are applied. Moreover, in case some other environmental externalities like; surface and ground water huge consumption, losses of land, forest, peat and accompanying mineral resources, will be considered, the electricity producer price will be further raised. This will give obvious advantages to wind energy based electricity production and will allow phase out appropriate share of fossil fuel based power generation. This will be in good coherence with the requirements of the referred above EC Directive on RES wider promotion in Europe

4. Pakri Peninsula wind farm cost-efficiency analysis

Investments for Pakri Peninsula wind farm

Price estimates of wind turbines include the design, manufacture and supply of complete standard wind turbines with steel foundation sections and steel conical tubular towers. A two year warranty with 5 preventative maintenance visits and remote control equipment are included in the price of turbine. All prices exclude import duties and VAT.

Comparison of wind turbines V52- 850 kW- 65m, V80- 2000 kW- 67m, V80-2000 kW-78m, S70- 1500 kW- 65m and S70- 1500 kW- 85m indicated that the most suitable wind turbine for Pakri wind farm is V80-2000kW -78m.
The total price of 36 wind turbines V80 for Pakri wind farm is EUR 57 million.

Transportation cost of the wind turbines, towers and foundation sections from place of manufacture to Paldiski is estimated according to International Incoterms 2000 DDU-on site (Delivery Duty Unpaid on site).
Total transportation cost of 36 wind turbines V80 is EUR 3 million.

Erections of wind turbines and towers on foundations prepared by the client are performed by the supplier. Erection cost include the provision of the needed cranes, project management, one qualified and experienced working supervisor and experienced service engineers for the duration of the assembly and erection of the wind turbines as well as the tests and commissioning of same.
Total erection cost of 36 wind turbines V80 is EUR 1.6 million.

Wind turbine steel conical tower foundation cost include the geological investigations, excavation, concrete and construction works made under the supervision of wind turbine supplier.
Total cost of 36 foundations for V80 is EUR 1.4 million.

Wind turbines are located near the existing local roads and about 100-400 m of new roads or the average road construction cost of EUR 8500 are estimated for each wind farm tower. Total cost of Pakri wind farm roads construction is about EUR 0.3 million.

Land purchase is not included into the investment costs, because it is not clear right now how much, mainly state-owned, land is needed for each wind turbine and for the roads. The average cost of grid connection and transformer is estimated about EUR 64,000 per 1 MW of rated power. For the pilot project this cost may be lower, in case the existing transformer can be used. But for the Pakri wind farm the new 100-200 MW transformer and new 100 kV cables are needed.

Grid connection cost for Pakri wind farm is about EUR 4.6 million.
Total investment costs (TIN) for Pakri wind farm are about EUR 69 million.

Annual maintenance costs are estimated 9.59 EUR/MWh (incl. insurance) for the Paldiski pilot project and Pakri wind farm.
Project management costs are assessed 2% of investments.
Land lease is about EUR 64,000 for Pakri wind farm.

Wind energy based electricity production cost

The cost of wind energy based electricity may depend on Estonian oil shale electricity prices, electricity market liberalisation and Estonian new RES policy. In case the government will decide to stimulate the profit-oriented wind energy production, the wind energy based electricity feed-in tariff must be at least 90 EEK or 5.75 EUR/100 kWh (in Germany the relevant rate is approximately 6 EUR/100 kWh). The higher purchase price to grid will accelerate the growth of wind energy production, but it also will increase the consumer prices. If the wind based energy share will stay less than 10% of total electricity consumption, then the additional increase of electricity prices for consumers will be about 1-2 % per year only. The another strategy is to minimise the electricity price and the cost of wind energy based production. Then the proportion of equity capital must be higher and the interest rate lower.

The Pakri Peninsula wind farm feasibility study compared 3 financial models of wind energy based electricity production for selected wind turbines for 20 year depreciation period (without taking into account the inflation). Brief results on three options are presented below.

A. Profit-oriented option

1/3 TIN - equity capital with 8% interest rate per year (20 years);
2/3 TIN – 6% loan paid back in 10 years;
depreciation 8% during the 11-20 years;
electricity feed-in tariff - 5.75 EUR/100 kWh (20 years).
Profit-oriented wind energy production (model A) has the annual costs for the first 10 years in Pakri wind farm - 5.12 EUR/100 kWh and the next 10 years - 4.80 EUR/100 kWh (incl. depreciation).

B. Profit-oriented option with investment subsidies

1/3 TIN - equity capital (state) with 0% interest rate;
2/3 TIN – 3% (subsidised) loan for 10 years;
depreciation 8% during the 11-20 years:
electricity feed-in tariff - 4.48 EUR/100 kWh (20 years);
annual profit at least 10% of annual income.
For model B the annual costs for the first 10 years in Pakri wind farm are - 3.75 EUR/100 kWh and the next 10 years - 3.85 EUR/100 kWh (incl. depreciation).

C. Non-profit co-operative option

TIN – 100% co-operative equity capital;
electricity feed-in tariff - 2.56 EUR/100 kWh (20 years).
Non-profit wind energy production (model C) has the annual depreciation 4%. Total

sum of depreciation is 80% of the TIN. It is enough, as the wind turbines prices are declining, foundations and towers can sustain wind turbines at least for 40 years. Wind energy based electricity production annual cost for Pakri wind farm in model C is only 2.42 EUR/100 kWh.

The most cost-efficient option is C, however, it can be used for co-operative members with enough investment power only. Therefore, more realistic for Estonia is the option B, which presumes firstly the participation of the government in the implementation of the first climate oriented renewable energy wider promotion project. Secondly, the participation of the country in the climate change mitigation oriented international co-operation towards the implementation of Joint Implementation between Un FCCC Annex I parties, foreseen in the Kyoto Protocol. Favourable long term loans form actually the driving force and financial basis of this option.

5. Public participation and capacity building

The local community needs appropriate information about planned activities on wind energy potential further possible use in Paldiski region since the very early stage of the investment project. Major conflicts and misunderstandings by general public and in particular by local community could be avoided in case the relevant capacity building measures are planned in advance. Close contact between project developers and local authorities is also important.

The aims of public participation and capacity building in the frame of the Pakri Peninsula wind farm project could be listed in the following:

- to encourage the favorable social and economic changes like increase of the employment, integration of the non-Estonian people to the society, to increase the tax base, etc. in the community of Paldiski region;
- to inform local people about the designing of the wind farm project;
- to provide appropriate information to the technical, environmental and economical experts but also to the representatives of the government and local authorities;
- to raise the general knowledge in Estonia about renewable energy resources, to introduce wind energy related RES possibilities and promote its' wider use;
- to promote the implementation of the Estonian and EU energy policy in Estonia.

The target groups for public participation regarding the Pakri wind farm project are determined on the basis of their interest in relation to the wind power use. The target groups are defined on the ground of their relationship to the activities planned in the project. The following target groups could be differentiated:

- group what is directly influenced by the project implementation activities, i.e. inhabitants of Paldiski community and local authorities;
- group what is influenced indirectly by the activities entrepreneurs, farmers, landowners, fishermen, people oriented to recreation, or business in Paldiski region, etc.;
- people from public, also experts in their field, who have the professional interest towards the nature and nature conservation objects in the area of project implementation like experts on nature conservation and environmental protection, green movement, experts on energy, NGOs, teachers, students, academic staff, journalists, etc.;
- the general public of Estonia;
- public in neighbouring countries like Finland, Sweden, other Baltic States and Russia.

Local community habitants in Paldiski town and Pakri Peninsula often are considered as a socially vulnerable group having social problems like high rate unemployment, integrating to Estonian society, problems based on lacking of local language skills, etc. This target group needs a special attention from the point of view of capacity building and adult education. The economic development in this area; extension of the Paldiski harbor, establishment new enterprises, starting the tourism and recreation, starting the wind farms or beginning the production of wind turbines parts, also being involved in construction of turbines foundations and roads, etc. creates very probably a number of new jobs, also opens new opportunities for the local people.

Several other target groups need particular attention as they may pose a source of conflicts between developers. For example, nature conservationists and environmentalists. There are the Important Bird Areas and a landscape protection area what are in focus of mentioned groups. Considering different levels of those groups in early planning stages, also the general public involvement with informing, participation and consensus, the highest level of the public participation – consensus – could be achieved here in a reasonable way. On this level the people outside the project management team could give their advice and support to the project developers and assist in relevant manner the decision-making process.

There is number of different methods suitable for capacity building and public participation process for wind park project. The use of them depends on the specific character of target groups, however, also the human, time and financial resources are needed to be foreseen in the wind farm development project.

6. Concluding remarks

The Pakri Peninsula wind farm feasibility study has revealed a number of significant conclusions of generic policy character, also detailed technical and economic character.

The study was organised in a bottom-up way (i.e. from single to generic approach). This means from single wind turbine analysis to small-scale pilot project including several options as for the number and rated power of turbines and finally to wind farm spread over whole Pakri Peninsula. The wind energy potential however, was studied for even more wide scale area – Paldiski region, which covers additionally two neighbouring to peninsula islands. It was studied bearing in mind the more strategic approach towards extensive use of good wind resources potential available in this region. However, for the present feasibility study 36 potential sites proved on the basis of EIA have been selected out and mapped. The VESTAS 80 wind turbines of 2.0 MW rated power have been chosen to perform detailed calculations with the help of three different financial models A, B and C.

Model A was the profit-oriented wind energy investment with 6-8% annual interest. Model B was the moderate profit-oriented investment with state and international support and with low annual interest rate (3%). Finally, the model C was an example of co-operative wind energy investment without loans and interest rates paid. Most realistic to be tested in nowadays economic conditions in Estonia was chosen the model B. According to calculations based on the model B the annual costs for the first 10 years in Pakri find farm are 3.75 EUR/100kWh and the next 10 years 3.85 EUR/100kWh.

The study reveals an important energy policy and economical result - the oil shale and wind energy based electricity prices could be comparable already at present. If the level of pollution charge rates in Nordic countries would be taken for basis of oil shale based power production cost calculations, the results are rather surprising - the wind energy based electricity production used in present Feasibility Study by model B will have higher cost-efficiency compared with today's oil shale based electricity production. This reflects the increasing competitiveness of wind energy in the future in accordance with the development of national system of environmental charges. The competitiveness will further increase, also, in accordance with the changes to be done in the state energy strategy and policy towards RES wider promotion. In case when many other environmental externalities will be internalised into calculation of the oil shale based electricity production cost on fair basis, the comparison between RES and fossil based electricity costs may show up challenging results.

Some conclusions and remarks of generic policy character as the result of the study to be recommended to Government and policy-makers were made. The authors of present study have reached the consensus that the minimum programme for Estonia's wind energy development in <u>near-term future</u> should include initiating the following supportive measures:

- introduction of fixed feed-in tariff for wind-generated electricity supplied to national grid (transmission or distribution network), the continuation of purchase obligation for networks is assumed;
- providing the long-enough duration of the fixed feed-in tariff (e.g. for the first 10 years from the installation of wind turbine);
- restructuring of the electricity sector of Estonia to avoid monopolistic character of electricity market based on vertically integrated utility;
- unbundling generation, transmission and distribution into separate enterprises.

The mid-term measures should include:

- the substantial increase of pollution charge rates, in particular the rate on CO_2 emission;
- use part of revenues from pollution charges for supporting of renewable energy research and development (e.g. design of wind farms, mapping of wind resources, preparing technical infrastructure, assistance in grid connection, etc.).

The long-term measures should include:

- The target to be reached in a more distant time scale could be the objective for complete internalization of all kind of externalities for all energy resources.

At present a fair basis for the adequate comparison of fossil fuel based and RES based electricity production price is requested in Estonia. The need to follow the EU new strategic directions in energy strategy will urge government to pay more attention to the high potential of local renewable energy sources including wind energy. It is also important from point of view of responsibility of Estonia as an Annex I Party to UN FCCC and the signatory of Kyoto Protocol in international climate change mitigation co-operation.

The yearly output of electricity based on Paldiski region wind energy forms rather significant share in the total consumption of the country. Assuming the yearly average consumption of electricity in Estonia of 5500 GWh the present test area's share electricity production reaches approximately 3.5%.

From the point of view of climate change mitigation and Joint Implementation foreseen in Kyoto Protocol the avoided yearly amount of CO_2 reaches the value of approximately 0.25-0.3 million tonnes. This is rather considerable amount of reduction which contributes to mitigation of global climate warming.

３．報告書（英文）

Pakri Peninsula Wind Farm (Estonia) as a climate change mitigation pilot project in the frame of Joint Implementation, Feasibility Study

Pakri Peninsula Wind Farm (Estonia) as a climate change mitigation pilot project in the frame of Joint Implementation

Feasibility Study

March 2002

Tallinn, Estonia

Commissioned by: *Overseas Environmental Cooperation Center,*
Japan Ministry of the Environment

Executing Agency: *Stockholm Environment Institute Tallinn Centre,*
Estonian Institute for Sustainable Development
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Cover photo presents the bird eye view from the top of Pakri Peninsula

Preface

An attempt to study the wind energy potential of the Paldiski region for the purposes of Joint Implementation has been undertaken on the request of the Japan Ministry of Environment and the Overseas Environmental Cooperation Centre.

The Japan Special Fund in Hungary has been the important stakeholder to arrange the call for tender in May 2001 and organised the phases of step-wise selection between project proposals. After this stage the director of the Japan Special Fund Mr Kazunobu Onogawa and the project technical co-ordinator Mr. Francesco Rizzo from the Regional Environmental Center for Central and Eastern Europe in Szentendre got introduced with the applicant institution – Estonian Institute of Sustainable Development (SEI-Tallinn) and have proceed the two-days workshop in Tallinn, Estonia. The purpose and general set-up of the feasibility study of Pakri Peninsula wind farm was fixed then.

The project was carried out under the general co-ordination of SEI-Tallinn in close cooperation with the scientists of Tallinn Technical University and Tartu University, Pakri wind farm developer O/Ü Trocader, also with REC Estonia, the Estonian office of the Regional Environmental Center for Central and Eastern Europe. Mr Kei Endo from REC had the responsibility to carry out the interpretation of the Executive Summary of the project report into Japanese language. The team of ten experts has worked enthusiastically for the whole project period, particularly at the end of the project, when the basic results received in the course of the study offered a lot of topics for hot discussions and additional research. Altogether seven seminars have been built up to work on the issues related to basic topics of the Pakri Peninsula wind farm feasibility study.

This report is the result of efforts of many people. Initially, I wish to thank the authors of the chapters for their most valuable contributions, which allowed us to create a volume containing of seven basic parts each devoted to their specific, still common, topics. It has been a privilege to work very closely with so many colleagues and acquire a deeper understanding of their views and perspectives on the climate related wind energy application. Our team has worked with extremely tight time schedules and I am most appreciative of the authors support and co-operative enthusiasm.

I wish to thank Mr Kazunobu Onogawa who has collaborated in different ways to make this project happen. I am grateful to Mr Yasutaka Watanabe for his great effort to coordinate the process of project organisation on behalf of the Overseas Environmental Cooperation Center. My sincere thanks belong to Mr Francesco Rizzo who has been the central axis to make the whole project running smoothly.

We all hope that the authors joint efforts will be of benefit to all readers, providing them with useful information and contributing to the renewable energy sources much stronger promotion in connection with the practical application of Kyoto Protocol and in particular – Joint Implementation between Japan and Estonia.

Tiit Kallaste
Editor
Tallinn, March 2002

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List of Acronyms

a.g.l. – above grund level
AIJ – Activities Implemented Jointly
CEF – carbon emission factor
CHP – combined heat and power
COP – Conference of Parties
CPI – consumer price index
DKK – currency unit of Denmark
EAES – Environmentally Adapted Energy Systems
EC – European Commission
ECT – The Energy Charter Treaty
EE – Eesti Energia AS – leading power company in Estonia
EEK – currency unit of the Republic of Estonia (Estonian kroon)
EIA – Environmental Impact Assessment
EMI – Energy Market Inspectorate
ERU – emission reduction unit
EU – European Union
EUR – currency unit of EU
GDP – gross domestic product
GEF – Global Environment Facility
GHG – greenhouse gases
GT – gas turbine
HVDC – high voltage direct current
IBA – Important Bird Area
IEA – International Energy Agency
IPCC – Intergovernmental Panel on Climate Change
JI – Joint Implementation
LCA – Life Cycle Analysis
LPNO – Law on Protected Natural Objects
n.a. – not available
NC – national communication
NEAP – National Environmental Action Plan
NP – net power production of wind turbine
NUTEK – National Board of Industry and Technology of the Sweden Kingdom

O&M – operation and maintenance
Pakri WF – Pakri Peninsula wind farm
PBA – Planning and Building Act
PHARE – Poland and Hungary Assistance to Reconstruction of their Economies
PP – power plant
PP1…PP5 – Paldiski pilot project alternatives
PPP – Paldiski Pilot Project
RA – rotor area of wind turbine
RES – renewable energy sources
RP – rated power of wind turbine
RT – Riigi Teataja (State Gazette – official journal of Estonian legislation)
SEI-T – Stockholm Environment Institute Tallinn Centre, Estonian Institute for Sustainable Development (SEI-Tallinn)
STEM – Swedish National Energy Administration
TIN – total investments
TPP – thermal power plant
TTU – Tallinn Technical University
UN CED – United Nations Conference on Environment and Development
UN EP – United Nations Environment Programme
UN FCCC – United Nations Framework Convention on Climate Change
VAT – value added tax
WF – wind farm
WT – wind turbine

Units Conversion Factors

kilo (k)	10^3	tera (T)	10^{12}
mega (M)	10^6	peta (P)	10^{15}
giga (G)	10^9		

Conversion of Energy Units

1 MJ = 0.278 kWh	1 kcal = 4.187 kJ
1 kWh = 3.6 MJ	1 kJ = 0.239 kcal

Coal equivalent (ce)
1 t_{ce} = 7 Gcal = 29.31 GJ = 8.15 MW·h = 0.722 t_{oe}

Oil equivalent* (oe)
1 t_{oe} = 40.61 GJ = 11.28 MW·h = 1.38 t_{ce}

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Different sources give different numbers (Ed.)

Conversion of Monetary Units

1 EUR = 15.6466 EEK
1 USD = 18.0000 EEK (in February 2002)

Introduction

General information of Estonia

Estonia is situated in the North-East of Europe, on the east coast of the Baltic Sea, with a total area of 45,215.4 km^2.

The country is located between 57°30'34" and 59°49'12"N and between 21°45'49" and 28°12'44"E. Estonian territory extends 350 km from east to west and 240 km from north to south. In the north and west it has a long coastline with the Baltic Sea, with numerous bays, peninsulas, and straits between islands. The eastern border runs along Lake Peipsi and the Narva River. Altogether Estonia has 3,794 km of coastline; of that 2,540 km is of the coastline of islands. Estonia shares a land border of 339 km with Latvia and 294 km with Russia, making the total land border of 663 km.

The Estonian landscape bears distinct traces of glacial activity. As a part of the Eastern-European Lowland, Estonia is characterised by a flat surface topography with undulating plains and small hills. About 40% of the Republic's territory lies at an absolute height of 50 to 100 m and only one tenth has an elevation over 100 m above sea level.

Estonia belongs to the Atlantic continental region of the temperate zone. The mean annual temperature at the westernmost point is 6.0ºC and at the easternmost point 4.2ºC. summers are moderately warm (mean air temperature in July is 16–17ºC) and winters moderately cold (mean air temperature in February is between -3.5ºC and -7.5ºC).

The climate of Estonia is humid because precipitation exceeds evapotranspiration. Mean annual precipitation ranges from 550 to 750 mm. Due to a very intense cyclonic activity in northern Europe, the mean wind speed is comparatively high (5–7 m/s in the coastal zone).

Estonia is one of the smallest and least populous countries in Europe – its total population is 1.37 million, about 70% live in urban areas. The population density is 31.8 inhabitants km^2 only.

Estonia in Northern Europe

Main natural resources

In spite of its small area and relatively simple geological structure, Estonia is rich in mineral resources occurring both in the crystalline basement and bedrock and also in Quaternary sediments. Estonian oil shale reserves are the largest commercially exploited deposit in the world. Oil shale has low calorific value, compared to other fossil fuels it is less than for brown coal. The kukersite oil shale is the most important mineral resource in Estonia. It is a major source for power generation and the main resource for the petrochemical industry. Oil shale's share in the total fuel consumption is about 63%. The calorific value is estimated approximately 7.5...18.8 MJ/kg (1,800–4,000 kcal/kg). The richest in value deposits have been exhausted and mines are moving to the fields where the calorific value is lower. Oil shale is a sedimentary formation, which consists of organic matter or kerogen (15–46%), carbonate matter (26–57%) and clastic material (18–42%). Oil shale contains 1.2–1.7% sulphur, mostly as sulphide. Oil shale comprises an important part of the national wealth and at the same time – environmental problems. The biggest environmental concerns originate from oil shale mining as well as using it for power generation and as raw material for the petrochemical industry. Oil shale burning for electricity generation gives huge CO_2 emissions and thus plays a role in implication on climate.

Phosphorite reserves have been studied in several places. The Toolse deposit where the phosphorite reserves are estimated at 330 million tonnes and the depth of the phosphorite layer is favourable for mining will claim particular attention in the nearest future. Altogether the reserves of phosphorite are estimated at 700 million tonnes.

Estonia is rich in wetlands and consequently in peat. There are some 165,000 mires larger than one hectare in area, of which 132 peatlands are larger than 1,000 ha. The total area of peatlands measures 100,901 ha and makes up 22.3% of Estonia's territory. At present, the total peat reserves are estimated at 2.37 billion tonnes. A smaller share of the reserves are suitable for animal litter, and the rest can be and are currently utilised as fuel and for soil improvement.

In Estonia there are altogether more than 900 gravel and sand deposits, the commercial reserves of which are evaluated at about 250 million m^3. Gravel and sand are intensively used in the construction of roads and as a main resource for building materials.

Limestone is used as a raw material in the production of lime, cement, building stone and glass; it also has its applications in the chemical, pulp and paper industries. Dolomite is suitable for making glass and facing stones.

Curative mud has been used in the health resorts since the beginning of the 19th century. Its use is about 700 tonnes a year in major resorts in Haapsalu and in Saaremaa. Mineral water with a different degree of mineralisation and balneological properties is used in many parts of Estonia.

The main industrial sector in Estonia is energy production. Oil shale is a major source for power generation and the main resource for the petrochemical industry. Primary energy use and energy consumption by end users have decreased since 1990. The biggest decline in energy consumption has occurred in industry and agriculture.

With high rate of emissions (SO_2, NO_x) and ashes, oil shale based energy production process causes negative impact to the environment and thus plays a role in implication on climate. Producing energy in this way utilizes notable amount of oil shale and water, and generates big part of the total waste volume of Estonia. Because of the environmental problems caused by oil shale combustion Estonian Government has to consider the use of the other (alternative) energy sources.

As Estonia is a country in accession to EU, the country is making quite an effort at present to approximate the energy and environmental sector legislation with the EU's. The liberalisation of energy market and significant increase in renewable energy use are priorities presented in many appropriate directives. As for renewable energy, Estonia stands quite close to EU target 12% to year 2010 in primary energy use, Estonia has reached the figure 10.5% to year 1997 already. Country has rather good experience in biomass use and small hydropower. Wind energy wider introduction, also new biomass technologies development are the next most challenging areas.

Pakri Peninsula – the test site for the first large-scale wind farm

Pakri Peninsula (40 km^2) is located about 50 km from the capital Tallinn. The peninsula is situated on the limestone plateau between the Pakri and Lahepera Bays along the Estonian northern coast (see the map of Estonia!).

The former Soviet Naval Base located in town and port of Paldiski and its surrounding Pakri Peninsula has a high potential for development. The most important favouring factors for the economical development of the area are a non-freezing port, railway network, a favourable geographical position, a functional town infrastructure and a lovely nature.

The coastal region to the Southwest of Tallinn is easily accessible through good transport links. Compared to the other ports of the Baltic Sea, Paldiski Harbour is virtually ice-free during winters. The two ports – northern (deep-sea potential) and southern (less deep, owned by Tallinn Port) are handling volumes of traffic increasing by about 20% a year. In longer run, an oil terminal is being discussed. A ferry link able to carry 49 trailers has been operating successfully to Kappelskär near Stockholm since 1999. Paldiski deep-sea port could – if developed – handle all vessels capable of entering the Baltic.

The road linking Paldiski to Tallinn has recently been upgraded with EU funds, permitting direct connections to St Petersburg (Via Vironia), Tartu/Moscow (Via Estica) and Riga/Warsaw (Via Baltica). The railway connection is to be improved by allowing freight trains to travel directly, via a new 8 km section from Männiku to Laagri, to the ports (trains, making up about 70% of the port's traffic, now have to travel via Tallinn, where they change direction).

A military airfield is located at about 20 km distance at Ämari, with a runway of approx. 2,000 m able to take aircraft up to 180 tons.

The military activities in the peninsula have, however, resulted in a number of environmental and social problems. Many of these problems still exist since the restructuring of the former military town for the civil life is not an easy challenge. A prerequisite for a better living condition for the inhabitants of the Pakri peninsula and its further development is the solution of its environmental problems.

After the Soviet Army had left the town a number of important sectors of economy built up their plans to rebuild the town. At present there exists the general development plan for next 10 years. The following main development lines are foreseen:

- Port development;
- Metal works;
- Recreation and tourism;
- Nature Park;
- Logistics centre.

Favourable geographical position, existing transportation network, local labour and the support of a local government are the most important advantages for the wind farm development in Pakri peninsula.

Map of Estonia

An establishment of Paldiski Free Harbour and construction of new piers can in the future facilitate the growth in the town again up to a population of 10 000, secure employment, and provide opportunities for new industries to develop. Nowadays Paldiski has a population of about 4,300 people (versus more than 10,000 under Soviet rule). Development of local industries will also increase the energy demand. Local labour can effectively be employed in construction of wind turbine foundations, grids and roads.

Estonian Institute for Sustainable Development, SEI-Tallinn has started in co-operation with the local government – Paldiski Municipality a Sustainable Development programme titled "Green Paldiski", which is aimed at comprehensive sustainability and includes co-development of technical infrastructure together with social and economic development ruling from environmentally friendly approaches. The latter means to the first renewable energy supply for town, efficient use of natural resources, nature conservation and environmental management according to principles accepted in Europe and foreseen in Estonian Environmental Action Plan.

Pakri Peninsula Wind Farm as a potential project for Joint Implementation

To start with the renewable energy wider introduction in the frame of the "Green Paldiski" programme, the possibilities of wind energy implementation were started to study in spring 2000. SEI-Tallinn built up the preliminary plan together with the wind energy development oriented company O/Ü Trocader about searching opportunities to launch the stages of planning of the wind farm. Local Paldiski town municipality was involved from the very beginning to get the project idea accepted in the early stages of planning. Local municipality has been stakeholder in the planning process of wind energy wider development on the whole Pakri Peninsula. As the unemployment is one of the critical issue in this town due to its' past as described in above, the municipality is interested to be a partner to develop renewable energy based projects, which very probably could decrease the unemployment rate in the town and whole Paldiski region.

To get the reliable data about wind energy situation the developer, company O/Ü Trocader established the 40 metres wind measurement mast in the middle part of the Pakri Peninsula, equipped with the Wilmers automatic measurement station in October 2000 (see the photo). The computer on the mast stores the various measurement data – wind velocity at 20 and 40 m height, wind direction and temperature. Data about air pressure is obtained from nearby (1.5 km) meteorological station in Paldiski. Wind measurements at 40 m height, also at the 20 m height are carried out continuously and averaged in every 10 minutes. The data are saved and could be received via modem, using GSM Link, to main computer in wind farm developer's office. The authentic internationally unified methodology for wind measurements worked out by World Meteorological Organization is used in the site.

The highly reliable data are need as a precondition for international financing institutions, funds, banks, investors and climate co-operation networks etc. to start with the credit lines for relatively big investments. As a common practice, one megawatt of installed power of the wind turbine costs one million of US dollars. From

The wind measurement mast in Pakri Peninsula

the another point of view, the continuous statistics on the wind conditions is absolutely necessary for making the important decisions on most cost-efficient wind turbine to be chosen for the wind farm, also the orientation of the turbines inside of the farm, also for planning the potential of wind energy yield in the area under the consideration.

Due to its favourable geographical position the Paldiski region has much better location compared to the other regions in Estonia from the point of view of launching wind energy use for electricity production. The other alternative sites for wind farm development in Estonia, still have good opportunities too. This can be said taking into the consideration rather wide spectrum of various restrictions standing against the construction of single wind turbines or wind farms. One of the key advantages is the closeness of two 110 kV power lines from the planned wind farm site, also the 36 MW power transformer, which capacity is only partly used at present.

Successful co-operation with the wind farm developer has lead to new perspectives as regard of joining the renewable energy promotion and climate change mitigation aspects. As the overall wind energy potential of Paldiski region is significantly high, it could be used to introduce the project into the frame of international climate co-operation. Compared to any other option to produce power, wind energy is considered one of the most "clean", safe and sustainable alternative for electricity production in the country where nowadays 90% of power is produced based one of the most low-graded and polluting fossil fuel – oil shale.

As Estonia as a party to UN FCCC has had good start to launch first pilot phase project towards energy saving, energy conservation, fuel switch, etc., country has a certain level of preparedness to successful partnership in international climate co-operation. The overall economic growth after switching from the centrally planned economy to market in 1991 gave new perspectives to country's development in good coherence with the general lines adopted in the European Union. Close co-operation with neighbouring Nordic countries have paved a way to successful joint activities in the field of climate mitigation. Wind energy wider promotion has an important role to play in the light of prevailing in whole world tendencies towards the sustainable development.

1 Estonia as a co-operation partner in Joint Implementation

1.1 Estonia as a party to UN Framework Convention on Climate Change

1.1.1 Estonia as a signatory to climate convention

Estonia is a party to several directly and in-directly climate related international conventions. Amongst them the following could be mentioned. Convention on Long-Range Transboundary Air Pollution (Geneva 1979), Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters (Aarhus 1998). One of the most important besides the others is considered the framework convention on climate change. Estonia signed the United Nations Framework Convention on Climate Change (UN FCCC) during the UN Conference on Environment and Development (UN CED) in Rio de Janeiro in 1992. In May of 1994, the Riigikogu (Estonian Parliament) ratified the Convention which was subsequently promulgated by the President of the Republic. By October 1994 the Act came into force.

In January 1995 a Governmental Committee on the Implementation of the UN FCCC was established and took it upon itself to consider greenhouse gases (GHG) emission reduction strategies and mechanisms for compliance with international requirements fixed by the Convention and its Kyoto Protocol. The task of the Committee is to prepare the national plans based on the UN FCCC directives and support the government to achieve the main targets set by climate programmes. Committee is responsible for all work in the field of climate change mitigation domestically and internationally. For the time being the committee's responsibilities have been transferred to several other entities in the Ministry of the Environment. Reforming of the management and coordination of the climate change work in the country needs further improvement.

Estonia is accounted in the group of Annex I countries to UN FCCC, which means country has fixed it's GHG emission reduction to the first commitment period, 2008–2012. In December 1998 Estonia signed the Kyoto Protocol of the UN FCCC. Since that time the possible implementation of flexible mechanisms foreseen in the protocol have been in the focus of the Ministry of the Environment. In 2002 Estonia is planning to ratify the Kyoto Protocol, appropriate preparations have been started last year.

1.1.2 Responsibilities of the country under the climate convention

Estonia as a party to UN FCCC has demonstrated its' high commitment to further GHG emissions reductions. Estonia's position on the Kyoto UN FCCC Conference of Parties, COP 3 in December 1997 was in conformity with the European Union's target, which was rather significant reduction of emissions of CO_2 to the year 2005 and to 2010. The commitment of the country was fixed in the protocol – GHG emissions should be decreased to 8% compared with 1990 to the first budget period, 2008–2012. In numerical value this means not exceeding of GHG total yearly emissions at the level of 34 million tons of CO_2 equivalent. To stabilise the GHG emissions at such level, considering at the same time the forecasted significant GDP yearly growth rate, means that efficient changes to Estonia's legislative, policy, economic and institutional structure will need to take place. As the energy sector is the largest contributor to GHG emissions, the biggest potential for further GHG reduction with the help of Kyoto flexible mechanisms, is placed mostly in the energy sector.

One of the major obligations of the party to UN FCCC is regular performing of national GHG inventories and compiling National Communications (NC). This has significant importance to create the internationally comparable data basis for all parties involved to climate change mitigation activities.

Estonia, under Articles 4 and 12 of the Protocol, fulfilled its initial treaty obligations by presenting The First National Communication to the time of the first Conference of Parties (COP 1) in March of 1995. Estonia was assisted in the preparation of its communication by the United States Energy Department under the 1994 framework programme called the "US Support for Country Studies to Address Climate Change". The basic methodological principles for the world-wide unified inventories were introduced. The report presented of GHG inventory including the energy, industry, transport, agriculture, forestry and land-use sectors. GHG emissions estimation was to conform to IPCC methodological guidelines, thus a baseline year of 1990 was employed. The Second National Communication under the UNFCCC was presented to the Secretariat in autumn 1998. According to it, the total emission of GHG decreased significantly by 1996 compared with 1990. As for CO_2 only, the decrease had been almost twofold due to reductions in energy demand resulting from economic transition. The Third National Communication [1] was accomplished in November 2001 and presented to the Convention's Secretariat in Bonn. It is available on the secretariat web-site. The GHG emission has decreased to 16.4 million tonnes in 1999.

Estonia has with no doubts realised the significance of closely intertwined character of energy and climate issues, therefore the activities in energy conservation field started in early 1990ies already. The first Energy Conservation Programme was approved by the Government in 1992, this was focussed on heat conservation. The main policy instrument used were budget allocations. The overall potential of heat conservation was evaluated to approximately 30%. In practical terms the big potential in heat conservation refers to huge potential of saving of GHG emissions. It means the *business as usual* in case of Estonia is strongly oriented to implementation of energy conservation measures. Certain progress has achieved in heat conservation, but still the relatively overall low performance dominates. Government has recently (2000) passed a new Energy Conservation Target Programme[2] up till the year 2005. Main direction has taken towards supporting the energy efficiency plans at local level, i.e. at county government level and local administration level. Appropriate preparatory work has been carried out under European Commission PHARE programme, where total of 27 local energy efficiency oriented Development Plans were worked out. Their main objective is to prepare the actual investments in energy sector and enhance the

[1] Estonia's Third National Communication under the UN Framework Convention on Climate Change. Ministry of the Environment. Tallinn, 2001. 79 p.

[2] Energiasäästu sihtprogramm. (2000). EV Majandusministeerium, Tallinn.

institutional capability at local level. General economic development trend in Estonia described in the monograph[3] could be easily classified to those of *business as usual*. As for GHG reduction due to various energy efficiency activities it could be defined as *baseline* of GHG emission.

For Estonia to reach the fixed international obligation in GHG reduction in most cost-efficient way, the bigger variety of mechanisms, also more large-scale activities oriented to bigger reduction potentials should be foreseen in the nearest future. Estonia actually has no problems with the fulfilment its' Kyoto target as the country's emissions have dropped significantly after the restructuring of whole economic system in the beginning of nineties. In case of Estonia the particular issue – oil shale based power generation should be strongly emphasised. Here the new technological options of power generation should be taken into consideration in the longer term planning of whole energy sector. Reconstruction of two oil shale fuelled power plants on the eastern border has started last year. Two boilers will be changed to nowadays technology - atmospheric fluidised bed combustion. This gives a significant reduction in GHG emissions, also in other air pollutants, mainly sulphur compounds and fly ash, threatening the environment.

Also, the much more intensive involvement of renewable energy sources (RES), particularly biomass, for heat and power co-generation is of high priority in case of Estonia. A new wave to promote RES introduction in energy sector has recently started. The nowadays development path towards RES promotion policies in EU could make certain shifts towards slight decrease of the share of fossil fuels in primary energy balance.

As for other responsibilities foreseen for a party of Climate Convention, Estonia is in line with all main requirements. By its location in the region of Baltic Sea, Estonia is participating in the regional energy co-operation network BASREC – Baltic Sea Region Energy Co-operation. In the frame of BASREC one working group out of four is the Ad Hoc group on climate change, which is targeted towards the initiating and launching of Joint Implementation projects in the Baltic Sea region. The donor countries around will discuss the opportunities of performing joint climate change mitigation projects in Estonia, Latvia, Lithuania, Poland and Russia. The basis for planning such type of co-operation projects together with countries in economic transition is the issue of significantly higher economic efficiency in cutting carbon emissions.

Estonia is participating in international climate co-operation network. The representative of the country, so-called "climate focal point", who is the responsible for climate change issues in the Ministry of the Environment, participates in the COP&MOP meetings, also OECD Annex I Expert Group meetings and in other international cooperation networks, common studies, conferences, etc. The local experts, also are involved in co-operation carrying out the tasks foreseen by the international climate community.

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[3] Possible Energy Sector Trends. Context of Climate Change. (1999) Ed by Kallaste, T., Liik, O. and Ots, A. SEI-Tallinn, Tallinn Technical University. Tallinn. 190 p.

1.2 Estonia's Greenhouse Gas Emissions in 1990–1998

Shortly after the ratification of the climate convention, a first bigger and internationally co-ordinated climate project in June 1994 was launched. It was named Estonian Country Study on Climate Change GHG Emissions Inventory, Impacts and Adaptations Assessment in the Republic of Estonia and it was initiated within the U.S. Climate Change Country Study Programme. The project was aimed at raising Estonia's capacity to meet the requirements of the UN FCCC in the sphere of climate studies, particularly through the inventory of GHG emissions, finding contemporary trends to investigate the impact of climate change on the Estonian ecosystems and economy and to formulate national strategies for Estonia addressing global climate change.

From 1994–1996 a GHG inventory was compiled for the baseline year of 1990 using IPCC Guidelines for National GHG Inventories. Later on the same methodology was applied in the compilation of GHG Inventories for 1991–1996.

The IPCC Guidelines for 1994 and 1995 do not contain information about the Estonian oil shale and its carbon emission factor. As oil shale is Estonia's main indigenous fuel and highly important from the point of view of construction of baseline for the purpose of international climate cooperation, a short description of it is given below.

Estonian oil shale as fuel is characterized by high ash content (45–50%), a moderate content of moisture (11–13%) and of sulphur (1.4–1.8%), a low net caloric value (8.5–9 MJ/kg), a high content of volatile matter in the combustible part (up to 90%). The dry matter in Estonian oil shale is considered to consist of three main parts: organic, sandy-clay and carbonate.

In 1996 oil shale reserves in the Estonian field amounted to 4,400 million tonnes, while commercial supplies are estimated at 1,200 million tonnes. Oil shale is produced in three open pits and six underground mines and oil shale is mined in two qualities: coarse (grain size 25–250 mm) or crushed (grain size 0–25 mm). Coarse oil shale is processed into oil shale oil. Crushed oil shale (approximately 80%) with a caloric value of 8.5–9 MJ/kg is suitable to be used as boiler fuel in big power plants.

From the point of view of greenhouse gas emissions, it is important to note that during combustion of powdered oil shale, CO_2 has been formed not only as a burning product of organic carbon, but also as a decomposition product of ash carbonate part. Therefore the total quantity of carbon dioxide increases up to 25% in flue gases of oil shale.

A specific for Estonia factor is derived on the basis of formula introduced by Estonian scientist, Dr. A. Martins (Estonian Energy Research Institute), for calculation of Estonian oil shale carbon emission factor, taking in consideration the decomposition of its ash carbonate part. The net calorific value of oil shale is changeable, showing decrease tendency, because of the oil shale layers with best quality are mostly already exhausted. In 1990, the medium net caloric value of oil shale, burned in power plants, was 8.6 MJ/kg (data from the electricity utility company Eesti Energia AS).

Calculation of oil shale carbon emission factor gives the value 29.1 (tC/TJ). This is the value which has been taken for the basis already in all next IPPC Guidelines.

As for solid biomass, IPCC Guidelines[4] require that CO_2 emissions equal zero during burning. Hence, biomass is considered neutral renewable source of energy. In Estonia wood, incl. wood, wood-waste, saw mill dust, bark, wood chips, etc. is used as biomass fuel, the other categories of biomass are not in use as fuels. All calculations of emissions from burning wood, etc. are carried out using a particular constant from the IPCC Guidelines, but are not taken into account in the total CO_2 balance.

The GHG Inventory, with the respective emission data for was performed by the Estonian Energy Research Institute for the energy, industry, transport, agriculture, forestry and land-use sectors; in other words, for all activities related to emissions of greenhouse gases in Estonia. An overview is given below in Table 1-1.

Table 1-1. CO_2 and non-CO_2 emissions by Sector in 1990, thousand tonnes

Sector	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
Total (Fuel Combustion)	**37,184**	**2.61**	**1.417**	**79.41**	**183.54**	**22.92**	**239**
Energy Industry	28,461	0.05	0.002	35.78	7.33	n.a.	232
Industrial	2,897	0.05	n.a.	4.85	1.67	n.a.	
Transport	2,656	1.93	0.036	32.64	171.95	22.92	
Household*	1,588	0.46	0.425	3.04	0.95	n.a.	
Other Sectors	1,581	0.12	0.954	3.13	1.62	n.a.	

Note: The Totals provided here do not reflect emissions from fugitive emissions.[5]

At present energy related activities are the most significant contributors to Estonian greenhouse gas emissions. The production, transmission, storage and distribution of fossil fuels also serve as sources for greenhouse gases, as do primary fugitive emissions from natural gas systems, oil shale mining and shale oil production. For a comparison of GHG emissions with the agreed base-year of 1990, the appropriate emissions according to sectors are given in the following Table 1-1 and Table 1-2.

Table 1-2. CO_2 and non-CO_2 emissions by sectors in 1998, thousand tonnes

Sector	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
Total Energy (1+2)	**18,890**	**34.75**	**0.14**	**40.72**	**158.57**	**24.34**	**139.8**
1. Fuel Combustion	**18,890**	5.49	0.14	40.72	158.57	24.34	139.8
Energy Industry	15,731	0.39	0.06	23.47	14.06	2.45	
Industrial	666	0.02	0	1.16	0.92	0.03	
Transport	1,236	0.18	0.01	12.97	66.58	12.61	
Households	1,079	4.08	0.07	2.87	75.74	9.09	
Other Sectors	177	0.1	0.1	0.25	1.27	0.16	

[4] IPCC (1996). Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories. Vol. 1-3.
[5] By fugitive emissions the leakages of methane from the natural gas grids or from oil shale mining, for example, are considered

2.Fugitive emissions		29.26					

The major part of primary energy in Estonia is converted to electricity and heat. In 1990 the total CO_2 emissions from the consumption of fossil fuels was 37,184 thousand tonnes, but to 1998 the indicator was decreased to 18,890 thousand tonnes already. This means that during these years the total emission of CO_2 from energy production and use decreased by 49% (see Table 1-3). Related to the decrease of CO_2 emissions, the reduction of fossil fuel consumption, especially that of imported fuels, was a major factor. The CO_2 emissions, according to fuel types, decreased as follows: natural gas by 50%, coal by 80%, gasoline by 38%, kerosene by 38%, heavy fuel oil by 81% and diesel oil by 35%.

The decrease of CO_2 from the use of domestic fuels was not so big. For example, the decrease of CO_2 from oil shale consumption was 43% and from peat about 38%. The total emission from solid biomass consumption increased 214%.

Unfortunately the statistical data on biofuels does not give a sufficient picture about the state of art. Namely, the fuel-wood production growth took place in two leaps (in 1993–1994 and 1995–1996), that is mostly related to the improvement in the collection (accounting) of statistical data. Earlier, in 1980ies and in the beginning of 1990ies, the fuel wood used in small households was only partially statistically reflected. The actual growth in the production and use of fuel wood can be approximately evaluated by comparing the two following periods: 1996–1998 and 1994–1995. In these two periods, the system of the collection and processing of statistical data was (similar and) representative.

In 1998, 136 PJ of primary energy was produced in Estonia of which oil shale formed of 83%[6]. The remaining 17% come from natural gas, heavy fuel oil, or other energy sources. Oil shale, across all sectors of the economy, was responsible for about 69% of Estonia's total energy related CO_2 emissions, see Table 1-3. This reflects slight decrease compared with 71.4% in 1997.

[6] Energy Balance. (1999). Statistical Office of Estonia.

Table 1-3. CO_2 emission from energy sources, thousand tonnes

Fuel Types	1990	1991	1992	1993	1994	1995	1996	1997	1998
Fossil fuels total*	**37,183.8**	**36,342.2**	**27,453.3**	**21,786.0**	**22,667.5**	**20,637.6**	**21,216.2**	**21,362.3**	**18,889.6**
Liquid fossil fuels	**9,734.4**	**8,566.6**	**5,023.4**	**5,191.4**	**4,782.3**	**3,721.6**	**3,647.2**	**3,933.1**	**3,851.2**
Natural gas liquids	95.6	91.9	40.4	21.6	30.3	21.2	14.2	24.5	24.9
Gasoline	1,688.4	1,417.3	681.4	694.6	858.1	649.6	740.8	1,099.75	1,043.7
Kerosene	335.7	262.7	68.8	157.6	147.2	70.4	139.3	140.7	208.5
Jet Kerosene	112.1	109.9	37.3	57.4	47.4	52.5	49.0	67.6	0.1
Diesel oil	1,887.0	1,826.2	1,198.9	1,280.1	1,174.7	1,100.0	1,043.4	1,137.8	1,218.3
Heavy fuel oil	5,500.2	4,700.0	2,921.2	3,229.2	1,975.0	1,247.5	1,194.4	990.1	1,025.5
Other oils	115.4	158.6	75.4	525.3	549.6	580.5	466.1	472.7	330.2
Solid fossil fuels	**24,595.4**	**24,908.6**	**20,753.5**	**15,761.6**	**16,690.2**	**15,549.9**	**16,064.7**	**16,097.6**	**13,625.1**
Oil shale	23,051.4	23,011.7	19,347.8	14,854.9	15,867.1	14,727.1	15,196.7	15,029.3	13,040.8
Coal	880.1	863.4	536.3	282.4	211.6	201.1	229.2	231.8	176.3
Peat / peat briquette	653.7	1024.1	861.3	615.9	605.3	615.6	635.6	834.8	404.7
Coke	10.2	9.4	8.1	8.4	6.3	6.2	3.1	1.68	3.3
Gaseous fossil	**2,854.0**	**2,867.0**	**1,676.4**	**833.1**	**1,193.9**	**1,366.1**	**1,504.4**	**1,276.7**	**1,413.3**
Natural gas	2,854.0	2,867.0	1,676.4	833.1	1,194.9	1,366.1	1,504.4	1,276.7	1,413.3
Biomass total*	**1,074.0**	**797.5**	**843.7**	**793.4**	**1,289.3**	**1,445.9**	**1,613.5**	**2,633.6**	**2,303.4**
Solid biomass	1,074.0	796.5	843.7	793.4	1,289.3	1,445.9	1,613.5	2,633.6	2,303.5

**biomass is not included into fossil fuels total´*

1.3 Methodological issues of Joint Implementation

Anthropogenic emissions of GHG are assumed to be a major cause of global warming. In its turn energy sector is responsible for approximately 80% of CO_2 emissions and over two thirds of all emissions of GHG. If current trends continue, it would be very probable that they will lead to higher average global temperatures. This may cause serious damage; changed patterns of vegetation and production, rise in sea level, drought and less predictable basic climatic conditions. In contrast with other environmental problems, the potential damage caused by the greenhouse effect is independent of where the emissions take place. Besides, with current technologies it is very expensive to clean emissions of most GHGs. Emission reductions are therefore greatly dependent on reductions in the use of fossil fuels, such like coal, oil shale, petroleum and natural gas. Mitigation of GHG emissions thus is logically focused on changing the consumption patterns for carbon-intensive energy sources. This change certainly involves the significant expenditure. Enterprises must change their production processes to pay for GHG emissions, and consumers are facing higher prices when CO_2 emissions are taxed and industry and other sectors change to less fossil intensive fuel. Other measures, as it was mentioned above, may include energy saving and investment in renewable energy sources.

Because of the associated high estimated costs of stabilising GHG emissions, the climate change issue became a major challenge for international co-operation. The cost of reducing GHG emissions varies between regions and countries, also inside of the region. GHG emission reduction brings global benefits and it does not matter where, in which particular country the most effective measures have been carried out. It makes sense to apply the abatement measures in the countries, where the costs are minimized. Usually, it is the case of countries where the technical infrastructure, financial basis and institutional build-up are not that advanced compared with developed countries. This is the reason why so-called international cost effectiveness is a basic principle of the Climate Convention in the process of negotiations and in implementation. Analysis in many OECD countries of implementing sufficient measures on national basis has shown the measures are far greater than if similar resources were invested in GHG reductions in countries where the marginal costs of such measures are lower.

This particularly applies to countries that use greater proportion of non-fossil energy and therefore have limited possibilities for substitution, e.g. Norway, Sweden, etc.[7]

In spite of its primary focus on national measures, the UN FCCC therefore allows countries to implement various measures in co-operation with other countries in order to fulfil their national climate targets. Article 4.2 of the Convention states: "…These Parties, the OECD countries and countries with economies in transition, may implement such policies and measures jointly with other Parties and may assist other Parties in contributing to the achievement of the objective of the Convention".[8]

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[7] Joint Implementation as a Measure to Curb Climate Change – Nordic perspectives and priorities. TemaNord 1995:534. 98 p. Appendixes.

[8] United Nations Framework Convention on Climate Change. UN FCCC Secretariat. UNEP/IUC/00/11. Bonn.

1.3.1 Definition of Joint Implementation

Due to the high costs of reducing emissions in many countries, the considerable differences in costs between various countries and regions the joint implementation (JI) mechanism of GHG reduction was identified. *JI is defined as the least cost GHG reduction activities between Parties to Convention in Annex I (those are the countries with GHG emission reduction targets).*[9] There will be therefore the buyer country that has high emission reduction costs and a seller country, where the costs of reducing emissions are low. In so-doing the buyer country receive credits which may contribute to compliance with their targets. The concept of Joint Implementation has been incorporated into the Kyoto Protocol of the UN FCCC. In principle, it is argued, this should allow for greater cost-efficiency in meeting global targets, since abatement action can taken first, where it is least costly to do so.

To give a definition of JI on the state level, it could be the following. *Joint Implementation on state level means that a country (the investor country) where the costs of reducing GHG are assumed to be high, invests in emission-reducing measures in a country with lower reduction costs (the host country) and is credited, in whole or in part, for emission reductions in its own GHG accounts*. In principle, agreements on JI are a matter for the individual countries disturbed.

To define JI on a company level means, that companies may also be involved in finding JI projects or being responsible for transfers of technology, or as independent parties. Companies are required to reduce emissions or pay taxes on emissions of GHG at home, but may be exempt from taxes if the company instead carries out emission-reducing measures in other countries. Companies will then be allowed to increase emissions at home provided that they reduce emissions in countries and regions where similar measures are less expensive. This is called *the project level Joint Implementation.*

There is also an option to use a wider definition of Joint Implementation. It may cover more general co-operation between two or more countries on measures to reduce GHG emissions where the costs are the lowest. In this type of JI it is not necessary to measure the effects of individual projects, but on national level. Possible measures to avoid GHG emissions might include support for institutional development, implementing economic reforms, apply financial instruments, etc.[10]

At the First Conference of Parties COP 1 in Berlin in 1995 the Parties decided to launch the pilot phase of JI as the political and institutional situation among the parties to convention was not ready to practical implementation of accreditation of emission reductions between countries. As the international climate policy was still at a rather early stage that time some preparation time was needed. It became obvious to establish the necessary international institutions and rules for handling the climate problem, including the establishment of an apparatus to administer the joint

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[9] Article 12 defines a Clean Development Mechanism (CDM) under which countries with targets (Annex I) may receive credits for funding JI projects which take place in countries without targets (known as non-Annex I countries).

[10] Joint Implementation as a Measure to Curb Climate Change – Nordic perspectives and priorities. TemaNord 1995:534. 98 p. Appendixes.

implementation. It was therefore regarded as important to commence step-by-step institution-building and gain experience of how countries can enter into more tightly binding and efficient co-operation in climate change field in the longer term. One relevant step in this connection was the initiation of a “pilot phase” in which bilateral investments could be made (without crediting) for the purpose of testing various aspects of Joint Implementation. The goals of such pilot phase projects are primarily; to the first, to gain experience of how trans-national measures and projects can gradually contribute towards effective reductions in total emissions and, second, to start building institutions and gaining the necessary experience to establish a framework for international co-operation in this field.

The pilot phase of Joint Implementation was titled Activities Implemented Jointly (AIJ) to differentiate it from the JI. During AIJ no emission reduction accreditation, which is the main element of JI, was foreseen during the pilot (preparatory) phase.

1.3.2 Accreditation

Early accreditation of emission reduction could be started in case the Joint Implementation mechanism would be ready to meet all the requirements. Until present time it could be said that the setting up of well defined rules and regulations for accreditation will take some time, yet. The accreditation is one of the central topics of Joint Implementation.

The accreditation aspect is what differentiates JI from other instruments and the problems related to accreditation are the ones to be solved to make JI fully operational. Issues like baseline, additionality, incremental costs, cost curves, fairness and equity – widely discussed at present literature on JI – are actually all closely related to the accreditation methodology.

To say it again in short – the reason why donor countries are interested in financing emission reductions in other countries is that JI allows the donor countries to substitute between emission reductions at home and abroad, and allow them to be accredited the emission reductions financed abroad. The accreditation of emission reductions abroad is crucial to the donor countries because the higher the accredited emission reduction, the easier and the less expensive it will be to fulfil the national emission reduction target. The accreditation procedure is an administrative procedure involving official acceptance of every single JI project.

There is a study available made for the DG XII of the EC under the Environment and Climate Programme, which is devoted to Accounting and Accreditation – *Accounting and Accreditation of Activities Implemented Jointly*. Final Report, March 1999. Prepared for DG XII of the EC under the Environment and Climate Programme 1994–1998, Contract No. ENV4-CT96-0210 (DG12-ESCY).[11] Estonia and Czech Republic were chosen for the study areas in this international project.

[11] Accounting and Accreditation of Activities Implemented Jointly. Final Report, March 1999. Prepared for DG XII of the EC under the Environment and Climate Programme 1994-1998, Contract No. ENV4-CT96-0210 (DG12-ESCY).

1.3.3 Additionality

Article 6.1 of the Kyoto Protocol lays down a provision regarding the additionality of projects, and states that such projects should be "supplemental" to domestic policy. To date neither of those criteria are clearly defined and require clarification. The requirement of additionality demands an appropriate procedure for determining what would have happened if the project had not been implemented, and this in its turn requires the elaboration of baselines in host country. The accreditation (on the project level) is impossible, if the emission reductions associated with different JI projects and other investments are not separable.

A large amount of the future investments in donor and host countries may imply reduced emissions. But not all these investments will be approved as JI projects – and therefore credit will not be given for every emission reduction observed in the future. Projects suitable for JI are usually limited to *additional projects*, i.e. projects which would not have been carried out without JI. Countries are supposed to make projections of the economy – reference scenarios or "baselines" – showing the development of the economy and the future emissions without JI (i.e. without the additional projects). But if JI becomes a possibility, JI may change the investment behaviour, and additionality may be a very difficult criterion[12].

To-date it could be generalised that the results and current definitions of additionality do not provide enough guidance for determining project baselines. It is somewhat surprising, that until now considerable difficulties still remain in determining project baselines that are environmentally sound, which have minimal transaction cost implications and are at the same time, also politically feasible. The latter suggest that projects should meet the policy objectives of the participating parties, such as the integration of national development objectives, etc.

The main purpose of JI is to reach the international environmental goals at as low costs as possible. The outcome of an efficient international market for JI is to give donor country as much direct and indirect emission reduction as possible per unit of cost. Emission reductions which are secondary effects of normal investment practise are free. Therefore JI financing should not be given this type of projects – and this type of projects should be excluded from the "optimal" JI market. The maximum emission reduction is obtained when the JI projects supplied at the market for JI are additional. If the JI projects are not additional it will be much harder, and much more expensive, to the Annex I host country to reach the emission reduction targets it has committed itself to reach.

1.3.4 Baseline issue

The Kyoto Protocol establishes two project-based mechanisms: Joint Implementation and the clean development mechanism. *Emission baselines for JI (and also CDM)*

[12] Ibid.

projects aim to quantify "what would have happened" in terms of greenhouse gas emissions in the absence of those projects. Actual emissions from projects are measured against baseline emissions, and if lower, they can generate emission credits. Baselines are, by definition, hypothetical reference cases and are subject to a number of uncertainties.[13] In other words, *a baseline is a projection of the development path of the economy and technology into the future. The baseline is a "business as usual" scenario and does not include additional JI projects.* Therefore the baselines are important in deciding which potential JI projects are additional (they are not included in the baseline). If the baselines are used to define additional projects, will it then be necessary to give these baselines international status. Will there be "official national baselines", and can these baselines be revised? And if, then how often? What would be the optimal period for revision? Those and many other questions have been in the centre of attention of researchers for some years already.

The question of construction of different types of baselines for JI pilot phase is extremely acute at present. Most of the Annex I donor countries for the purpose of starting the JI mechanism have taken for the job to study their own approach to baselines. International organisations like OECD and IEA have invested a lot of effort to define the baseline issue.[14] Many researchers work towards establishing the common rules for baseline construction at present. Michaelowa, 1999[15], J.Ellis and M. Bosi[16], Ellis and Bosi, 2000 in OECD Environmental Directorate and International Energy Agency have given the set of various definitions of different types of baselines including various definitions on baseline as following; fixed baseline, hybrid baseline, multi-project baseline, project specific baseline, revisable baseline, etc. From this variety of names for baselines one can understand that there is still a lot of issues not yet agreed at the international level.

Approaches used to calculate emission baselines in AIJ projects are rather diverse, if not to say to some extent controversial. In fact, there are many feasible options from which to choose when determining an emissions baseline. This is particularly valid in case of new projects, so-called "greenfield projects", where no direct comparison for fuel or technology is available for a situation in which an AIJ project was not implemented. It should be pointed out that even emission baselines for replacement or technology transfer projects are subject to significant uncertainties, although the range of feasible baseline possibilities is limited.

The guidance book on baselines[17] has been recently published by OECD Environmental Directorate to help the countries to define the baselines. Parties to Climate Convention make remarkable efforts to try to fix the basic principles on baselines construction (setting). At present one could follow a very fast progress in baseline development issue, the final definition of baseline, still, will very probably be

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[13] Ellis, J. and Bosi. (Oct. 1999). M. Options for project emission baselines. OECD and IEA Information Paper. Paris, 60p.

[14] Setting a Standard for JI and CDM. Recommendations on Baselines and certification based on AIJ Experience. Report by Joint Implementation Registration Centre, The Hague, February 2000.

[15] Michaelowa, A. (1999). Project-specific, benchmark, top-down approaches for baselines and additionality: a comparison. Presentation for the UN FCCC Technical workshop on Mechanisms, Bonn, April 9-15, 15p.

[16] Ellis, J. and Bosi, M. Draft framework for baseline guidelines. Annex I Expert group meeting, OECD Febr. 2000. Paris. 16p.

[17] Emission Baselines. Estimating the Unknown. (2000). (Eds.) J.Ellis, M.Bosi. OECD, IEA. Paris.

the topic for the future. Manu countries around have promised to give their effort to work out relevant guidance materials to start the Joint Implementation in the region. Denmark, e.g., is presently working on JI Handbook both for its' country as well as for the BASREC Ad Hoc Group on climate change practical launch of JI.

It should be recognised that the development and agreement upon common framework on baseline rules and the needs for reporting is very important for the process of implementing the basic requirements of the UN FCCC. In principal, other, more standardised and easily applicable means of setting up baselines are also welcomed. These approaches may have both advantages or disadvantages when compared to the aggregated or project by project options. Agreed commonly rules will, in turn, influence the cost and complexity of setting up project based mechanisms and therefore the number of JI and CDM projects in operation. The rules will determine the incentives for project based activities and via this their environmental integrity

Estonia has a certain experience in construction of baselines for heating sector, where a number of registered in UN FCCC Secretariat AIJ projects have implemented in co-operation with donor country – Sweden. The projects are so-called "fuel-switch projects" from heavy oil to local biomass – wood waste, bark saw dust and wood chips. The top-down approach was used to keep the transaction costs low.[18] The work on construction of baselines for power generation and housing sector is planned the next. This type of work gives reliable basis for monitoring and reporting of GHG reduction in host country, also facilitates the identification and verification of future JI pilot phase projects in Estonia. Construction of baselines and making them available for potential investors planning the JI projects in host country avoids gaming.

1.4 The Joint Implementation pilot phase in Estonia

1.4.1 EAES Programme in Estonia

Thanks to good geopolitical location Estonia has historically close relations to Finland and Sweden, many cultural, business, science etc. contacts were established in the beginning of 1990ies and particularly, shortly after regaining of Estonia's political independency in August 1991. Many activities in the energy sector with the neighbouring Nordic countries, particularly with Sweden, started in the form of co-operation projects to mitigate GHG emissions through common energy conservation and energy efficiency projects shortly after the Rio Conference in 1992.

Sweden has been a pioneer with its EAES (Environmentally Adapted Energy Systems) Programme among the parties to the UN FCCC in implementing a rather impressive number of AIJ projects in Baltic States, Poland and Russia as early as 1993. The Swedish Government initiated this programme aimed at mitigating climate change through improvement of the energy systems in the form of energy efficiency measures and increased use of renewable energy sources. The EAES programme was

[18] Kallaste, T., Roos, I. (2000). Top-down CO_2 Emission Baselines for the Estonian District Heating Sector. ER 15:2000. Swedish National Energy Administration, SEI-Tallinn Centre, EERI. Eskilstuna. 40 p.

actually one of the very first state level programmes aimed at the rapid and efficient implementation of the UN FCCC in the world. The EAES Programme was designed to be in line with the AIJ criteria agreed upon at the first Conference of the Parties in Berlin in April 1995.

Estonia has participated in the Swedish agency NUTEK AIJ pilot projects from the very start. In 1998, the governments of Estonia and Sweden agreed on mutual co-operation on monitoring, reporting to Climate Secretariat and verification of the results of these projects.[19] The programme was financed by special allowances from the Swedish state budget. The total programme budget over the period 1993–1997 was 295 million SEK, which is around 42 million US dollars, of which 230 million SEK or ~78% have been used to finance favourable investment loans and the rest has been used for consultancy in the whole region. These significant funds were allocated to develop various types of energy projects leading to cutting GHG emissions in abovementioned five countries with economies in transition. The EAES Programme got from government some further 350 million SEK for next period 1998–2005. An expansion could be expected towards the Russian Federation, in particular in the Barents Region (Karelia and the Murmansk, also Archangelsk regions) for starting the Joint Implementation. NUTEK was assigned as the implementing authority by the Government until the end of 1997. As of 1 January, 1998, the new Swedish National Energy Administration (STEM) has taken over the responsibility for the EAES.

The general direction of the EAES programme laid down from the start comprises the following four categories of projects:

- Conversion of heat production plants from fossil fuels to the local bio-fuels;
- Reduction of heat losses in district heating systems;
- Energy efficiency in the end-use in buildings;
- Comprehensive projects, which combined all three abovementioned projects.

The investment priorities are slightly different from those of the first stage. In recent years the programme has been further adjusted following the experiences gained and is now directed towards:

- Combined fuel conversion and measures in distribution and/or end-use;
- Combined heat and power production (CHP);
- Use of waste heat from industrial production for district heating and power production.

The bilateral climate co-operation between two Annex I parties - Sweden and Estonia will continue to focus on joint projects based on further introduction of environmentally friendly technologies for energy production and use in the Baltic Sea region and Eastern Europe.

1.4.2 Analysis of first AIJ projects

[19] Still, no Memorandum of Understanding exists.

For the first wave of AIJ projects with the first donor country Sweden has certain objectives set. They could be listed as the following:
To

- limit the emissions of GHG to atmosphere in a most cost-effective way;
- provide loans to the AIJ projects at the local level for increasing the efficiency in production, distribution and consumption of preferably renewable energy for heating and power generation.[20]
- facilitate a transformation to an ecologically sustainable energy system subject to the condition of the Climate Convention;
- build up climate related capacity at local, also at governmental level;
- contribute to realisation of cost-effective climate measures by increased use of renewable energy sources both in heat and electricity production, also to decrease energy losses at distribution grids;
- change to more energy saving consumption patterns;
- develop experience of Joint Implementation so that the most important Kyoto flexible mechanism for Estonia can become an efficient tool in donor/host country international climate co-operation;
- develop a network for energy and climate co-operation in Baltic Sea region based on Kyoto Protocol target for reduction of GHG emissions;
- contribute to increased awareness and knowledge in energy and climate field, aimed on decreasing the fossil fuel use;
- support socially, economically and environmentally sustainable transformation and development by increased efficiency in production, distribution and consumption of heat and electricity;
- initiate business co-operation between donor and host countries companies and municipalities.

On the example of co-operation with Sweden the abovementioned targets are mostly fulfilled. Sweden is till present time the only registered by UN FCCC Secretariat donor under the JI pilot phase for Estonia. However, the next JI projects to be registered in Bonn are “in pipe” with Finland already. Also the Netherlands and Denmark have expressed their interest to launch bilateral climate co-operation with Estonia. The number of Memorandum of Understanding are in the preparatory phase at present time.

1.4.3 Experiences received for developing the international climate co-operation in the frame of Joint Implementation

Through the implementation of 21 related projects,[21] the EAES Programme’s main activities were directed towards the reduction of CO_2, NO_x and SO_2, emissions, hazardous to the global climate and the local environment. Estonia has been good host country in the sense that it had relatively good technological know-how level and a

[20] The loan conditions are set extremely favourable for the host country enterprises or municipalities; the loans are long term with the payback period up to 10 years.
[21] Different sources of information give the slightly different number for AIJ projects. Report of STEM presents the number 21 for AIJ projects in Estonia. The list of registered AIJ projects in Bonn, UN FCCC Secretariat gives the list of reported projects limiting to 20. The reason might be the measure of relevance of the projects to set criteria.

keen interest for fuel switch and energy conservation and energy. It should be mentioned here that there was an economic blockade for supply of heavy and light fuel oil from east, which in its turn accelerated the initiating of local renewable energy based projects.

The main objectives of the programme were reached in “fuel switch” projects via heavy oil or coal fired boiler conversion to local fuel, mainly wood, in the form of wood waste, saw dust, bark and wood chips. Such projects gave the major share of GHG emission reduction. Transfer from heavy fuel oil or coal to natural gas was not applied in the frame of EAES Programme. The replacement of warn-out pipelines in heat distribution grids with pre-isolated pipes was important for maintaining the existing district heating network. Hence, eliminating the heat losses gave a significant energy saving, contributing to CO_2 reduction. These projects may be considered as technology or know-how transfer to recipient countries. Heat conservation projects in the housing sector also had an important role to play. Energy efficiency in residential buildings was emphasised as part of both the overall concept of energy conservation, as well as energy efficiency. Although the expected outcome of the project in terms of carbon emission reduction is somewhat lower, the residential buildings were significantly upgraded, which is equally important in terms of life quality and living standard.

The Implementing Agency NUTEK/STEM of the donor country, Sweden has been responsible for the selection of possible project sites and appropriate and most relevant enterprises for technology transfer either in Sweden or in Estonia. The agency has launched the AIJ projects in co-operation with the host country, introduced and discussed the loan conditions with local authorities, boiler-house owners and housing co-operatives. This may be seen as having both a positive effect in a sense of wide experience and contact network, as well as a negative one, since the authority of the host country in deciding on its priorities has been reduced. However, most of the boilers in Estonia are either partly or fully owned by the municipality. Hence, the local people have basis to participate in major decisions regarding them. Additionally, when operational changes are planned, tenant/housing associations are consulted.

The projects initiated by the Swedish party in the context of the UN FCCC have had an impressive positive influence in overall GHG abatement in Estonia. The Swedish JI pilot phase projects can be assessed to account for up to 15% of the reduction in Estonia, which is a quite significant result in the post-Kyoto process. Future research, conducted by the Swedish National Energy Administration, has to determine the exact abatement figures. In addition, other sectors should be analysed.

The calculations made by STEM over the projects’ lifetime show that as the result of the different AIJ projects in Estonia, the saved/converted energy equals to 302 770 MWh/year, which means 1 635 900 tonnes of cumulatively avoided CO_2. It is especially important to stress beside of mitigation of the emission of greenhouse gases, also significant decrease other environmentally hazardous compounds. For example, annual emission of the main GHG – CO_2 was reduced by 100 260, SO_2 by 1,120, NO_x by 40 tons and solid particulate matters by 130 tonnes[22].

Assessment of the economic indicators of CO_2 abatement costs may give the preliminary evaluation on the costs per ton of avoided CO_2. The average investment cost per ton of CO_2 over the programme is 18,3 EUR/t of CO_2 and for Estonia – 20 EUR/t. Average consultancy costs are 4,9 EUR/t, and for Estonia – 5,3 EUR/t of CO_2. Two countries, Estonia and Latvia differ with their significantly better results of emission reductions, having at the same time rather similar investment and consultancy costs. This means, avoiding GHG emissions could be considered comparable in those countries. One should still consider the very different character of implemented project categories, host countries' economic conditions and the growing experience of the donor country in the course of implementation of programme. Nevertheless the figures are rather fluctuating by five countries, still some tendencies could be figured out on that basis.

The important principle applied by the donor country is that the AIJ projects are performed prevailingly with the help of loans. The share of grant is relatively low, ~15%, in case of Estonia. The long-term loan conditions, of course, are extremely favourable for host country enterprise or municipality. Compared to many other AIJ projects launched in other countries with economies in transition like, for example, Poland, the grants for investments of AIJ projects are not the practise in case of Sweden–Estonian Joint Implementation. The major conclusion, based on the experience of Estonia, is that the grants could not be the most efficient way to reduce the GHG emissions as the enthusiastic involvement of host country project owners could be hindered by relatively low incentive.

The social and economic consequences of the projects are hard to predict. One significant change was the rapid increase in the price of wood chips, which has almost doubled in the period of 1994 to 1997, resulting in increased heating costs. The main reason for the wood chip price increase was an upsurge in demand for export after Estonia liberalised its trade. Prices have now stabilised, but the saving margin envisaged in the conversion project estimate has shrunk. A positive aspect of the growing use of wood chips has been an increase in employment in rural areas. Unemployment is a growing problem (7–10%) in the country, but the increase in revenue from forestry sector has helped to control it. It is estimated that every installed MW of biomass based boilers creates new jobs for three persons.

To conclude, it must be said that AIJ projects have played an activating role in overall GHG abatement at local level. Co-operation projects should be continued to pave the way for the next Joint Implementation projects which results could be accounted for the first commitment period. Judging on the basis of preliminary calculations, the avoided GHG tonnes are to be considered significant for small country.

[22] Climate related international energy co-operation. (1998). Progress report of The Swedish Government Programme for an Environmentally Adapted Energy System (EAES), Stockholm, 14 p.

1.5 Conclusions and recommendations

The Joint Implementation pilot phase efficient implementation has played a significant role in country's meeting the Kyoto Protocol targets. It has been a preparatory phase for Estonia as a party to UN FCCC to take an active part in international climate co-operation to elaborate the mitigation of global warming. The important precondition of increasing the scope and variety of Joint Implementation projects is the capacity building at various levels of decision making and also at various recipient levels. At present the awareness on climate issues in general and in Joint Implementation particularly has raised significantly since the first AIJ projects in Estonia were launched. Still, in certain issues the knowledge has to be improved and positive experience with current JI pilot phase projects must be spread over the country.

The share of participation of Estonian Government in choosing, verification, monitoring and reporting on JI projects should be significantly raised. The task belongs mostly to two ministries, the Ministry of Economic Affairs and the Ministry of Environment. Voluntary work to prepare the country to Joint Implementation oriented climate co-operation has started within the Inter-ministerial JI Steering Group based on non-governmental organisation – SEI-Tallinn. Institutional capacity has to be improved within coming years. Further supporting activities must be foreseen for enlivenment of the work in climate and energy related sphere. The financing of governmental institutions also the research and development institutions dealing with climate mitigation and RES oriented problems should be improved to have more experts involved to related work.

Monitoring, reporting and verification of the future JI projects should be well defined at the start-up phase of each particular project, this will give a good basis for following reporting procedure to UN FCCC Secretariat as well for further emission trading activities. The JI principles rules and regulations should be discussed openly and fixed in relevant documents available to investors, donor country representatives and local entrepreneurs. The issues of additionality and baseline must be clarified well in-advance in the early stages of selection process. The procedure of selection and approval of JI projects itself must be public, should be prepared by the relevant experts in the Ministry of Environment and the Ministry of Economic Affairs. All interested groups must have access to project planning in the initial stage. Public opinion must be more strongly considered according to recently enforced Arhus Convention ratified by Estonia in 2001, also adopted by the Government the Public Information Act.

Private sector is increasingly being involved and activated in JI related energy projects. Growing number of stakeholders are involved in capacity building seminars and renewable energy workshops. Private sector is actively looking for RES wider introduction in energy sector. The major barrier is still the finding of partner countries and enterprises to initiate next JI projects. As a result, a number of potential activities, co-operation projects and also JI projects are not developed till the practical implementation. The work towards opening up new contacts with the next possible donor countries is under way at present.

The Estonian Government recently launched the preparation of the national programme for GHG emission reduction (the national climate programme), the draft of it will be written by experts from various institutions. Implementation of the flexible mechanisms, foreseen in Kyoto Protocol, has an important role to play in this programme. It is foreseen the adoption of the national programme in the second half of 2002.

The appropriate legislative basis should be worked out to prepare good investment climate to donor countries to start any other category of JI projects in Estonia. The conditions should assure the donors with all needed guarantees and relevant information. The work has started with building up the capacity in government. Hopefully in the frame of national climate programme the relevant proposals towards JI promotion will be worked out to formulate the appropriate legislative basis in the country.

The further development of JI projects in Estonia should be oriented towards the widening of the scope of potential donor counties, also the variety of different categories of projects. This will allow to gather valuable knowledge for the implementation also of other flexible mechanisms, like emissions trading in frame of the Kyoto Protocol.

The substantial experience what Estonia as a successful host country has gathered since the start of first AIJ projects in the frame of the Swedish EAES Programme in 1993 should be generalised, relevant methodological guidelines elaborated, the set of criteria for next JI projects compiled. Estonia as host country in JI will have enough attractiveness and translucency for the donor countries to be approached.

2 Legal and institutional issues in relation to wind energy

2.1 Energy policy in EU and in some Member States towards RES

2.1.1 EU *acquis communautaire* on renewable energy

The main priorities of the EU energy policy are:

- security of energy supplies,
- competitiveness, and
- environmental protection.

Promotion of renewable energy sources (RES), aimed at increasing their share in the primary energy supply is compatible with all these policy objectives, being at the same time one of major elements of sustainable development.

Elaboration of EU strategy on renewable energy sources on wider basis started with the relevant Green Paper[23] of the European Commission in 1996. Already in 1997 the relevant White Paper[24] was issued. In these documents it is noted that renewable sources of energy are currently unevenly and insufficiently exploited in the European Union. Although the potential is quite significant, renewable sources of energy make a contribution of less than 6% to the EU's overall gross inland energy consumption.

In these Papers it is stressed that if the EU does not succeed in attaining a significantly higher share of renewable energy in its energy balance, it will become increasingly difficult to comply with the international commitments concerning environmental protection. Also, failure to increase the share of renewable energy sources will have negative effects on other important policy objectives, in particular security of supply, economic and social cohesion, and on economic competitiveness.

To counteract these obstacles, in these Papers there was proposed to implement a policy strategy consisting of four distinct elements. Firstly, the increase in the contributions of RES to the Community energy balance should be aimed for at Community level. Secondly, it was proposed to strengthen Member State co-operation on RES. It was emphasized that to achieve the target, strong policies will have to be implemented at national level and it is necessary to have a mechanism for coordinating efforts at Community level. Thirdly, it was suggested that the Community should reinforce its policies affecting development of renewable sources of energy. The provisions of the Treaties and the internal market requirements were considered to offer substantial opportunities for the promotion of renewable energy sources. Moreover, given the fact that cost constitutes the largest barrier to a more widespread use of RES the policy instruments must address in particular this problem. Internalisation of external cost was considered a key concept in this respect. The

[23] Communication from the Commission (EU). Energy for the Future: Renewable Sources of Energy. Green Paper for a Community Strategy. COM(1996)576, 20.11.1996.
[24] Communication from the Commission (EU). Energy for the Future: Renewable Sources of Energy. White Paper for a Community Strategy and Action Plan. COM(1997)599, 26.11.1997.

fourth element of the strategy was the proposal for a strengthening of the assessment and monitoring of the progress towards achieving objectives set for the penetration of RES.

As a concrete target, the White Paper set out the objective of increasing the share of renewable energy to 12% of gross inland energy consumption in EU by 2010. As a follow-up to the 1997 White Paper, in 1999 the Commission launched the Campaign for Take-Off [25]. The campaign identified three key renewable energy sectors to be promoted during the period 1999–2003:

- solar energy (photovoltaics and solar thermal);
- wind;
- biomass.

In 1990ies the EU started the process of liberalisation of electricity and gas markets. This process has significant implications for renewable energy, especially on the proportion of electricity produced from renewable sources. According to the 1996 EU directive[26] on the internal market for electricity, Member States have been obliged to gradually open their national electricity markets to competition which, combined with some other developments, has led to reduction of prices on electricity generated using conventional energy sources. This means that as the EU electricity market becomes increasingly liberalised, it may become progressively more difficult for renewable energy to compete with the conventional sources without any support mechanisms. Still, there is a stipulation in the electricity Directive enabling to take some measures against this tendency. As to electricity generated from renewable sources the Directive provides an explicit mechanism for the favourable treatment. In Article 8(3) it is provided that:

> *"A Member State may require the system operator, when dispatching generating installations, to give priority to generating installations using renewable energy sources or waste or producing combined heat and power".*

As this provision of the Directive has not been sufficient to solve the problem, new measures were planned. The enforced in October 2001 Directive on promotion of renewable electricity in the EU[27] attempts to address this issue. The Directive aims to create a framework for support to electricity from RES sources, which will contribute towards achieving the indicative target of a 12% RES share in gross inland energy consumption by 2010. The Directive requires Member States to take appropriate steps to encourage greater consumption of electricity produced from renewable energy sources by setting and achieving annual national indicative targets consistent with the Directive and with national commitments fixed in Kyoto Protocol. The national indicative targets should be consistent with an increase in the share of electricity generated from renewable energy sources in the EU from 13.9 % in 1997 to 22.1 % by 2010. Although only indicative (i.e. non-compulsory) targets are set for each of the Member States to increase their share of RES, the Directive allows the European

[25] Campaign for take-off. Energy for the future: Renewable sources of energy (community strategy and action plan). SEC(99)504, 09.04.1999.
[26] Directive of the European Parliament and of the Council concerning common rules for the internal market in electricity (1996/92/EC), 19.12.1996.
[27] Directive of the European Parliament and of the Council on the promotion of electricity from renewable energy sources in the internal electricity market (2001/77/EC), 27.09.2001.

Commission to propose more mandatory legislation if it judges countries have not made sufficient progress.

As EU Member States differ considerably in terms of the contribution made by renewable energy to their energy consumption, it can be concluded that at present stage and probably in mid-term future the EU targets for renewable energy would be achieved through actions at the national, regional and, increasingly, local levels.

2.1.2 Incentives for use of wind energy in some of EU Member States

In this sub-section a brief overview of situation is given on policy and measures for supporting wind energy in three EU Member States, where the development has been most successful.[28] The main production indicators of wind energy of these countries are given in the Table 2-1.

Table 2-1. Development of wind energy use in Germany, Denmark and Spain

Country	Installed capacity, MW	Electricity production, GWh		
	2000	1993	2000	Increase
Germany	6095	674	8400	1146%
Denmark	2338	1034	4240	310%
Spain	2334	116	4162	3488%

Source: IEA Wind Energy Annual Report 2000. National Renewable Energy Laboratory. 2001.

These three countries dominate the wind power market in the EU. The incentives and support schemes to the use of wind energy these states have used, are quite simple, providing guaranteed power prices, over a number of years. This type of arrangement has removed a large amount of the uncertainty and risk associated with the development of renewable energy schemes in these countries. Other Member States have generally not achieved such high take-up rates.

2.1.2.1 Promotion of wind energy in Germany

Germany may be called a world leader in wind power. As of 30.06.2001 10,033 wind turbine generators with a rated power of 6,916 MW were installed in Germany.

[28] Main sources for compiling the overview:

1) Renewable energies: success stories. Environmental issues - Report No 27. European Environment Agency. Office for Official Publications of the European Communities, Luxembourg 2001.
2) Environmental Policy – It's our future. Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. Berlin 2000.
3) New and Renewable Energy: Prospects for the 21st Century. Supporting Analysis. ETSU R-122. Crown Copyright. 1999.

During the first half of the year 2001 alone, 674 wind generators with a rated power of 823 MW were installed.[29]

Federal support for renewable energy started with the *250 MW Wind Programme*. The programme had been initiated in June 1989 as a *100 MW Wind Programme* and was extended in February 1991 to 250 MW. Germany increased the number of turbines installed considerably during the 1990ies. Many of the projects established in Germany before the mid-1990ies were small to medium-sized installations, often with a high degree of participation from the local community. Many German regions or municipalities have targets for increasing their level of renewable energy utilisation, including wind energy use.

The most important factor for successful implementation of wind energy in Germany has been the feed-in law. From 1991–2000, the *Electricity Feed-In Law* (*Stromeinspeisungs-gesetz*) provided a guaranteed market and fixed price for the electricity produced from renewable energy sources. Wind energy schemes benefited considerably during the late 1990ies from the favourable tariffs available through these support measures.

Under the feed-in law, operators of the grid were obliged to purchase electricity produced from RES within their respective supply areas, at agreed and fixed prices. In Table 2-2 the annual development of feed-in tariff rates is given together with dynamics of average electricity prices for households and industrial consumers.

Table 2-2. The development of average feed-in tariff and electricity end-user prices in Germany, EUR/100 kWh

	1992	1993	1994	1995	1996	1997	1998	1999	2000
Feed-in tariff	8.45	8.47	8.66	8.84	8.80	8.77	8.58	8.45	8.23
Households	11.58	12.52	12.80	13.19	12.93	12.50	12.57	12.93	11.99
Industry	8.78	9.19	9.35	9.56	8.77	8.29	8.24	7.93	6.72

In order not to overburden grid operators in areas where there were high rates of RES based generation with having to purchase at premium prices, a limit of 5% renewable electricity was set from 1998 that applied within each region. Above this mark, operators of the grid were exempted from the obligations of purchase and refund. As the amount of electricity from renewable sources expanded, a number of regions exceeded the 5% ceiling. There was also an uneven financial burden between grid operators in regions close to the 5% ceiling and regions with low levels of RES generation. In order to address these and some other issues the law was replaced by the *Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz, EEG)* enforced on 1 April 2000. This Act continues to provide a guaranteed market and fixed favourable tariffs for electricity generated from renewable sources. The 2000 Act abolished the 5% cap and introduced a system that allows transmission grid operators to share amongst themselves the costs of compensation to renewable electricity producers. The *EEG Act* fixed the feed-in tariff for wind energy to the level of 9.10 EUR/100 kWh for five years and 6.19 EUR/100 kWh after that. Only the first offshore installations, installed before 2007 located at more than 3 nautical miles from the coast, will receive

[29] Ender, C. Windenergienutzung in der Bundesrepublik Deutschland - Stand 30.06.2001 - Wind Energy Use in Germany - Status 30.06.2001. *DEWI Magazin.* Nr. 19, August 2001

the rate 9.10 EUR/100 kWh fore nine years. The added cost for wind-generated electricity is paid by all electricity customers via their electricity bill. The contribution to the final electricity price as a result of cost-sharing mechanism of subsidies to renewable electricity (not only wind-generated) has been estimated only as 0.0511 EUR/100 kWh. Even in case of powerful growth in renewable energy this contribution may rise to max of 0.102 EUR/100 kWh.

The system of feed-in tariffs is differentiated in a way that the subsidy payment per energy unit (kWh) is the lower the better are the wind conditions at the turbine location. This principle has to ensure that wind turbines will be located all over Germany, not concentrated only in the windiest regions. For guaranteeing the planning and investment security it is particularly important that the feed-in tariff rates would be fixed for up to 20 years.

There are also fiscal measures taken to support wind energy: private individuals can offset the costs of investment in a wind farm against tax. This makes wind farms an attractive investment option, especially for smaller investors. Several German regions provide also financial support to renewable energy schemes, including investment subsidy programmes, to implement their energy policies. A number of German financial institutions provide low-interest loans suitable for renewable energy projects. As a rule, loans may amount to 50% of investment costs. Loans to wind energy projects over the period 1990–1997 reached 1.78 billion EUR out of the 2.13 billion EUR disbursed to all renewable energy projects.

As the public acceptance is becoming a problem in areas with a number of wind turbines, the help to overcome local opposition to wind power developments and planning guidance is now being developed in some regions to identify areas acceptable for installation of wind turbines. In addition, federal land use directives are in preparation to indicate how much renewable energy should be developed in each of the regions, particularly in regions where there is a high level of wind energy developments.

And last, but not least, there is generally a high level of environmental awareness among German citizens and an interest in wind energy as an alternative to conventional energy sources. Wind energy is of especial interest to farmers, who see it as an opportunity to provide an alternative income stream through land rentals or through electricity sales. Quite often, the municipalities are also involved in wind energy projects, particularly through partial financing.

2.1.2.2 Measures of support to utilization of wind energy in other EU Member States

In addition to Germany, several other EU Member States, at a national level, have adopted ambitious targets for the contribution of RES to their energy balances, and are promoting renewable energy sources through a variety of economic and political incentives.

Denmark has led the way in exploiting wind energy over the past 20 years. It has achieved a long and sustained growth in wind power installation during the 1990ies, mainly due to developers being able to sell their power at a known and economically favourable rate. As a result, until the mid-1990ies Denmark had the greatest use of wind energy in Europe.[30]

Danish energy policy seeks to replace electricity produced from coal with that from CHP, natural gas and renewable energy. Throughout the 1990ies, a series of energy strategies has progressively raised the targets for renewable energy use. The most recent (1996) strategy, Energy 21, set a target of 1,500 MW of wind turbines by 2005. This target was exceeded already in 1999. The government now intends to provide 50% of Danish electricity consumption from wind energy by 2030.[31] A major part of this will come from on and offshore wind power.

The feed-in law has had an important influence on the development of wind energy projects in Denmark. Electricity from wind farms is sold to the local utility under the feed-in law, enforced in 1992, which guarantees a commercially favourable fixed tariff and market for electricity generated from renewable energy sources. The local utility is obliged to take all the output from the plant. Prices available vary depending on whether the producer is a private company or a utility, and are enhanced by 'reimbursements' of CO_2 tax and government subsidy. In 1998, private and decentralised electricity producers received an incentive of 2.27 EUR/100 kWh, and all renewable producers (including utility companies) received an additional 1.33 EUR/100 kWh) as an internalisation of the external costs of fossil fuels (CO_2 tax). A new pricing system was introduced in the year 2000 with the Danish electricity reform and after a transition period of 5 to 10 years, all wind power producers will receive only the market price and green certificates.

The Danish government provided subsidies of up to 30% of wind turbine installation costs. These subsidies were discontinued in 1989. Hence, this early support helped to establish a strong home market and associated indigenous industry as well. Grants for replacement of old wind turbines are also available.

During the late 1980ies the Danish government provided financial support to development projects in the emerging Danish wind energy industry, which is now the strongest in Europe. Domestic wind developments benefit from this success by having ready access to high-quality Danish turbines, components, sales and service. Some subsidies are still available from research funds, including the programme for new renewable energy technologies, which supports non-commercially sustainable renewable energy technologies, including wind, and the energy research programme, which supports the implementation of Danish energy policy.

Spain is rapidly becoming one of the leaders in wind power exploitation in Europe. There is high wind energy potential in Spain and wind energy development is expanding considerably, mostly due to financial support through national feed-in tariffs but also because of capital subsidies, in particular at the beginning of a development.

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[30] Danish Wind Turbine Manufacturers Association Annual Report. Wind Power Note, no. 25, March 2001. Copenhagen

[31] Climate 2012. Status and Perspectives for Denmark's Climate Policy. (2000). The Ministry of the Environment and Energy. Copenhagen

Political support to implementation of RES, including wind energy, is available at both national and regional levels. The *National Energy Saving and Efficiency Plan*, 1991–2000, aimed to increase the overall use of RES by 46 PJ by the year 2000, including an increase in the contribution of non-hydro RES in electricity generation from 0.5% in 1990 to 1.4% in 2000. This support is endorsed and implemented at the regional level. The plan presented funds for energy projects at national level until 1999, when responsibility for distributing the funds was transferred to each autonomous region. Spain has already reached the 2000 RES target. *The Plan de Fomento de las Energías Renovables* (2000–2010) has set a new target of 12% share of RES in gross inland energy consumption by 2010.

The main driving force behind renewable energy comes from a series of royal decrees issued in the 1990ies to support the electricity generation from renewable energy sources, wastes and combined heat and power. The decrees guaranteed access to the electricity grid and the purchase of electricity from renewable sources at a fixed price, at 80–90% of the average electricity tariff from conventional power sources. From 1999, wind electricity producers could receive either:

- the fixed tariff of 6.26 EUR/100 kWh or
- the average hourly market price of electricity plus a bonus 2.87 EUR/100 kWh.

Financial aid in the form of state and regional subsidies is also available. The plan presented subsidies in the form of capital grants, up to 30% of eligible costs of the project. In addition, each autonomous region has established relevant support for investment and project financing.

As to administration issues, local involvement in renewable energy planning is essential. Responsibility for renewable energy sources belongs chiefly to the autonomous communities (the regions). This allows each region to have authority over the various administrative procedures, including planning and environmental impact assessments, when renewable energy projects are implemented.

2.2 Situation in Estonia

2.2.1 Energy aspects

2.2.1.1 Energy policy

Sustainable Development Act[32] sets the most general principles for sustainable development and therefore forms the basis for formulation of national and regional policies and programmes. This document enacts the most general national strategic basis for the sustainable development guided by principles given in the resolution of the UN Conference of Environment and Development (Rio de Janeiro, 1992).

As to the energy issues, the major document is *The Long-term National Development Plan for the Fuel and Energy Sector* (hereinafter the Plan). It was approved by the

[32] Sustainable Development Act, RT (State Gazette) I 1995, 31, 384; 1997, 48, 772

Parliament (Riigikogu) in 1998 as a national level plan for the energy sector.[33] In the Plan there are set targets for development of the fuel and energy sector up to the year 2005 and given principal development trends till 2018. As the environmental impact from energy sector cannot be reduced to the required level without restructuring the use of energy sources, the major part of energy demand increase is projected to be met by natural gas resulting in doubling its share in primary energy supply in 10–15 years. Still, among the Government's strategic goals there is the following one:

- to promote wider use of RES with applying tax allowances both on the respective investments and energy production based on those investments.

The Plan sets a target to increase the share of RES and peat in the primary energy supply by 2/3 to the year 2010 against 1996. The wider use of renewable sources is planned, hence, mainly in the form of electricity and heat co-generation based on these fuels. It provided that to implement the Plan, a target programme *Economically justified implementation of peat, biofuels and other RES in energy production* shall be developed. At present, the elaboration of this target programme is still in the progress.

The *Estonian National Environmental Strategy*[34], approved by the Parliament in 1997, is the major basis document for the policy-making process in the field of environment. The strategy envisages as one of the priorities reduction of negative effects of the energy sector and improvement of air quality. Among others the following goals are fixed:

- to reduce the environmental impact of the energy sector;
- to direct energy policies towards energy efficiency technology development programmes, more extensive use of renewable energy resources and reduction of greenhouse gas emissions;
- to include all environment-related costs of energy consumption in the energy price.

In the *National Environmental Action Plan* (NEAP), adopted by the Government in May 1998, there are defined concrete conceptual, legislation, organisational, educational, training and also investment measures for reaching the objectives set in the National Environmental Strategy. The NEAP defined both short-term (for 1998–2000) and long-term (2001–2006) actions for the ten priority goals. To take into account changes in Estonian economy and to specify the needed actions, the Ministry of Environment organised the revision and updating of the first NEAP. As an outcome of this process, the NEAP for 2001–2003 was prepared. The document was approved by the Government in June 2001. The implementation process of the NEAP is in progress.

As to international agreements, Estonia has signed (03.12.1998) the *Kyoto Protocol of the United Nations Framework Convention on Climate Change*. Hence, the Protocol has not been ratified yet. In 1994 Estonia has signed *The Energy Charter Treaty* (ECT). The ECT, together with the *Protocol of Energy Charter on the More Efficient Energy Use and the Related Environmental Aspects*, were ratified by the Parliament of Estonia in February 1998, and entered into force on 02.08.1998 (RT II 1998, 8–12,

[33] Long-term National Development Plan for the Fuel and Energy Sector, RT I 1998, 19, 295
[34] Estonian National Environmental Strategy, RT I 1997, 26, 390

18). Under Estonian Constitution (§ 123), all ratified international agreements are superior to national law, i.e. if laws or other legislation of Estonia are in conflict with international treaties ratified by the Riigikogu (Parliament), the provisions of the international treaty shall apply.

In 1995 Estonia signed the European Agreement and applied for membership of EU. In December 1997, the European Council of Ministers made the decision to invite Estonia to negotiations to join the EU. In March 1998 the accession process was formally launched. An analytical examination ("screening") of the *acquis communautaire* was started in April 1998 and concluded in autumn 1999. Foreign Ministry has set 1 January 2003 as a possible target date for accession preparations. Therefore the approximation of EU legislation in all fields, including environmental and energy issues, is in progress.

2.2.1.2 The Energy Act and related secondary legislation

The *Energy Act* was entered into force on January 1, 1998 (RT I 1997, 52, 833). The Act has been amended in 1998, 1999 and in 2001. The latest amendments were enforced on May 17, 2001.[35]

In the following the main provisions related to energy markets, electricity system, renewable energy sources and particularly wind-generated electricity are reviewed using text of unofficial translation of the Act into English.

The Act regulates the fuel and energy markets, and state supervision over the fuel and energy sector. In this Act, the term "energy" means comprehensive designation for both electric power and heat.

As to provisions towards electricity sector the following new for Estonian energy sector principles were introduced:

- obligatory differentiation (at least on accounting level) of the fields of activity;
- third party access to energy networks;
- prohibiting of cross subsidisation of different activities in case of vertically or horizontally integrated companies;
- transparency requirement to pricing and accounting;
- introduction of the regulation system.

In the Act the transmission network is defined as a high voltage network with a voltage of 110 kV or higher. A transmission network operator who owns the transmission network is required to connect larger power stations and substations into a unified power system which may be connected to the transmission networks of other states, and transmit electric power to distribution networks and users connected to the transmission network.

The distribution network is defined as a low or medium voltage network with a voltage of 110 kV or lower. A distribution network operator who owns a low or

[35] Energy Act, the consolidated text in RT I 2001, 52, 303

medium voltage network is required to distribute and sell electric power to users, which is purchased from power stations and the transmission network, and to provide services related to the transmission of electric power.

The Act stipulates that persons whose power equipment is connected to a distribution network shall enter into a contract with the distribution network operator, which shall determine the rights and obligations of the parties, the principles for determining the price for electric power and rates for the supply of services, and the procedure for payment for services.

A network operator shall permit connection to a network owned or possessed by the network operator to all users, producers and energy networks that are within the network operator's licensed territory and comply with requirements established by the Act and other legislation. Network operators have the right to collect justified connection fees from connected parties. The principles on which connection fees are based shall be submitted for prior review to the Energy Market Inspectorate, which may issue a written mandatory precept to the network operator to establish the connection fees.

Large (eligible) users who are connected to a network have the right, within the limits of the network's technical possibilities, to purchase energy from any energy or network operator operating within the territory of the Republic of Estonia. Similarly, it is stipulated that within the limits of the technical possibilities of the network, energy producers have the right to sell energy to every large user and network operator within the territory of the Republic of Estonia if the large user or network operator resells the energy to other large users connected to the network of the large user or network operator. Small users shall purchase energy from the distribution network that services them. It is provided (in §18) that the definition of "a large user of electrical power and heat" shall be established by a regulation of the Government of Estonia based on usage capacity and the amount of energy used per year. According to the regulation (No. 206, 29.06.1999; RT I 1999, 57, 604) of the Government the large user of electricity is defined as a user with the 8 MW or higher capacity connected to network and with the annual electricity consumption of 40 GWh. All other users are treated as small (non-eligible) users.

As to smaller wind electricity producers the following articles of the Act have great importance.

> *§18 (6). If the electric capacity of energy equipment installed by an energy producer does not exceed 10 MW per energy producer and if electric power is produced in the process of combined heat and power production or alternatively within the meaning of § 28¹* {see below} *of this Act, the energy producer has the right to sell electric power directly or, within the limits of the network's technical possibilities, through a network to every user on the basis of a contract entered into with the user.*

For all wind electricity producers the following provisions have major importance.

> *§ 28¹. Obligation to purchase alternatively produced electric power.*
>
> *(1) An energy undertaking dominating the market is required to purchase electric power from undertakings connected to its network and who*

produce such power from water, wind or solar energy, biofuel, or tail gas produced in the pyrolysis of oil shale.

(2) An energy undertaking obligated under subsection (1) of this section shall purchase alternatively produced electric power at a price which constitutes 90 per cent of the basic rate for residential customers provided that the sales volume of alternatively produced energy in the Republic of Estonia does not exceed 2 per cent of the amount of electric power utilised in the Republic of Estonia during the previous year. If the sales volume of alternatively produced electric power exceeds 2 per cent of the electric power utilised in the Republic of Estonia during the previous year, the Estonian Energy Market Inspectorate shall confirm a set sales price for the network operator of between 60–90 per cent of the basic rate for residential customers.

(3) The obligation to purchase alternatively produced electric power does not apply if:

1) *a producer of alternative electric power sells the electric power pursuant to subsection 18 (6)* {see above} *of this Act;*

2) *the technical parameters of alternatively produced electric power do not allow the operation of the power system pursuant to the provisions of subsection 20 (2) of this Act.*

The summarised above essential to wind energy developers issues of energy-related legislation are referred to with status as of February 1, 2002. It is important to point out that in the end of the year 2000 it was decided to rearrange the energy-related legislation in Estonia. According to the plan the current *Energy Act* shall be replaced by three new acts: *Electricity Market Act*, *Gas and Heat Supply Act* and *Liquid Fuels Act*. The preparation of these new acts is in progress. Hence, this process on the *Electricity Market Act* is still in the phase in which no information on principles and provisions of the new electricity market are not yet available.

2.2.1.3 Energy related taxation

Excise duty is the only specific tax that is applied directly on fuels, mainly to motor fuels. Hence, since December 1997 the excise tax is levied on light fuel as well. In the appendix of the *Fuel Excise Tax Act*[36] there was stipulated a plan for gradual increase of tax rates up to the end of 2001 with the goal to reach the level required by EU directives. Due to the rapid price increase on world oil market this plan has been repealed by amendments to the *Fuel Excise Tax Act* passed by the Parliament in June 2000 (RT I 2000, 59, 380). As to boiler fuels, at present only light fuel oil is taxed with excise duty – with the rate of 27 EUR/1000 l. In the preliminary draft of the new excise tax act prepared by the Ministry of Finance in the end of January 2002, there is planned to levy an excise tax also on heavy fuel oil, with the rate of 6.39 EUR/t.

[36] Fuel Excise Tax Act, RT I 1993, 38, 563; …; 2000, 59, 380

Since January 1997 there was enforced an element of indirect support to the wider use of renewable energy resources in Estonia – according to the amendment to the *VAT Act*[37] there has been made tax exemption for electricity generated by hydro and wind turbines – the rate of 0% is levied up to the end of 2006. At the same time the exemption is not applicable for the rest of RES based power generation, e.g. in case of biogas from farms or landfills.

In February 1999 the completely new *Pollution Charge Act*[38] was passed by the Parliament repealing the previous *Pollution Charge Act* (RT I 1994, 1, 2). The new Act provides rates of the charges to be paid for the release of pollutants or waste into the environment and the procedure for the calculation and payment of the charge. The rates for emission of major pollutants into ambient air are given in Table 2-3.

In Estonia the pollution charge on CO_2 emission was introduced only in 2000. The CO_2 charge has to be paid by all enterprises with total capacities of boilers over 50 MW, excluding ones firing biofuel, peat or waste. Up to the year 2005 (incl.) the increase of rates of pollution charges is fixed in the Act. The Ministry of Environment has prepared a plan to continue the increase of rates with the same annual pace (approximately 20%) up to the year 2015 but this plan has not been stipulated in the Act yet.

Table 2-3. Rates of pollution charge for release of pollutants into ambient air (2002–2005); EUR/t

Pollutant	**2002**	**2003**	**2004**	**2005**
Sulphur dioxide (SO_2)	5.05	6.07	7.29	8.76
Carbon monoxide (CO)	0.70	0.89	1.02	1.28
Nitrogen oxides (as NO_2)	11.63	13.93	16.74	20.13
Particulates	5.05	6.07	7.29	8.76
Volatile organic compounds	11.63	13.93	16.74	20.13
Carbon dioxide (CO_2) *	0.48	0.48	0.48	0.72

Source: Pollution Charge Act

* - *paid if the total rated thermal input of the combustion plants of a source of pollution of an energy undertaking is greater than 50 MW; not paid if these combustion plants utilise biofuel, peat or waste.*

The Act provides higher rates for some areas in Estonia – densely populated, resort/recreation areas and areas with heavy industrial load. It is also provided that the application of measures, which prevent or reduce environmental damage, or participation in approved programmes or projects for the preservation or improvement of the state of the environment may, under the conditions and in the amount provided for in this Act, substitute for the obligation to pay the pollution charge.

2.2.1.4 Present structure of the electricity sector and liberalization process of electricity market

At present the electricity sector of Estonia is dominated by a state owned public limited company Eesti Energia AS, which is a vertically integrated company being in

[37] VAT Act, RT I 2001, 64, 368; …; 2002, 11, 60
[38] Pollution Charge Act, RT I 1999, 24, 361; … ; 2001, 102, 667

charge of generation, transmission, distribution and sales as well as of exports of electricity. Hence, there are some private owned companies dealing with generation (mini hydro, small-scale and some industrial CHP plants) and with distribution of electricity.

The list of larger power plants of Estonia with data on installed capacities and electricity production in 2000 is given in Table 2-4. All four plants are owned and operated by Eesti Energia AS, Eesti PP and Balti PP are business units of Narva Elektrijaamad AS. The power plants of Eesti Energia AS generate approximately 97% of the electricity in Estonia.

Table 2-4. Estonian power plants in 2000

Power plant	Installed capacity, MW	Electricity production (gross), GWh	
Estonia	1,610	5,557.1	65.3%
Baltic	1,290	2,086.2	24.5%
Iru	190	493.4	5.8%
Kohtla-Järve	59	125.2	1.5%
Others	62	251.1	2.9%
Total in Estonia	**3,211**	**8,513.0**	**100.0%**

Sources: Eesti Energia AS; Energy Balance 2000. Statistical Office of Estonia. Tallinn 2001.

Due to decreased consumption and small possibilities of export there is a large surplus of electricity generation capacity in Estonia – the actual maximum load has been 1800–1900 MW_e.

Several options for restructuring and later also for privatisation of the electricity sector have been in Estonia under discussions for several years already. Several governmental and ministry level documents with different development variants have been issued. The latest plan provides that Eesti Energia AS will be restructured in a way that its main activities – production, transmission and distribution of electricity – would be carried out by separate entities included into a holding-type parent company (a concern) Eesti Energia AS, excluding some small distribution companies that have been privatised already. In 1999 the two biggest in Estonia power plants – Eesti EJ and Balti EJ – were merged into one company named Narva Elektrijaamad AS with all shares owned by Eesti Energia AS.

As a parallel process to restructuring, negotiations between the Republic of Estonia and NR Generating International B.V. (NRG) were held since 1996. NRG – a Netherlands registered subsidiary of the large power utility (Northern States Power Inc.) from the United Sates (based in Minnesota) – had signed an agreement of mutual interest with Estonia concerning the sale of certain generation assets (as 49% of shares) of Eesti Energia AS to NRG. During the negotiation process (in July 1999) Estonian Government decided to reform the energy sector in a way that AS Narva Elektrijaamad became the owner of 51% of shares in AS Eesti Põlevkivi (previously 100% state-owned), the almost only fuel (oil shale) supplier to Narva Elektrijaamad AS. The Estonian Government retained a holding of 49% in AS Eesti Põlevkivi.

On January 8, 2002 the Estonian Government stated that the NRG deal had been essentially called off. Also, the agreement signed on August 25, 2000 between AS

Narva Elektrijaamad, Eesti Energia AS and NRGenerating Holdings (No 14) BV on basic terms of the contracts connected with Narva Elektrijaamad AS has expired without the respective contracts being signed.

As to networks of electricity system, new entities were established on the basis of Eesti Energia's the main grid and distribution companies (except two). Two small distribution companies (in Läänemaa county and Narva region) have been privatised. All shares of AS Läänemaa Elektrivõrk were purchased by Imatran Voima Oy (IVO, now Fortum Group; Finland). AS Narva Elektrivõrk was privatised to AS Startekor Investeeringud, shares of which are co-owned by Cinergy Corp. (50%; USA) and Estonian investment company AS Sthenos Group (50%). Inside Eesti Energia AS the separate enterprise (business unit) Jaotusvõrk (*Distribution Network*) was established on 1 April 1999. This unit is responsible for electricity distribution and sales at voltage levels lower than 110 kV.

The power generation in all largest power plants of Estonia is based on firing of oil shale. The oil shale mining company AS Eesti Põlevkivi has a monopoly on oil shale mining in Estonia, producing lump and fine oil shale for the oil shale processing industry and fuel for power stations. As mentioned above, the Government decided to privatise 51% of shares of AS Eesti Põlevkivi together with the shares of AS Narva Elektrijaamad.

Regarding possible interconnection of Estonia's electricity system to the ones of EU Member States the first practical attempt was initiated at the end of 1998 when there was established a steering committee for a potential project *Estlink* to investigate and evaluate the feasibility of linking the power systems of Estonia and Finland using a modern direct current marine cable based on HVDC Light technology. The preparations for the project are still in the preliminary phase.

2.2.1.5 Conditions for network services

In the Energy Act (§15) "network service" means the provision of transmission and distribution services using a network connection and the existence of such connection. Insofar as technically possible, network operators are required to provide transmission or distribution services to all other network operators and large users.

The Energy Act (§16) stipulates that a network operator shall allow connection to a network owned or possessed by the network operator (including the use of a network connection) to all users, producers and energy network operators that are within the network operator's licensed territory and comply with requirements established by this Act and other legislation.

According to the Act the procedure for connection to a power network and the calculation of connection charges, shall be established by the Government of the Republic. The latest version of official procedures for connection to electricity network were approved by the Government (regulation no. 234 of 18.07.2000). The terms and conditions of connection contracts are the issues to be reviewed by the Energy Market Inspectorate (EMI).

Network operators are required to obtain the approval of the EMI to the rates for network services prior to the establishment thereof. Network operators are required to observe the provisions of §19 (4) and (5) (see subsection 2.2.1.6 of the current report) of the Energy Act upon the formation of the rates for network services. Within the licensed territory of one network operator, the transmission or distribution rates shall not be dependent on the distance of transmission or distribution. Transmission or distribution rates may depend on the amount of energy to be transmitted or distributed, voltage schedules, system-wide peak hours, voltage levels and the reliability of energy supplied.

As to technical conditions for connection to the network Estonian electricity utility Eesti Energia AS has introduced a company standard[39] to be used as a guidance upon the connection of wind turbine generator systems and wind farms to the electrical network of Eesti Energia AS at voltage over 1000 V. These requirements are described in the standard.

2.2.1.6 Regulation and pricing principles for electricity

State supervision over the fuel and energy sector is exercised by following supervisory authorities:

- the Technical Inspectorate;
- the Energy Market Inspectorate.

As to economic regulation, the Energy Market Inspectorate (EMI) carries out all functions of the Regulator. According to §26 of the Act the EMI is a government agency within the area of government of the Ministry of Economic Affairs, with competence to:

- supervise the fuel and energy markets;
- issue, supervise compliance with and revoke fuel and energy market licences;
- review the financial performance of fuel and energy traders dominating the market;
- foster competition;
- review, approve and confirm the prices of fuel and energy sold by enterprises dominating the market;
- review and approve connection fees and the terms and conditions of connection contracts;
- monitor compliance by fuel and energy traders with their activity and development obligations;

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[39] Company Standard EE 10421629 St 7:2001. Technical requirements for connecting wind turbine installations to the power network (Introduced with the Directive No 47 of 22 May 2001). The standard is based on following documents:

- Draft IEC 61400-21, *Ed. 1* Wind turbine generator systems – Part 21: Measurement and assessment of power quality characteristics of grid connected wind turbines. IEC, 2000.
- IEC 61000-3-7 Electromagnetic compatibility (EMC) – Part 3: Limits – Section 7: Assessment of emission limits for fluctuating loads in MV and HV power systems – Basic EMC publication.
- CCITT 1978 Directives Concerning the Protection of Telecommunication Lines Against Harmful Effects from Electric Lines, 1978.

- monitor the quality of fuel and energy being sold;
- co-operate with consumer protection associations.

As to pricing issues, the Energy Acts provides that an energy undertaking dominating the market shall sell fuel, energy and related services at prices and rates approved by the EMI. The prices and rates approved by the EMI together with applicable taxes shall be made public, including by publication in at least one national daily newspaper, not later than six months prior to entry into force thereof.

At the request of the Energy Market Inspectorate, a fuel or energy undertaking dominating the market shall justify the principles applied in setting prices and rates.

According to the Energy Act (§19 4) and 5)) the prices and rates for products and services and other conditions of sale are deemed to be justified if they correspond to the rational use of resources, do not contain cross-subsidisation between areas of activity, and ensure the necessary development of the energy enterprise, reasonable profits and the legal rights of users to use fuel and energy. The prices for the products and rates for the services of a fuel or energy undertaking dominating the market shall be established in a manner, which ensures:

- production costs necessary for activities;
- investments for performance of activity and development obligations;
- compliance with environmental protection requirements;
- compliance with quality and safety requirements;
- justified profitability.

It is also stipulated that a fuel and energy undertaking dominating the market shall keep separate accounts for the production, transport or transmission, distribution or sale of fuel or energy, and provision of related services.

At the request of the Energy Market Inspectorate, a fuel or energy undertaking dominating the market shall permit inspection of its accounting and provide necessary explanations regarding its financial and economic activities.

To give more flexibility to pricing mechanism, it is provided that upon a change in price components which are independent of the seller, a fuel or energy undertaking dominating the market may revise the prices of products and rates for services pursuant to a formula approved by the EMI.

2.2.1.7 Electricity tariffs in Estonia

In the end of September 2001 the Energy Market Inspectorate, as a response on relevant application, approved new price for electricity sold by Eesti Energia AS. As stipulated in the Energy Act the new tariff rates would be enforced after six months, i.e. on April 1, 2002. According to Eesti Energia AS this price marks the completion of important phase of the pricing reform and ends the practice of cross-subsidising household consumers by the rest of electricity users. Therefore, as of April 2002, there will be no separate price lists for residential and business customers. A major change, compared to the previous (current) tariff packages, is a separation of fixed costs of supply from the energy (kWh) price. As the result, a monthly fixed fee of 1.08 EUR (excl. VAT) would be introduced.

According to information given by Eesti Energia AS, as the result of price increase on 01.04.2002 the weighted average price of electric power will grow by 21%, to 5.04 EUR/100 kWh. An average price rise for the residential customers and low voltage business customers will be 33% and 5.6%, respectively. The structure of the new end-user price (basic price for households) of electricity according to the tariff to be introduced on April 1, 2002 is presented in Figure 2-1.

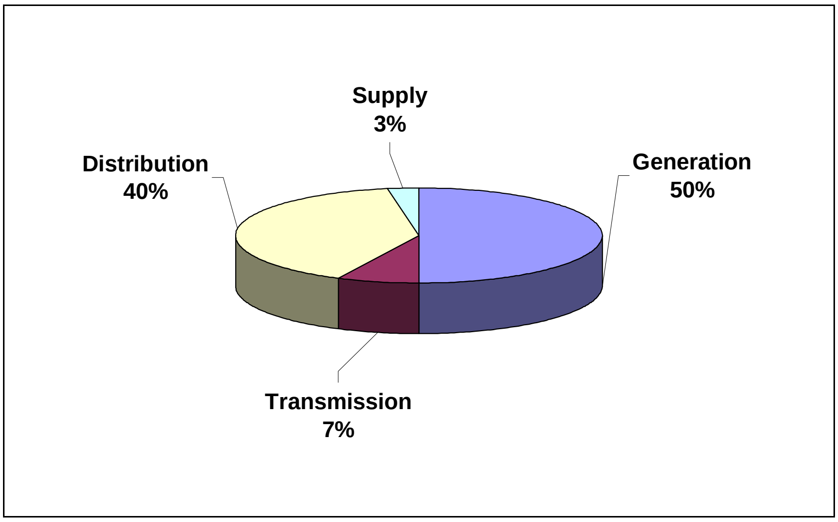

Figure 2-1. Structure of end-user electricity price (as of 01.04.2002)

As to wind electricity, the key tariff rate (as long as the relevant provisions in present Energy Act are in force) is the basic tariff for households, as the feed-in tariff for obligatory purchase of renewable electricity is directly related to this rate (see section 2.2.1.2). As in the new tariff structure there are no separate rates for households, the key rate is the basic rate for consumers at voltage level of 0.38 (0.22) kV. This rate is 5.96 EUR/100 kWh. The resulting feed-in tariff for renewable electricity would be then 5.36 EUR/100 kWh.

In case the producer of wind electricity has found a customer who is ready to purchase wind-generated electricity and there is no direct line between generator and consumer, the network has to be utilised. Therefore, the tariffs for electricity transport would be important elements of the final cost of electricity. In Table 2-5 there are given new transmission and distribution tariffs, which will be introduced on April 1, 2002. As new application procedures are not yet available, some major issues from the present (in force up to 01.04.2002) procedures are described in the following. The customer shall order the grid/network service for one year and shall pay monthly 1/12 of the annual fee. The annual fee shall be determined at the consumption place of the connected to the power network customer, based on the tariff and the maximum consumption capacity ordered by the customer for a half an hour or hour period of the year. In case the recorded during the year consumption capacity in the half an hour or hour period exceeds the ordered capacity:

- up to 1.1 times, then the customer shall be additionally charged for each kilowatt, based on the tariff;
- more than 1.1 times, then the customer shall be charged for the kilowatts exceeding the ordered capacity under a double tariff, and starting from this moment the customer shall be calculated, based on this recorded consumption capacity, a new grid/network fee for the entire period of the ordered grid service.

Table 2-5. Transmission and distribution tariffs (as planned since 01.04.2002)

Tariff	Service	Unit	Tariff rate (excl. VAT)
TRANSMISSION			
E1	Transmission fee at 330 kV	EUR/100 kWh	0.128
E2	Transmission fee at 110 kV	EUR/100 kWh	0.134
E3	Transmission fee to the lower voltage terminals of 110 kV transformer	EUR/100 kWh	0.256
E4	Grid fee at 110 kV	EUR/kW per year	21.19
E5	Grid fee to the lower voltage terminals of 110 kV transformer	EUR/kW per year	24.78
DISTRIBUTION			
JK	Distribution fee at 6–35 kV	EUR/100 kWh	0.354
	Network fee at 6–35 kV	EUR/kW per year	47.17
JM	Distribution fee at 0.38(0.22) kV	EUR/100 kWh	1.26
	Network fee at 0.38(0.22) kV	EUR/A per year	6.37
	Measurement fee at 0.38(0.22) kV	EUR/point per month	0.844

The level of electricity price in Estonia together with the fixed feed-in rate provided by the *Energy Act* (90% of households' basic tariff) can serve as a basis element for wider introduction of wind energy based generation of electricity in Estonia. Government has to promote wind energy with various indirect measures, to make this sector rapidly developing. Nevertheless, there are some other important factors, which influence the confidence of potential investors when making decision on coming to Estonian electricity market.

2.2.2 Environmental and land use aspects of wind energy utilization

Wide exploitation of wind energy is limited by number of environmental and land use factors in addition to economic and technical ones. Most of these factors are related to land use type, wildlife, landscape aesthetics and safety requirements. In Estonia currently no specific acts or laws are not enacted which regulate wind energy utilization. The only wind energy related specific document as company standard is issued by Eesti Energia AS[40]. However, these instructions and guidelines by Eesti Energia should be followed in order to secure a safe and proper connection to main distribution network.

Therefore other acts should be used as guidelines on environmental and land use issues when planning wind turbine or wind farm construction. The most important basic laws and acts that create an outline for installation of wind turbines are the following:

- Planning and Building Act[41]
- Environmental Impact Assessment and Environmental Auditing Act[42]
- Law on Protected Natural Objects[43]
- Law on the Protection of Marine and Freshwater Coasts, Shores and Banks[44]
- Heritage Conservation Act[45]
- Law of Property Act[46]

Both, Planning and Building Act (§2, 3) and Environmental Impact Assessment and Environmental Auditing Act (§17) enables participation of all stakeholders in wind farm planning and design process. This creates fully functional system that ensures accordance with legal acts and interests of different stakeholders.

2.2.2.1 Legislative aspects of physical planning

The purpose of the Planning and Building Act (further: PBA) is to ensure conditions which take into account the interests of the widest possible range of society's members for the transformation of the environment, its long-term sustainable development, the use of land and the interrelation of socio-economic and physical planning. The PBA describes four categories of plans:

- national plans;
- county plans;
- comprehensive plans;
- detailed plans.

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[40] Company Standard EE 10421629 St 7:2001. Technical requirements for connecting wind turbine installations to the power network (Introduced with the Directive No 47 of 22 May 2001). The standard is based on following documents:

- Draft IEC 61400-21, *Ed. 1* Wind turbine generator systems – Part 21: Measurement and assessment of power quality characteristics of grid connected wind turbines. IEC, 2000.
- IEC 61000-3-7 Electromagnetic compatibility (EMC) – Part 3: Limits – Section 7: Assessment of emission limits for fluctuating loads in MV and HV power systems – Basic EMC publication.
- CCITT 1978 Directives Concerning the Protection of Telecommunication Lines Against Harmful Effects from Electric Lines, 1978.

[41] Planning and Building Act, RT I 1995, 59, 1006
[42] Environmental Impact Assessment and Environmental Auditing Act, RT I 2000, 54, 348
[43] Law on Protected Natural Objects, RT I 1994, 46/37, 773
[44] Law on the Protection of Marine and Freshwater Coasts, Shores and Banks, RT 1 1995, 31, 382
[45] Heritage Conservation Act, RT I 1994, 24, 391
[46] Law of Property Act, RT I 1993, 39, 590

The objectives of the four different plans are to determine the primary use of a given territory, i.e. whether the territory should be used as agricultural, industrial, recreation and leisure area or could it be use for other purposes like for construction of wind turbines. The national plan outlines the planning of the area of the state, and it is the basis for the county planning. A county plan outlines the planning of either one or several counties, and the adopted county plan serves as the basis for the comprehensive plan. An adopted comprehensive plan is the basis for the detailed plan. An adopted detailed plan serves as the basis for the design of structures (incl. wind turbines). The act sets up a number of rules and norms that must be followed in order to obtain a building or construction permission.

According to PBA (§2) there should be taken into account difference in planning rules between *high density areas* and *low density areas*:

> *§2 1) The construction of new buildings, additions to existing buildings, division of land into plots and alterations to boundaries of existing plots in cities and other high density areas are only permitted on the basis of detailed plans adopted by local governments (***mandatory plans for high density areas***).*
> *§2 2) In low density areas, the construction of new buildings and additions to existing buildings are permitted on the basis of design criteria issued by local governments (***mandatory design criteria in low density areas***).*

The PBA determine that the planning activities are public in order to ensure timely access to information by interested persons and to enable such persons to defend their interests (§2(3)) and the commencement of construction is permitted on the basis of building design documentation after receipt of a building permit from the local government (§2(4)). Mandatory permit for use enacts that the use of a structure is permitted only after the receipt of a permit for use from the local government.

Administration of planning, design and construction in the territory of a local government is within the competence of the local government. Local government must:

- ensure the preparation of plans which are the basis for land use and construction;
- ensure, as a prerequisite for adoption of a plan, the consideration and concordance of the interests of all interested persons;
- ensure adherence to and implementation of adopted plans;
- arrange for construction supervision.

A detailed plan is a plan which is prepared for a smaller part of a city or rural municipality and is the basis for construction activities in the short term. In the preparation of detailed plans, Acts in force concerning health protection, environmental protection, national defense and fire safety, other Acts and norms, and the results of environmental impact assessments shall be taken into account. A detailed plan determines the following:

- the division of the planning area into plots;
- the building rights of plots;
- planting of vegetation and provision of public services and amenities;
- clearances between structures;

- the location of utility networks and constructions;
- environmental protection measures;
- special requirements for land use and construction within protected areas and objects under protection pursuant to the Law on Protected Natural Objects (further: LPNO) and other Acts, and protection rules, statutes, protection obligation notices and other conditions for use established on the basis of these Acts, and also the making of proposals for the specification of protection rules, statutes and other conditions for use;
- proposals to place areas or objects under protection, if necessary;
- the essential architectural requirements for structures;
- the need for servitudes;
- other restrictions on immovable property ownership pursuant to law.

According to §9(4) the building rights of a plot include the intended use of the plot, the permitted number of structures on the plot (e.g. wind turbines), the maximum permitted area occupied by structures and the permitted height of structures.

Plan preparation may be initiated by the Government of the Republic, a ministry, county government, local government or other interested person. The preparation of comprehensive plans which are normally requested to build up wind turbines, is administered by the local governments and co-ordinated by the county governments and the Ministry of the Environment. The preparation of detailed plans are administered by the local governments.

It is important to mention that the local governments may enter into contracts to transfer the right to administer and finance the preparation of detailed plans to the owners of immovables or other persons interested in the preparation of a plan of an area. Owners of immovables, residents and other interested persons are involved in comprehensive and detailed planning. The local government shall organise public meetings to publicise the initial planning outline and draft plans. Concordance of comprehensive plans and detailed plans is guaranteed by co-operation with the corresponding state executive agency or inspectorate if monuments, natural objects or other objects under state protection are located in the planning area, or if the plan serves as a proposal for placing such objects under protection, or if earth deposits belonging to the state or underground mines are located in the planning area. The supervising county governor or the Ministry of the Environment shall determine requirements for other concordances which must be obtained for a plan prior to its public display. The local government or county government shall communicate the place, commencement and duration of a public display through the local and county media at least one week before the commencement of the public display. During a public display, interested persons shall have access to all materials and information relating to the plans which are at the disposal of the county government or local governments administering the planning, except information classified as a state secret. The duration of public display shall be: two weeks in the case of a detailed plan and four weeks in the case of a comprehensive plan.

A comprehensive plan or detailed plan is adopted by the local government. If an adopted detailed plan amends a current comprehensive plan and the county governor gives his or her consent to the amendments in the course of supervision, the local government shall make and adopt the corresponding amendments to the comprehensive plan. Notice of the adoption of a comprehensive plan or detailed plan shall be published in the local and county media.

2.2.2.2 *Legislative aspects of environmental impact assessment*

The purpose of environmental impact assessment is to identify, assess and describe the likely impact of proposed activities on the environment, analyse the possibilities for the prevention and mitigation of such impact and make proposals regarding the choice of the most suitable solution. Environmental impact means any change in the status of the environment resulting from activities or any direct or indirect effect of such changes on human health or property. According to Environmental Impact Assessment and Environmental Auditing Act [47] environmental impact shall be assessed if construction works, use of a structure or changes in the use of an existing structure are intended which would result in a significant environmental impact and require an application to be made for the right to exploit natural resources or for a permit for release of pollutants or waste into the environment, or amendment of an existing permit (§4 1). The environmental impact of activities proposed on the basis of a plan, national development plan or programme shall be assessed in the course of preparation or subsequent amendment of the plan, national development plan or programme (§4 2).

An environmental impact assessment shall be initiated by a decision-maker. The decision-maker is the issuer of authorisation. A developer shall organise environmental impact assessment and cover the expenses related thereto. A developer is a person who proposes an activity and intends to carry it out. A developer needs to have a authorisation. For the purposes of EIA, authorisation is the design criteria or building permit, the extraction permit, permit for special use of water, ambient air pollution permit, waste permit, or permit for release of genetically modified organisms into the environment or any other documents not specified in Environmental Impact Assessment and Environmental Auditing Act permitting commencement of activities with significant environmental impact.

A developer shall prepare an environmental impact assessment programme and submit the programme to the environmental authority of the site for approval. An environmental impact assessment programme shall contain a plan for the conduct and public disclosure of the assessment. At the request of a developer, the environmental authority shall submit prior written recommendations concerning the environmental impact assessment programme. An environmental authority shall approve an environmental impact assessment programme within two weeks after public consultation. If the environmental impact may extend to another county, a transboundary water body or the sea or become transboundary, the environmental authority shall forward the environmental impact assessment programme together with an opinion to the Ministry of the Environment within two weeks and shall inform the developer thereof. The Minister of the Environment shall approve such environmental impact assessment programme within two weeks after public consultation.

[47] Environmental Impact Assessment and Environmental Auditing Act, RT I 2000, 54, 348

If a developer fails to submit an environmental impact assessment statement to the decision-maker within two years after approval of the environmental impact assessment programme, the programme expires and a new environmental impact assessment programme shall be prepared in order to assess the environmental impact.

A developer shall organise an environmental impact assessment pursuant to the approved environmental impact assessment programme. Environmental impact shall be assessed by an expert holding an appropriate activity licence issued pursuant to the procedure established by this Act. Environmental impact may be assessed also by a legal person through an employee holding an appropriate activity licence. An expert shall prepare an environmental impact assessment statement (§13 2) which:

- describes the activity, its purpose, scope and site, the status of the environment at the site, and the potential consequences of the activities, e.g. water, soil and air pollution, noise, vibration, light, heat and radiation;
- describes alternative sites and designs, and indicates the reasons for the choice made, taking into account the potential environmental impact;
- determines the scope of the potential environmental impact on the status of the environment, human health, property, flora, fauna, soil, the landscape, climate, protected natural objects and objects protected under heritage conservation;
- assesses the effects of the likely environmental impact of the activities and describes the measures envisaged in order to avoid or mitigate the potential danger;
- assesses the efficiency of the use of natural resources;
- makes proposals for the conduct of environmental monitoring and environmental auditing;
- contains an environmental impact assessment programme;
- contains proposals from third parties and the reasons why they were taken into account or disregarded;
- contains a short summary of the assessment results.

In §15 is stated the access to environmental information. Persons or agencies holding environmental information concerning the likely environmental impact of an activity or the status of the environment at a site shall make such information available without charge to the developer, decision-maker, expert and person exercising supervision. Everyone has the right to obtain information concerning the likely environmental impact of an activity from the decision-maker, submit written and oral questions or make proposals and obtain responses thereto.

A decision-maker shall give notice of the initiation of an environmental impact assessment and of completion of an environmental impact assessment statement within ten days as of the making of the initiation decision or the receipt of the assessment. A notice shall set out the place and time of the activities, the place and time for access to information concerning the assessment of the likely environmental impact, and the place and time of public consultation.

After completion of an environmental impact assessment programme and statement, the developer shall organise public consultation in order to inform the public of the activities proposed by the developer. If necessary, a developer shall amend the environmental impact assessment programme on the basis of the proposals made.

Proposals made with regard to an environmental impact assessment statement shall be annexed to the statement. If a developer disregards the proposals, the developer shall annex the reasons therefor to the statement.

A developer shall submit an environmental impact assessment statement to the decision-maker who after annexing the proposals made in the course of public consultation, shall forward the statement for approval to the person exercising supervision. The person exercising supervision shall return the statement together with annexed environmental requirements to the decision-maker and the developer within one month as of the receipt of the statement.

If a developer fails to commence activities within two years as of the issue of authorisation, the environmental requirements expire and a new environmental impact assessment statement shall be submitted to the person exercising supervision in order to obtain new requirements.

2.3 Conclusions

2.3.1 Present constraints/barriers to extensive introduction of wind energy

The main direct barrier to extensive introduction of wind energy in Estonia is the lack of confidence in market conditions for potential investors as the level of feed-in tariff is annually pegged to the share of renewable electricity in the total electricity consumption in Estonia during the previous year (see section 2.2.1.2). In case this limit will be exceeded lower feed-in tariff would be introduced. Moreover, the Energy Act stipulating these support measures will be repealed and replaced with new acts, provisions of which are not yet known by public.

The next set of barriers is of more indirect character and is related to the structure of energy sector. The monopolistic build-up with the one and only vertically integrated electricity utility being responsible of generation, transmission, distribution and sales, does not enable wider development of independent power producers, especially the ones, which utilize renewable energy sources.

The situation in Estonian electricity sector is not favorable for installing new generation capacity (including renewable-based) as there is a high rate of surplus installed capacity in existing power plants.

The very low level of rates of environment-related taxation does not support the use of renewable energy sources. In such a situation the fossil fuels, in Estonia particularly oil shale, are in preferred status. As the result, even the direct impact of emissions on environment is not compensated, to say nothing of the internalizing externalities.

The effect of the limitations of the electricity network is complex, and needs relevant capacity and sensitivity analyses to be carried out. As an expert opinion, it can be stated that in many regions of Estonia with good wind conditions the network is the factor limiting installation of new capacity of wind generators.

Of course, several problems with wind energy usage are similar in almost all countries developing wind energy, e.g.:

- wind technology needs further development to continue to reduce costs. The technology also needs the economies of scale and experience that can only be obtained from an expanding market;
- authorities need further information, experience and confidence to assist them in producing well founded policies and plans against which to judge individual development proposals;
- the technology needs to be demonstrated and monitored to assess the environmental impact;
- the intermittent nature of wind power and variability of wind speed results in a variable electricity supply, which causes certain problems for electricity systems (need for rapid regulation, balancing, reserves, etc);
- lack of availability of good sites near centres of electricity demand raises issues relating to the capabilities and associated costs of the development of electricity distribution system.

2.3.2 Proposals for amendments in legislation, creation of incentives and introduction of promotive measures

Planning to take measures for addressing barriers and introducing effective incentives to support the use of wind electricity in Estonia has to take use of relevant experience of countries with successful policy in this field. Due to the wide range of possible measures taken in other countries the need and possibility of inventing completely new incentives is very small. However, local situation and all peculiarities of national economy and energy system should be taken into account when introducing new measures.

There are several options for grouping of possible measures for supporting wind energy use. Here the following measure groups are analysed:

- general national policy (especially towards energy and environment);
- pricing and taxation, e.g.:
    - of fossil fuels;
    - of RES, particularly of wind-generated electricity;
    - internalisation of external costs;
- measures related to electricity market, e.g.:
    - grid connection conditions;
    - guaranteed purchase obligation;
    - liberalization of market;
- support to investments;
- environmental norms and standards (particularly on usage of fossil fuels);
- promotional and demonstration activities;
- voluntary agreements.

In practice, every measure in the list presented above, has to be at first elaborated in the framework of **energy and environment policy** and after that enforced by a **legislative** act. In Estonia, Government targets for increased deployment of renewable energy at policy level do exist. Targets are generally insufficient on their own, as they need to be backed by specific measures, but they can give guidance to governmental priorities, and imply government commitment, thus raising the profile of renewable energy with the public, industry, planners and developers. Targets are also very useful in so far as they provide a benchmark against which to measure progress, or define the success or failure of a programme. In Estonia, the new long-term developing plans for energy sector will be elaborated in near future. Hopefully, the plan will be better combined with the actual measures for supporting renewable energy.

Measures addressing **energy pricing** can range from the abolition of subsidies on competing fossil fuels to the full internalisation of external costs for all energy sources. Many countries have subsidised energy prices in the past, for political reasons, such as support for national industries. These subsidies are now being phased out as most countries move towards liberalised and deregulated market economies. In Estonia phasing out of direct subsidies in energy sector is almost complete, hence, in order to minimise economic and particularly social hardship, some indirect support measures for Estonian major indigenous fuel – oil shale are still at the stage of gradual phase-out.

Guaranteed purchase and fixed price support (feed-in tariff) approaches tend to be the most successful support mechanism in many west European countries. This method has been most effective in attracting investors to support renewable energy. It can be implemented with or without a competitive element and there are several options to cover expenditures on support measures: it can be funded:

- by all taxpayers via state budget;
- by earmarked proceedings from environmental (energy, carbon, etc.) taxes;
- by all electricity consumers via utilities adding these costs to transmission tariff;
- by individual customers (green pricing).

In Estonia the feed-in tariff with the fixed rate should be the most realistic option with the costs covered by all electricity consumers, e.g. via transmission tariff component in the end-user price.

Another group of potential measures **encourage investments** in renewable energy. Investment support measures can be classified as fiscal ones and may take usually the form of

- grants;
- subsidies,
- low-interest (soft) loans;
- tax breaks;
- accelerated depreciation.

The earliest support measures implemented in western Europe were often focused on investment grants, and these appeared to be very successful in stimulating much wider use of RES in some countries. At present, several European governments are now moving away from direct investment grants towards tax breaks, which enable to lower investors' capital expenditures, also, the accelerated depreciation can enhance the promotion of wind energy power applications. In Estonia, strong support for investments in RES based power production would be needed (reasonable) as fossil fuel based power production has dominated for decades already. Creation of business confidence on the conditions on electricity market for a longer-term period, however, seems to have a highest priority at present.

Promotional measures can take the form of information and education campaigns, networks of energy centres providing advice to developers, and demonstration schemes. These measures are quite widespread and are valuable for increasing confidence amongst industry, developers and financiers, but they are generally less important than the market conditions or financial support. Large-scale demonstration/market stimulation measures may also be combined with direct investment support through grants or subsidies. These measures can be important to raise awareness and build confidence in new technologies. However, it is sometimes found that, when the support measure finishes, the market for the technology disappears.

Approaches based on legislation or restructuring can be used to improve the opportunities for small-scale renewable energy schemes to be connected to the grid and to sell their output in the energy markets. In other cases all day-to-day operation of electricity generation is still centrally run by the government, with no opportunity for other producers to sell their electricity**. Restructuring of energy markets** to give increased competition often creates, due to liberalization, new opportunities for renewable energy as well. On the other hand, it can also have a negative impact on previously protected markets, exposing renewable energy technologies to markets in which they are not ready to compete.

Voluntary agreements between governments and industry/utilities can be arrived at. These are more common in the energy efficiency sector, but there are some examples of voluntary agreements by utilities to promote renewable energy. In Estonia it may be too early to try to introduce this type of policy.

Finally, a full **internalisation of external costs is** generally held to be infeasible at present, due to the great uncertainty of assessing environmental and social impacts in money terms. However, many countries have considered the adoption of carbon or energy taxes as a partial measure. Some west European countries have implemented carbon or energy taxes. However, exemption or refund of the carbon or energy tax for renewable energy schemes can make a very significant difference to their financial viability (e.g. Denmark, the Netherlands). However, there is political opposition to carbon taxes in many countries and it is unlikely that a consensus on the EU-level tax will be achieved in the short term. Most countries therefore also apply environmental regulations such as emission limits or quotas and planning guidelines. The problem of considering external costs is an acute one in Estonia, particularly for oil shale. Hence, here the solution should be found and relevant decisions made not in one only country but on wider basis. This kind of decision would enable to approach barriers as a whole, rather than via focused initiatives aimed at certain aspects of individual barriers.

As a consequence, it appears reasonable to conclude that in order to develop positively in the future, renewable generated electricity will require two essential elements:

- a price support mechanism that enables RES producers of renewable energy to enter the market and to make a reasonable profit, and
- a stable regulatory environment such that investors can enter the market without concern that the price support mechanism will be modified in a manner likely to make their investment unprofitable.

The authors of the current study have reached the consensus that the **minimum programme** for Estonia's wind energy development in near-term future should include initiating the following supportive measures:

- introduction of fixed feed-in tariff for wind-generated electricity supplied to national grid (transmission or distribution network); the continuation of purchase obligation for networks is assumed;
- providing the long-enough duration of the feed-in tariff (e.g. for the first 10 years from the installation of wind turbine);
- restructuring electricity sector of Estonia to avoid monopolistic character of electricity market based on a vertically integrated utility:
    - unbundling generation, transmission and distribution into separate enterprises.

The mid-term measures should include:

- the substantial increase of pollution charge rates, in particular the rate on CO_2 emission;
- use a part of proceeds from pollution charges for supporting renewable energy research and development (e.g. design of wind farms, mapping of wind resources, preparing technical infrastructure, assistance in grid connection, etc.).

The target to be reached in long-term future should be the complete internalization of externalities for all energy resources.

In general the legislation related to planning and building or environmental issues in Estonia stimulates the introduction of wind energy. The administrative processes in relation to obtaining permissions either to aquire or lease land, for building and operating wind turbines are moderately easy and several initiatives are going on to ease it further. The public participation in planning processes is enabled and additionally quarantined by request of EIA.

3 Estonian electricity market and price dynamics

A peculiarity of the Estonian energy sector is production of electricity from local fuel – oil shale, which completely covers domestic electricity consumption and enables also to export electricity. The Estonian oil shale-based energy complex was founded during the Soviet period ensuing from demand for electricity in the north-western region of the former Soviet Union. Intensive development of this complex started in the 1950ies. Oil shale mines and quarries were established and two large (Balti PP and Eesti PP) and several smaller oil shale power plants were built, which enabled in the 1980ies to extract 25–30 million tonnes of oil shale and produce electricity in the amount of 17–19 TWh, from which 50–60% was exported to other north-western regions of the Soviet Union. Today Balti PP and Eesti PP are business units of the power generation company Narva Elektrijaamad AS (Narva Power Plants).

After regaining independence, the oil-shale energy complex inherited from the Soviet period no more satisfied the conditions of the Estonian economy and principles of sustainable development. It is a remarkable overcapacity that worsens the operating efficiency of the complex. The plants are old, need large investments for renovation, oil shale-based electricity production is extremely polluting and water consuming. Therefore, the long-term energy sector development plan[48] adopted by the *Riigikogu* (Estonian Parliament) in 1998 has envisaged gradual reduction of the share of oil shale-based electricity. However, it is still dominating, having dropped from 98% in 1996 to 91% in 2000. Therefore it is of crucial importance to analyse competitiveness of alternative electricity productions in Estonia in comparison with oil shale-based electricity production. The key issue here is full consideration of environmental costs.

This chapter analyses and forecasts formation of the oil shale-based electricity production price at Narva Power Plants against the background of the calculations of wind energy based electricity price in the Pakri WF. We have also prepared prognoses of electricity net production and domestic consumption in Estonia for the years 2005 and 2010.

3.1 Estonian electricity sector developments in 1991–2010

Production and consumption of oil shale-based electricity – the main output of Estonian energy sector – has been declining since 1991 (1996 and 1997 excepted). The decline has been due to the general structural changes in economy combined with the decline of industrial and agricultural production in Estonia and the fall in the exports of electricity. The respective dynamics is depicted in Table 3-1.

The efficiency of the Estonian electricity sector is far from satisfactory. The shares of energy system losses and own use of power plants are very high both in the gross production and electricity sales. And these indicators have worsened compared with the early 1990ies (see Table 3-1). This can be explained by the decline in electricity production and the ensuing worse consumption of capacities. The shortcomings in

[48] Long-Term National Development Plan for the Fuel and Energy Sector, RT I 1998, 19, 295

reforming the Estonian energy system have also contributed to the decline in efficiency.

Electricity consumption in Estonia has declined nearly 1.3 times and exports more than 5 times in the period 1991–2000. The latter fact is mainly due to the decline of exports to Russia, because demand by our second export partner – Latvia – has been relatively stable. Analysis of the dynamics of domestic consumption of electricity on the basis of Table 3-1 indicates that the sharp declining tendency in the initial years of transition began to be replaced by stabilisation of consumption only in 1994. Since 1996 the consumption of electricity has increased slightly. This dynamics is consistent with the general economic decline or growth in Estonia in the years under discussion.[49]

By now (2002) the annual electricity net production has stabilised around 7,500–8,000 GWh and inland consumption on the level of 5,500 GWh. A more detailed analysis of the dynamics of electricity consumption by branches of economy allows us to state that this also reflects quite well the respective structural changes and development tendencies. A stabilisation of electricity consumption could be observed in industry, construction and transport in the middle of the period 1991–2000. Reflecting the growth of the share of business and public sector, the electricity consumption by this sector also has a tendency to grow. Electricity consumption has declined most dramatically in agriculture (7.3 times during the period under discussion).

Electricity consumption by households reached the lowest rate in 1995, followed by a considerable growth until the end of the period (both in absolute terms and per capita). Eventually, the consumption by households in the last years of the period, in 1998–2000, exceeded the initial level of the transition period. Considering that electricity consumption by households is regarded as one of the life quality (standard of living) indicators, such development in our energy sector must be deemed positive.

Based on the dynamics presented in Table 3-1 the interval forecast of the electricity demand in Estonia is calculated for 2005 and 2010. These calculations are based both on extrapolation methods and expert estimations. The results of the forecast are presented in Table 3-2 and also in Figure 3-1 (electricity net production) and Figure 3-2 (domestic consumption).

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[49] Laur, A., Soosaar, S. and Tenno, K. (2001). Utilisation of Estonian Energy Resources: Towards Sustainability. In: Ü. Ennuste and L. Wilder (eds.). Factors of Convergence: A Collection for the Analysis of Estonian Socio-Economic and Institutional Evolution. Estonian Institute of Economics at Tallinn Technical University, Tallinn, 193–226.

Table 3-1. Dynamics of the electricity balance, GWh

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Gross production	14,627	11,831	9,117	9,152	8,693	9,103	9,218	8,521	8,268	8,513
Net production	13,061	10,437	7,993	8,006	7,607	7,987	8,065	7,538	7,352	7,591
Own use in power plants	1,566	1,394	1,124	1,146	1,086	1,116	1,153	983	916	922
Losses	1,086	1,029	1,470	1,527	1,773	1,710	1,510	1,569	1,470	1,240
Own use + losses	2,652	2,423	2,594	2,673	2,859	2,826	2,663	2,552	2,386	2,162
Consumption in Estonia	7,204	5,916	4,927	5,288	5,074	5,417	5,581	5,579	5,286	5,422
incl. in industry	3,369	2,487	1,990	2,021	2,087	2,243	2,488	2,260	2,234	2,183
in construction	81	79	50	188	120	119	110	102	99	100
in agriculture	1,595	1,101	784	434	366	341	247	269	238	219
in transport	172	165	137	194	191	105	108	113	91	91
in commercial and public services	857	854	871	1,181	1,243	1,375	1,423	1,486	1,261	1,363
in households	924	1,230	1,095	1,270	1,067	1,234	1,205	1,349	1,363	1,466
per capita (kWh)	589	796	722	847	719	840	826	931	945	1,020
Export	4771	3,492	1,596	1,191	760	860	974	390	596	929
Total sales	11,975	9,408	6,523	6,479	5,834	6,277	6,555	5,969	5,882	6,351
Own use + losses from gross production (%)	18.1	20.5	28.5	29.2	32.9	31.0	28.9	29.9	28.9	25.4
Own use + losses from total sales (%)	22.1	25.8	39.8	41.3	49.0	45.0	40.6	42.8	40.6	34.0

Sources: Statistical Office of Estonia. (2000). Statistical Yearbook of Estonia 2000. Tallinn (CD-ROM);
Laur, A., Soosaar, S. and Tenno, K. (2001). Utilisation of Estonian Energy Resources: Towards Sustainability. In: Ü. Ennuste and L. Wilder (eds.). Factors of Convergence: A Collection for the Analysis of Estonian Socio-Economic and Institutional Evolution. Estonian Institute of Economics at Tallinn Technical University, Tallinn, 193–226.

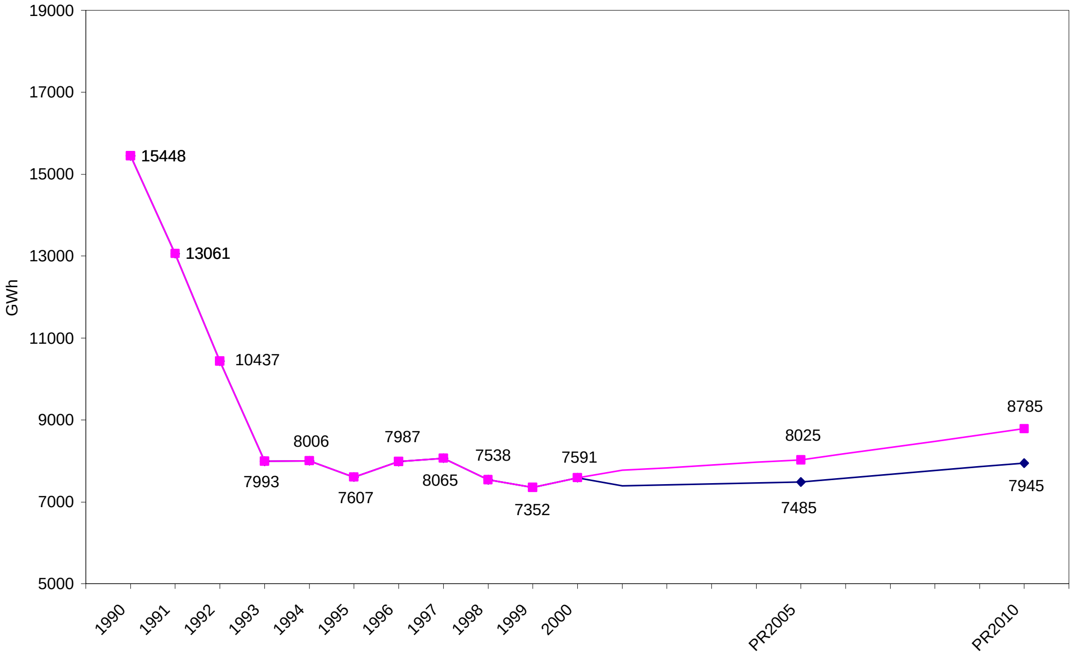

Figure 3-1. Dynamics and forecast of the electricity net production in Estonia

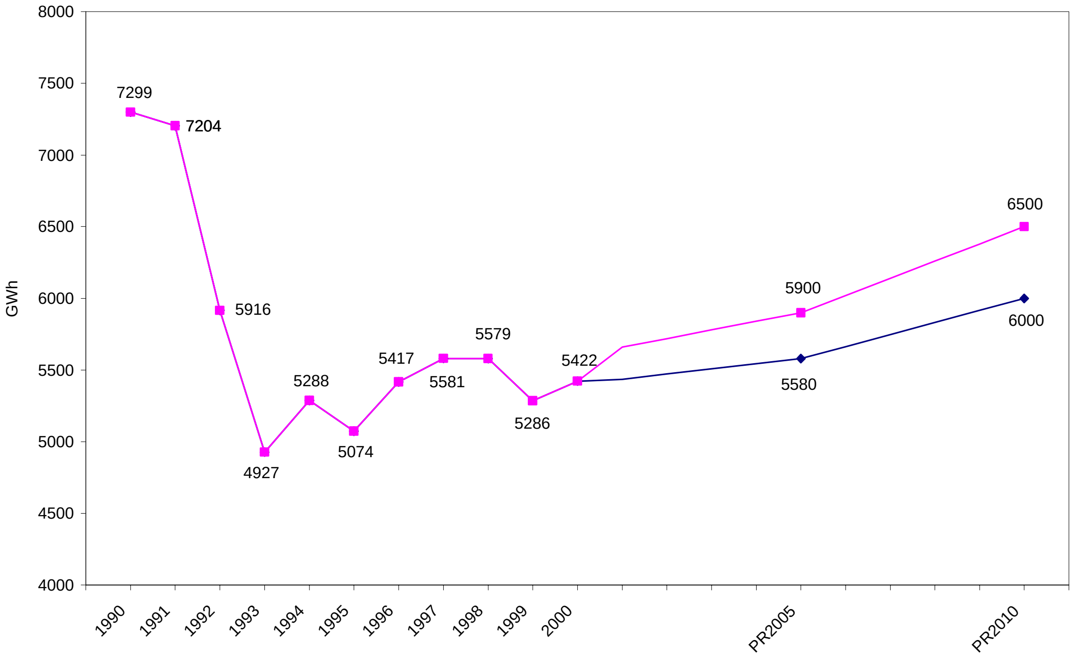

Figure 3-2. Dynamics and forecast of the electricity consumption in Estonia

Table 3-2. Forecast of electricity demand in Estonia until 2010, GWh

	2005	2010

Total demand for electricity (gross production)	8,380–9,050	8,900–9,850
incl. net production	7,485–8,025	7,945–8,785
incl. domestic consumption	5,580–5,900	6,000–6,500

Table 3-3 presents the changes in the use of fuels for electricity generation during the period 1996–2000. We can see that the share of oil shale dominating in power generation in Estonia has declined from 98% in 1996 to 91% in 2000. This reduction happened mainly at the expense of increased use of natural gas, while the use of other fuels and the production of hydroenergy remained at the levels of 1997 and 1998. The share of electricity produced from renewable energy sources remained less than 0.5% in 2000.

Table 3-3. Fuel consumption for electricity production

Index	1996	1997	1998	1999	2000
Electricity gross production, GWh	9,103	9,218	8,521	8,268	8,513
Share of oil shale, %	98	95	93	92	91
Consumption of natural gas, million m^3 Growth	11	21 +91%	26 +24%	34 +31%	89 +162%
Consumption of other fuels, TJ Growth	2004	2431 +21%	3041 +25%	3079 +1,2%	2324 -25%
Production of hydroelectric energy, GWh	2	3	5	5	5
Production of wind energy based electricity, GWh			0.30	0.32	0.33

The development of nominal electricity prices in the last 10 years (1992–2002) is given in Table 3-4 separately for average electricity price and basic tariff for households (both without VAT). Figure 3.3 gives a comparison of the development trends of the basic tariff for households and the consumer price index (CPI) in the period 1993–2002 (CPI is used as the main indicator of inflation in Estonia). We can see that the increase of the nominal end-user price has been mainly slower than the growth of CPI. The electricity price trend has reached the CPI level only at the end of the period, which means that the real price of electricity for households has not increased.

Table 3-4. Development of nominal electricity prices (excl. VAT)

Date of enforcing	Average price*		Tariff for households	
	EEK/kWh	EUR/100 kWh	EEK/kWh	EUR/100 kWh
01.12.1992	0.111	0.71	0.127	0.81
01.11.1993	0.158	1.01	0.161	1.03
01.09.1994	0.246	1.57	0.246	1.57
01.01.1995	0.297	1.90	0.297	1.90
01.10.1995	0.335	2.14	0.331	2.12
01.06.1996	0.385	2.46	0.381	2.44
01.05.1997	0.490	3.13	0.508	3.25
01.01.1998	0.510	3.26	0.551	3.52
01.01.1999	0.578	3.69	0.636	4.06
01.01.2001			0.763	4.88
01.04.2002**			0.932	5.96

* *After 1999 the average price for electricity has not been calculated*

** *New tariffs were approved by the Energy Market Inspectorate on the 28th of September 2001*

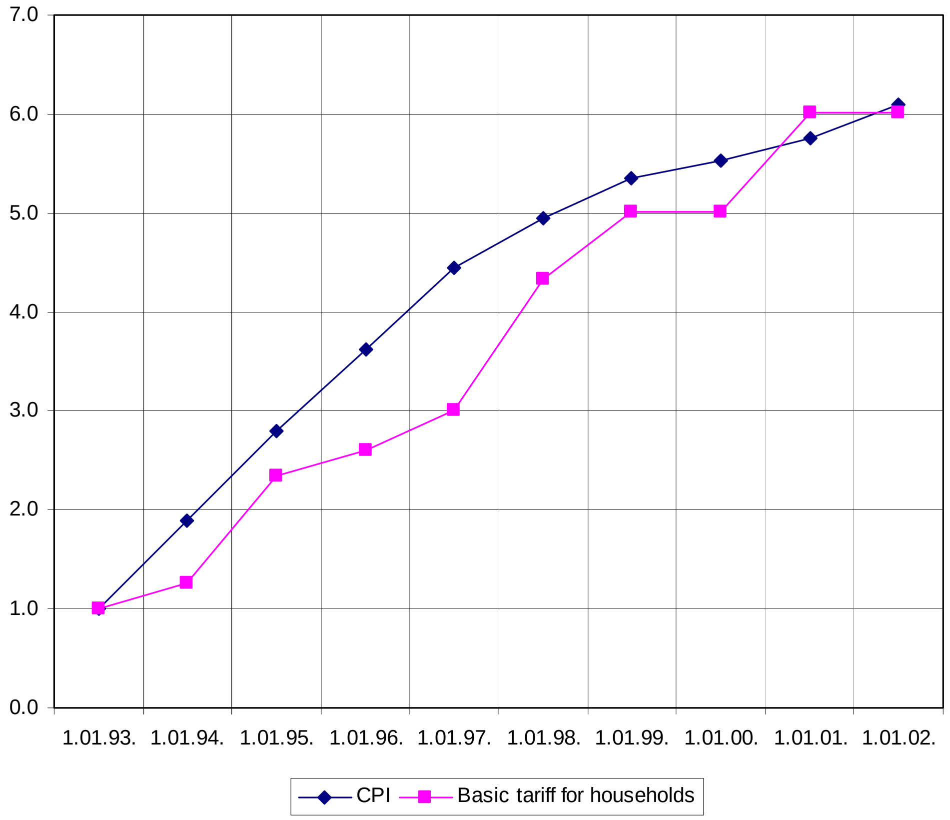

Figure 3-3. Development trends of the basic tariff for households and consumer price index

3.2 Baltic and Scandinavian electricity prices 1995–2000

In the following tables the (Table 3-5 and Table 3-6) average electricity prices in countries close to Estonia (Scandinavian and Baltic states, also for Russia) are presented and relevant development trends analysed. As background information, the data on electricity price development in EU is given. To ignore the impact of fiscal measures (due to huge differences in taxation) the prices are given without any taxes. This approach enables to see generic price differences and make some assessments of the future situation for Estonia in the electricity market, in case there will be interconnections between electricity systems of Estonia and EU (e.g. Nordic countries).

The comparison of electricity prices, even with excluded taxes, between countries is a complicated task due to several reasons. The main reasons are: at first, the tariff systems are usually complicated (many consumer categories, energy and capacity charges, time-of-day tariff rates, etc.) and at second, there is a need to take into account exchange rates between national currencies either on nominal level or using purchasing power parities. In addition, prices for large industrial users (in some cases even for medium size ones) are not available for official statistics, as considered confidential.

In the following analysis of the electricity price development in EU Member States the statistics from the Statistical Office of the European Communities (Eurostat) and the Union of the Electricity Industry (EURELECTRIC), were used. For Estonia, Latvia, Lithuania and Russia mainly national sources (statistics offices, energy utilities) and partially data from EURELECTRIC were used.[50]

Table 3-5. **Electricity price for medium industry user, EUR /100 kWh (without taxes)**

Country	1995	1996	1997	1998	1999	2000
Denmark	4.42	4.70	4.63	4.97	4.71	4.96
Finland	4.64	4.75	4.08	4.14	3.82	3.75
Sweden	n.a.	4.27	4.22	3.68	3.51	3.88
EU	7.13	6.85	6.63	6.44	6.32	6.44
Norway	3.25	4.28	3.53	3.59	3.40	3.16

Source: Eurostat
Notes: Prices as of on 1st July;
For EU weighted average according to national consumption.

As to the whole EU, electricity prices for industrial consumers have gone down in almost all Member States since the Electricity Directive was implemented. The prices given in Table 3-5 are in nominal values of current years. The downward trend is more explicit when using time series of deflated (e.g. using GDP deflators) prices. In general, the most significant price reductions can be found in the Member States that have opened market by 100% (Germany, Finland, Sweden, UK). Hence, it must be noted that in addition to the effect of liberalisation, the change in fuel costs and the fuel mix may also affect price developments in power generation. In Sweden and especially in Norway the price level is substantially influenced by the weather, as electricity generation there is based mainly on use of hydro energy. Due to the common Nordic market this impact is reflected on prices in neighbouring countries as well. Thus, the price evolution over time reflects the introduction of competition as well as the evolution in production costs, i.e. fuel costs, fuel mix and the introduction of new technology.

The electricity market liberalisation in EU started in UK, which is out of scope for the current study. Finland and Sweden were the next countries to carry out the liberalisation. Since the introduction of competition in 1995 in Finland prices have decreased by 20%. Similar results have appeared in Sweden where prices have decreased by 15% since the start of liberalisation in 1996. At the same time, the electricity prices in these two countries already were among the lowest in EU before liberalisation. By the way, in Germany, where liberalisation has taken place only recently, prices reduced rapidly by, on average, 25% between 1998 and 2000.

Table 3-6. Electricity price for medium household user, EUR /100 kWh (without taxes)

Country	1995	1996	1997	1998	1999	2000
Denmark	6.24	6.42	6.32	6.70	6.76	7.15
Finland	7.40	7.60	7.17	7.10	6.46	6.43
Sweden	n.a.	6.66	6.72	7.01	6.22	6.52

[50] In case of statistics for EU Member States the industrial electricity prices for Eurostat group Ie (annual consumption 2 GWh, max demand 500 kW with annual utilization of 4000 h) were used, which corresponds to group B2 in EURELECTRIC classification. Household prices are given for the consumer sub-group with the annual consumption of 3500 kWh, including 1300 kWh night-time consumption, with the subscribed demand of approximately 4–9 kW. This corresponds to the standard household consumer of group Dc in Eurostat classification and to the group C2 in EURELECTRIC classification.

EU	10.89	10.79	10.79	10.57	10.48	10.40
Norway	6.52	6.83	6.80	7.36	6.89	6.56

Source: Eurostat
Note: Prices as of on 1st July;
For EU weighted average according to national consumption.

The level of the price reductions is less pronounced for households, as can be seen in the Table 3-6. Again, the price reductions are connected to the market liberalisation. The largest price reductions in EU can be found in the Member States where it has been easy for households to change electricity supplier. Experience from Finland and Sweden shows that households benefited from liberalization, especially after the requirement to invest in expensive metering equipment was abolished and the concept of reference load curve profiles was introduced. This occurred in 1998 in the case of Finland and 1999 for Sweden. Since 1998, average prices (deflated using consumer price index) for domestic consumers have been reduced by 13% in Finland and by 16% in Sweden.

Table 3-7.Electricity prices in 2001, EUR/100 kWh (without taxes)

Country	Households	Industry
Denmark	8.13	5.64
Finland	6.66	3.80
Sweden	6.84	3.75
EU	10.33	6.33
Norway	8.75	4.15
Estonia	4.87	4.65
Latvia	5.90	5.18
Lithuania	5.00	5.83
Russia	1.44	2.00

Sources: EURELECTRIC (Estonia, Latvia, Lithuania – as on 1 January);
Eurostat (EU Member States and Norway – as on 1 July);
RAO EES Rossii (Russia – as in July).

The level of electricity prices in Estonia's neighbouring countries according to the latest available information is presented in Table 3-7. As can be seen, the present price level in Estonia is relatively high already, especially for industrial consumers.

In Estonia, the new, considerably higher tariff rates (for details see sub-section 2.2.1.7 to be introduced on 1 April 2002 have been approved by the Energy Market Inspectorate. The basic tariff rate for households will be raised to 5.96 EUR/100 kWh (excl. taxes). Additionally, there will be introduced a new obligatory monthly charge for household consumers of 1.08 EUR/month, therefore new average price for households (category Dc in Eurostat statistics) will be approximately 6.33 EUR/100 kWh.

There are known plans to increase electricity tariffs also in Russia (by approximately 32% during the year 2002). In Lithuania the energy utilities have applied to the National Control Commission for Prices and Energy for the price increase by 25% (as an average) starting from 1 April 2002. At present, plans for price increase in Latvia are not known yet. In other countries in the neighbourhood of Estonia the consumer prices are not regulated, therefore the price development even in near future can only be approximately predicted using forecast studies carried out by scientific researchers and experts of the electricity sector.

3.3 Oil shale-based electricity production prices of the Narva Power Plants in 2000–2010

3.3.1 Analysis and forecast of the main cost items

Below we shall analyse formation of the oil shale-based electricity price at Narva Power Plants in 2000. Special focus is on the role of environmental costs in the oil shale-based electricity production price. We also predict the oil shale-based electricity production price for 2005 and 2010 based on electricity consumption (demand) as forecasted in 3.1, as well as forecasts of the reduced share of oil shale-based electricity. The latter is predicted to decline from 90.6% in 2000 to 87% in 2005 and to 80% by 2010. On the basis of these (initial) forecasts we have predicted the amount of electricity transmitted from Narva Power Plants into network (net production) and the amount of oil shale needed for the production of this electricity. This serves as a direct basis for forecast of the oil shale-based electricity production price. All actual values of the above-mentioned basic parameters in 2000 and forecasts for 2005 and 2010 are presented in Table 3-8.

Based on the methods used, the forecasts received are nominal price forecasts, i.e. at the current price of respective year. Also, final results do not contain profit earned by power plants. As regards consideration of the environment component, this is the low-level version of the environmental costs which is based on the currently effective (up to 2005) system of environmental charges in Estonia. The prognosis for the year 2010 proceeds from the current national strategy for raising the rates of charges (maximally 20% annually).

Calculations and prognostications of oil shale-based electricity production prices (production costs) are based on data provided by the annual report of power company Eesti Energia AS (EE) for the financial year 2000/2001 and by the authors' calculations.[51] The annual report contains data on the period from 31.03.2000 to 31.03.2001. In order to identify production costs for oil shale-based electricity these costs must be separated from the total costs of power plants, because we don't have more detailed data on direct production costs of oil shale-based electricity at our disposal.

Table 3-8. Calculation and forecast of the oil shale-based electricity production and demand for oil shale

	2000	2005	2010
Electricity gross production, GWh	8,513	8,715	9,375
Electricity net production, GWh	7,591	7,755	8,365
Total sales, GWh	6,351	6,630	7,250
Incl. in Estonia	5,422	5,740	6,250
Export	929	890	1,000
Losses, GWh	1,240	1,125	1,115
Share of oil shale-based electricity, %	90.7	87	80
Gross production from oil shale, GWh	7,719	7,582	7,500
Incl. net production from Narva PP, GWh	**6,572**	**6,455**	**6,385**
Specific consumption of oil shale, thous. t/GWh	1.27	1.25	1.23
Needed amount for oil shale, thous. t	**9,832**	**9,478**	**9,225**

[51] Annual Report. (2000/2001). Eesti Energia AS, Tallinn.

The biggest expense item in electricity production certainly is the technological fuel – oil shale. As oil shale mining company AS Eesti Põlevkivi (EP) operates in the composition of EE as a subsidiary, oil shale production is a direct component of electricity production costs. It takes 87% of the expenses of EP (this part of oil shale output goes to power plants). Hence, production costs of oil shale-based electricity for 2000 are calculated in two parts: 87% of the EP expenses and expenses of power plants.

The cost item "Materials, consumables and supplies" also contains natural gas used by Iru PP, payment for water and other expenses.

The cost item "Other operating expenses" contains primarily environmental taxation related costs, which are calculated in detail below (see Section 3.3.2).

Separate cost items are "Personnel expenses" (wages and salaries, social charges, pension expenses), "Other expenses" and "Depreciation".

From total costs of electricity production we have subtracted shale oil sales and sale of heat from Narva Power Plants, turnover of Iru PP and turnover of Kohtla-Järve PP. All the other costs have been divided by net production of oil shale-based electricity from Narva Power Plants. The result, the oil shale-based electricity production price (without profit) in 2000 is 0.35 EEK/kWh (2.25 EUR/100 kWh), including 0.05 EEK/kWh (0.32 EUR/100 kWh) as environmental costs.

The following methodical principles have been used to forecast costs in 2005 and 2010.

The growth of natural gas and shale oil prices has been calculated on the basis of prognoses made by the Estonian Energy Research Institute.[52] The natural gas price will rise by 2005 1.16 times and by 2010 1.28 times compared with 2000. The shale oil price will rise by 2005 1.26 times and by 2010 1.36 times. According to expert estimates, the consumption of natural gas by Iru PP will grow 4% by 2005 and 10% by 2010 (compared with 2000).

The other operating expenses and other expenses are expected to grow by 2% annually, depreciation by 3% annually during the whole period under discussion.

Table 3-9. Calculation and forecast of the oil shale-based electricity production price, million EEK

	EP* 0.87	**Power Plants**	**Total 2000**	**Growth**	**Total 2005**	**Growth**	**Total 2010**
Materials, consumables and supplies	308	827	1,140		1,196		1,252
incl. natural gas at Iru TPP		247	247	1.16*1.04	298	1.28*1.1	348
water	5	20	25		30		36
other	308	560	868		868		868
Other operating expenses	204	373	577		734		1,022
incl. environmental charges	204	103	307		436		693
other		270	270	2% a year	298	2% a year	329
Personnel expenses	552	285	837	1.23	1030	1.43	1,197
Other expenses	11	3	14	2% a year	15	2% a year	17

[52] Vares, V. (ed.). (2000). Eesti majanduse erinevad arenguvariandid (Different development options of the Estonian energy sector). Contract No. 4/2000 report. Estonian Energy Research Institute, Tallinn. (in Estonian).

Depreciation	64	420	484	3% a year	561	3% a year	650
Total costs	**1,139**	**1,908**	**3,052**		**3,535**		**4,138**
Sale of shale oil Sale of thermal energy Iru TPP sales Kohtla-Järve TPP sales		-91 -147 -346 -152	-91 -147 -346 -152	1.26 1.04	-115 -147 -401 -152	1.36 1.1	-124 -147 -457 -152
Total oil shale-based electricity production costs	**1,139**	**1,172**	**2,316**		**2,720**		**3,258**
Net production, GWh		6,572	6,572		6,455		6,385
Production price, **EEK/kWh** **EUR/100 kWh**			 **0.35** **2.25**		 **0.42** **2.69**		 **0.51** **3.26**
incl. environmental costs **EEK/kWh** **EUR/100 kWh**			 **0.05** **0.32**		 **0.07** **0.46**		 **0.11** **0.73**

EP denotes AS Eesti Põlevkivi (oil shale mining company)

The growth of personnel expenses is calculated according to the inflation expectations – forecast of the consumer price index (CPI). The latter has been calculated on the following assumptions. The Estonian CPI in 2000 was 1.04 (consumer price rise 4%), in 2001 – 1.058. According to the prognoses made by analysts of the Bank of Estonia, the consumer prices are expected to grow in 2002 by 3.7% and in 2003 by 4%.[53] Next we forecasted the growth of consumer prices in 2004 and 2005 at 4%, in 2006–2010 at 3% annually. Based on these prognoses, the consumer price base index for 2005 against 2000 will be 1.23 and for 2010 1.43, which we used to forecast personnel expenses in oil shale-based electricity prices. The calculation process of the oil shale-based electricity production price on the basis of the above-described methods and the results are presented in Table 3-9. The oil shale-based electricity production price (without profit) at Narva Power Plants was forecasted to be 0.42 EEK/kWh (2.69 EUR/100 kWh) in 2005 and 0.51 EEK/kWh (3.26 EUR/100 kWh) in 2010, including environmental costs 0.072 EEK/kWh (0.46 EUR/100 kWh) and 0.114 EEK/kWh (0.73 EUR/100 kWh) respectively.

3.3.2 Detailed analysis and forecast of the environmental costs

Analysis and forecast of the environmental costs are based on Eesti Energia AS annual report for 2000/2001 and environmental report for 2000.[54] These costs are contained mainly in the cost items "Other operating expenses" and "Materials, consumables and supplies". The cost item "Other operating expenses" contains environmental taxation related costs presented by the following cost elements:

- pollution charges (for air and water pollution and solid waste);
- resource payments;
- costs for land rehabilitation;
- establishment and reduction of mining termination and environmental charges provision.

[53] Koovit, K. (2001). Eesti Pank langetas majanduskasvu ootusi (Bank of Estonia has lowered the expectations of economic growth). – Äripäev, 23. November (in Estonian).
[54] Environmental Report. (2000). Eesti Energia AS, Tallinn.

The first environmental taxation related cost element contains also the pollution charge for CO_2 emission that was established in Estonia in 2000 (Estonia has been the second amongst in EIT countries after Slovenia to introduce the CO_2 tax). The rest of the cost elements represent mining for oil shale.

Mining for oil shale and production of electricity also consume large quantities of water, which account for over 80% of the total surface water extraction and nearly 20% of groundwater extraction in Estonia. Payment for water consumption is contained in the cost item "Materials, consumables and supplies".

The respective data for 2000 and prognoses for 2005 and 2010 of all different environmental cost elements in the oil shale-based electricity production price are presented in Table 3-10.

Like in the calculation of the oil shale-based electricity production price, the main problem in the calculation of environmental costs was identification of expenses directly related with oil shale-based electricity production. So, in Table 3-10 we have subtracted expenses of heat and shale oil production at Narva Power Plants, as well as expenses of oil shale mining for production of oil. Forecasts for 2005 and 2010 take into account possible reduction of pollution amounts and increase in the efficiency of power plants as a result of technological improvements.

Table. 3-10. Calculation of the oil shale-based electricity environmental costs

	2000	**2005**	**2010**
Gross production from oil shale, GWh	7,719	7,582	7,500
Incl. net production from Narva PP, GWh	**6,572**	**6,455**	**6,385**
Needed amount for oil shale, thous. t	9,832	9,478	9,225
Emission of CO_2 from oil shale, thous. t	8,996	8,238	8,018
Pollution charge for CO_2, thous. EEK	44,982	93,089	204,459
Pollution charge, thous. EEK:			
- for other air pollutants	8,374	17,470	43,520
- for solid waste	13,912	24,572	48,842
- for water pollution	36,117	69,633	135,549
Establishment and reduction of mining termination and environmental charges provision, thous. EEK	145,063	145,063	145,063
Land rehabilitation, thous. EEK	23,975	35,963	43,156
Resource payments, thous. EEK	34,448	49,812	72,724
Payment for water, thous. EEK	25,223	30,268	36,321
Total environmental costs, thous. EEK	**332,423**	**465,870**	**729,634**
Environmental costs in production price:			
EEK/kWh	**0.051**	**0.072**	**0.114**
EUR/100 kWh	**0.33**	**0.46**	**0.73**

3.3.3 Concluding remarks concerning external costs for oil shale

Although the results of forecast indicate that environmental costs in the oil shale-based electricity production price will rise by 2010 compared with 2000, over two times (see Table 3-10), this still reflects the actual damage caused by the oil shale-based electricity production to the environment very little. Due to the still modest possibilities of Estonian economy the insufficient consideration of the environmental costs in the oil shale-based electricity price represents certain political and social compromise to control the electricity price. Unfortunately not for advantage of the environment. As an example here can be mentioned the reduced water supply tariffs for oil shale mining and power generation in comparison of other consumers. This regulation is enforced by Government until 2005. Calculating the payment for water according to the ordinary currently effective tariffs increases the environmental costs in oil shale-based electricity production price for example in 2000 by 50% – from 0.05 EEK/kWh (0.32 EUR/100 kWh) to 0.075 EEK/kWh (0.48 EUR/100 kWh).

Nevertheless Estonia has done the first steps towards internalisation of external costs for energy resources (introducing pollution charge for CO_2, attempts to rise pollution charges 20% annually etc.) the level is very low compared to developed European countries.

To demonstrate how strongly the oil shale-based electricity price can be influenced by introducing externalities the following hypothetical calculation has been done for 2000. For the simplicity only one externality – CO_2 was considered using the pollution charge rate introduced in developed Nordic countries. The pollution charge rate for CO_2 emission established in Denmark for coal is 242 DKK/t [55] (about 500 EEK/t) which exceeds the rate used in Estonia (see Table 2-3) by hundred times. In Sweden the pollution charge rate for CO_2 emission from coal is even higher – for industrial consumers 469 SEK/t (about 800 EEK/t). Using the relatively modest, compared to Sweden, the Danish rate for the CO_2 emission from oil shale-based electricity production in Estonia (8,996 thous. t in 2000) the environmental costs will increase very significantly. In particular case – the value increases from 0.05 EEK/kWh (0.32 EUR/100 kWh) to 0.73 EEK/t (4.65 EUR/100 kWh) and the total oil shale-based electricity production price from 0.35 EEK/kWh (2.25 EUR/100 kWh) to 1.03 EEK/kWh (6.57 EUR/100 kWh) i.e. about 3 times. Comparing this result with the calculations of the wind energy based electricity prices (see Section 5.2.2) one can conclude that introducing only one externality with rates accepted in neighbouring Nordic countries for power generation based on oil shale will give obvious advantages to wind energy based electricity production.

Fast and strong enforcement of such changes in legislative basis in the form of regulations is not actually possible in the short term considering the level and possibilities of country’s present economy and purchasing power of consumers. However, the government has to find the best available strategy for curbing the environmentally harmful electricity production, also for the development of significant increase of using local renewable energy sources in coherence with the requirements of the most recent EC Directive (2001/77/EC)[56] on RES wider promotion in Europe.

[55] Database on environmental taxes. (2001). (http://europa.eu.int/comm/environment/enveco/)

[56] Directive of the European Parliament and of the Council on the promotion of electricity from renewable energy sources in the internal electricity market (2001/77/EC), 27.09.2001.

4 Wind energy potential and planning processes according to EIA requirements

To promote sustainable exploitation of wind resources it is important to figure out the most favorable sites and areas for wind power plants in the early stage of planning. Acceptable sites are only those which are economically profitable (i.e., good wind conditions) and do not conflict with environmental and public interests.

To ensure full coverage of the Paldiski area with high spatial resolution of wind resources and factors affecting use of wind energy the multi-level approach is used. In first stage all calculations and environmental impact assessment are performed for Paldiski area and all unsuitable areas are eliminated. In next stage the detailed wind resources analyses are performed for Paldiski pilot project (Paldiski PP) area where also small-scale impacts according to technological solutions are taken into account in EIA. In final stage the experience of Paldiski pilot project is used for up scaling and determining all suitable sites for wind farms with exactly defined number of allowed wind turbines in each field of the potential Pakri wind farm study area.

The present study aims to take into account all known factors having impact on environment caused by wind energy utilization. In less extent also indirect social effects are considered in EIA as landscape aesthetics, alternative land use, etc. which are highly dependent on public opinion and are subject of change according to positive or negative feedback of construction of first wind farms. The public hearings and public participation in EIA process is avoided in frames of the current study as this stage presume exact wind farm building project with defined construction and technological solutions. Therefore public participation in EIA could be included in following stages when planned wind farm capacity, design and time-schedule are defined.

4.1 Estimation of wind characteristics

The results presented in this chapter are based on similar material and methods used for the European Wind Atlas[57] where the influence of nearby sheltering obstacles, roughness and orography of the surrounding area are taken into account when modelling wind resources. More attention has been paid on modelling the spatial and temporal distribution of wind resources over the whole Paldiski area. The PC program WA^{S}P (Wind Atlas Analysis and Application Program) worked out at Risø National Laboratory, Denmark, was used to perform the calculations.

Three different type of time series have been used:

- Long period mean monthly wind data (1899–1990);
- Hourly wind measurements from Pakri meteostation;
- High frequency measurements with automatic weather station.

[57] Troen, I. & Petersen, E.L., 1989. European Wind Atlas. Risø National Laboratory, Roskilde.

Based on the mean monthly wind statistics from Pakri meteorological station during 1899–1990 the long period variation of wind speed and energy density is calculated. Estimations of the lowest and the highest possible energy yields are performed.

Continuous time series with high-quality of measurements were chosen from Estonian Meteorological and Hydrological Institutes' (EMHI) Pakri meteostation to model spatial distribution of wind resources. The nominal period for model runs was 10 years (01.01.1981–31.12.1990) where data sets are consisting of observations after each 3 hour.

Wind measurements at 25 m and 40 m height are carried out with automatic weather station to validate measurement data from EMHI Pakri meteostation. Simultaneous data sets dated to 2001–2002 were analysed from Pakri meteostation and automatic weather station to compile wind data for WA^{S}P calculations.

4.1.1 Regional wind and wind energy characteristics at Paldiski area

Estonia is situated on the eastern coast of the Baltic Sea. This is a region with intensive cyclonic activity and therefore with a relatively high mean wind speed. The general character of the Estonian wind regime is determined by atmospheric circulation and its seasonal variation over the Atlantic Ocean and Eurasia. However, the Baltic Sea itself is a very important factor affecting wind climate, it has an especially strong influence on the wind regime in coastal areas (Figure 4-1).

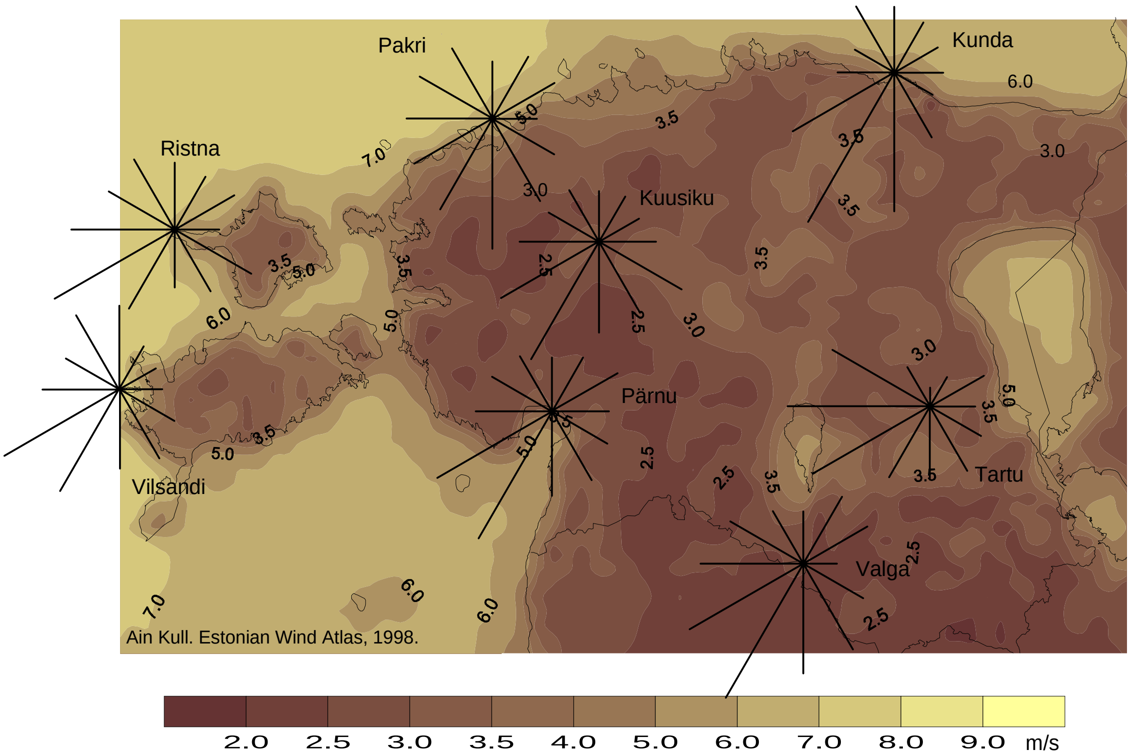

Figure 4-1. Mean annual wind speed at 10 m above ground level

The test area Pakri Peninsula is a typical coastal location with moderate to good wind condition and thereby it is very well suitable for feasibility study for wind farms that should represent Estonian coastal conditions. In winter the monthly mean wind speed on islands and on the western coast reaches 7–8.5 m/s, in the inland areas it remains between 4–5 m/s. In summer, the season with lowest wind speed, wind is blowing in average 4–6 m/s in coastal areas and in the inland parts of Estonia it is up to 3–3.5 m/s.

4.1.1.1 Mean annual wind speed (m/s) at 10 m, 67 m and 80 m

Mean annual wind speed in Pakri Peninsula is highly influenced by surface roughness and cliff. The cliff reaches its maximum height (25 m) in NW part of the peninsula, but it stretches out also all over the northern and eastern coast. On the islands Suur-Pakri and Väike-Pakri cliff on the northern and north-eastern coast have significant influence on wind. On the lower levels (e.g. 10 m above ground level) wind speed is decreased by influence of cliff for winds blowing from NW, N and NE sectors. On the higher level (e.g. 80 m) reduction in wind speed caused by cliff is not significant, however the higher turbidity of air flow is still characteristic for W, NW, N and NE sectors.

The combined effect of orography (cliff) and roughness (high share of forest) results in a perceptible decrease in the mean wind speed within a narrow transition zone in coastal area. Mean annual wind speed at 10 m a.g.l. in Pakri Peninsula remains between 3.5–4.5 m/s at wooded sites, while open areas and wooded meadows in inland areas have wind speed of 4.5–5.5 m/s and open coastal locations 5–7 m/s. Over the off-shore areas mean wind speed reaches 6.5–7.5 m/s (Figure 4-1).

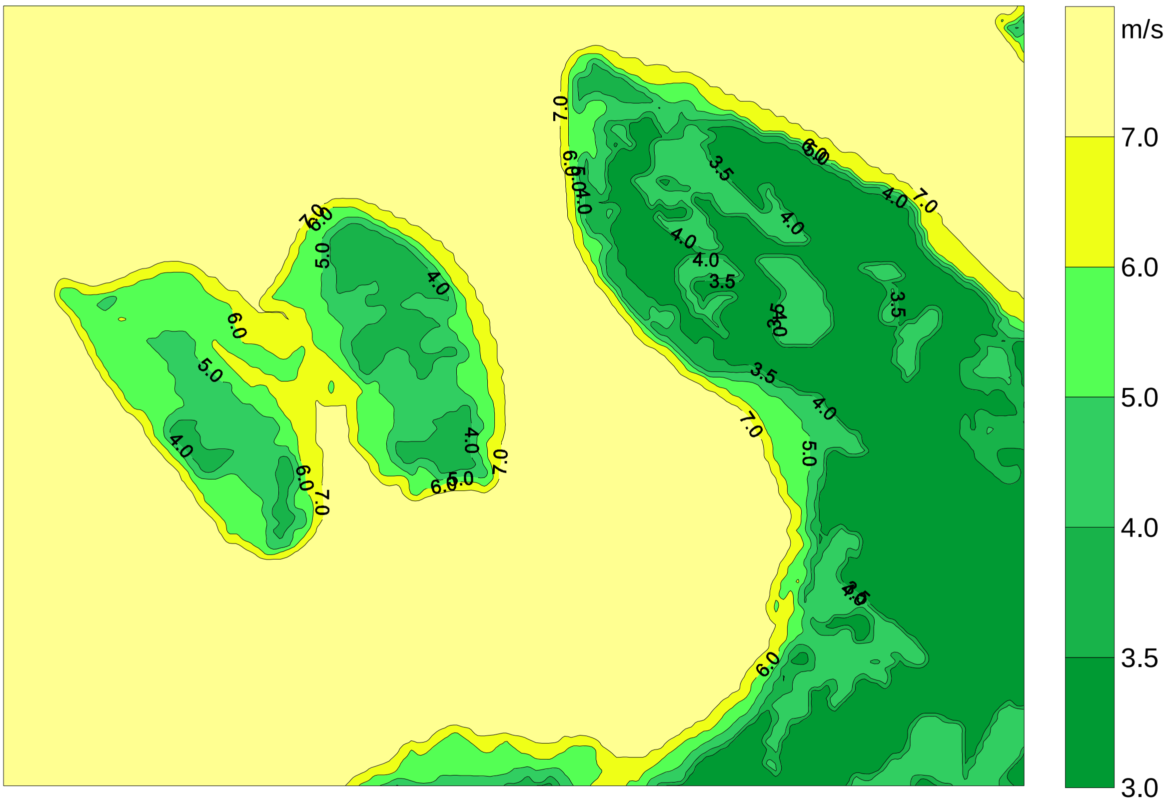

Figure 4-2. Mean annual wind speed at 10 m above ground level

Mean annual wind speed at wind turbine hub height (67 and 80 m a.g.l.) is less influenced by small scale fields and wooded meadows. Also effect of cliff is small, expressed mainly with slightly lifted air flow and higher turbidity. Over the sea differences in mean wind speed at 67 and 80 m a.g.l. are in range of 0.2–0.3 m/s, while in case of open fields in inland part of the peninsula differences reaches 0.3–0.6 m/s. At the height of 80 m a.g.l. the mean annual wind speed reaches 9.0–9.3 m/s over the off-shore areas, in coastal regions with open appearance the mean annual wind speed remains between 7–8.5 m/s and the open areas in inland parts of the peninsula have mean wind speed of 6.5–7.5 m/s.

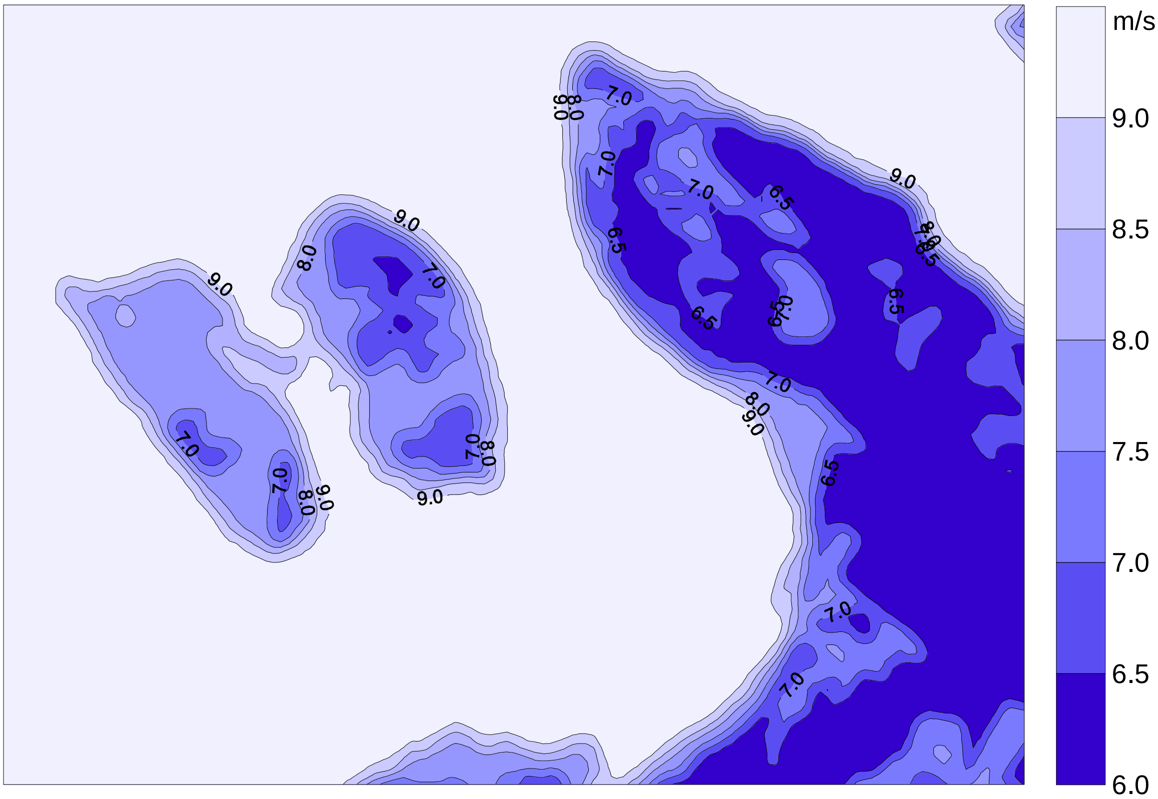

Figure 4-3. Mean annual wind speed at 80 m above ground level

The wind speed distribution has the highest occurrence of wind with speed of 4–8 m/s (68% of total). Share of stormy winds (>15 m/s) and calms (≤1 m/s) counts equally about 5% of total distribution of wind speed classes.

4.1.1.2 Mean annual energy density (W/m2) at 10 m, 67 m and 80 m

The mean energy density (W/m^2) is a wind energy characteristic that is proportional to the third power of wind speed and describes energy available in a flow of air through a unit area. Its temporal course is quite similar to the mean wind speed, but depends more on wind speed distribution. A greater wind speed variation can be observed in coastal areas, while inland parts have a more even wind distribution with a higher occurrence of wind speed in lower wind speed classes. Therefore the mean energy density in coastal areas is considerably higher than in inland areas.

The mean energy density is a characteristic which has practical importance in regional assessment of wind energy. Using wind turbine swept area and conversion efficiency the mean energy density gives an approximate value of the actual potential wind generated power.

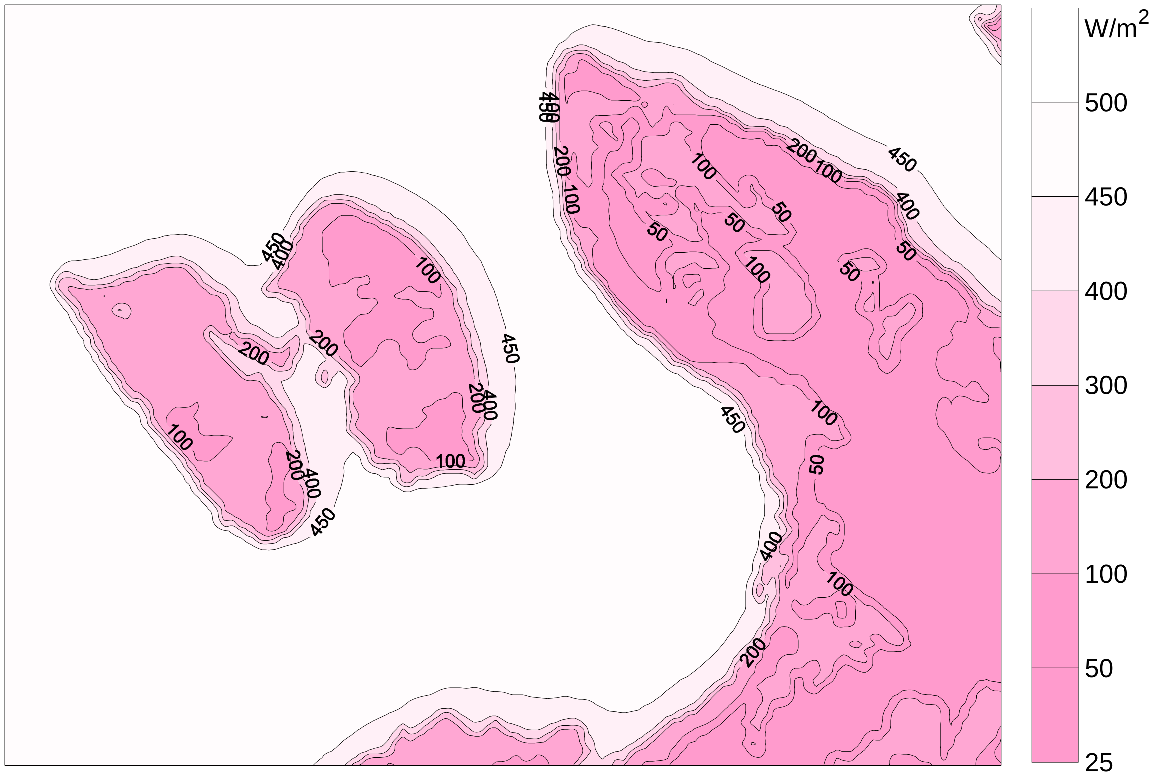

Figure 4-4. Mean annual energy density (W/m^2) at 10 m above ground level

On the coastal area of the Pakri Peninsula the mean energy density is up to 400 W/m^2 at 10 m height (Figure 4-4) above ground level and decreases rapidly from the sea to inland areas. In inland areas the energy density is relatively low, between 40 and 150 W/m^2 and increases from south-eastern part of the peninsula toward north-western Pakri. Even on the islands rapid decrease could be observed as the mean energy density drops from 450 W/m^2 to less than 100 W/m^2 in NE and SE part of the island Väike-Pakri.

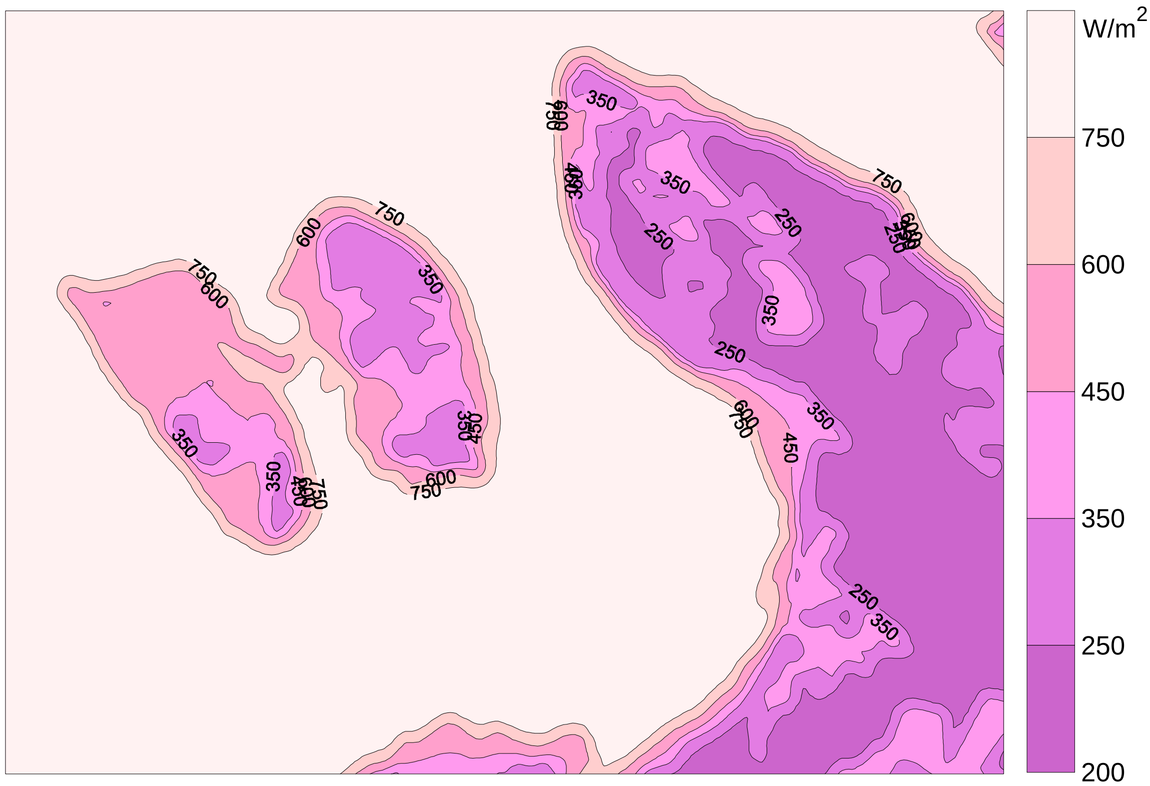

Figure 4-5. Mean annual energy density (W/m²) at 67 m above ground level

At a higher level the mean energy density increases as the influence of topography on wind speed decreases (Figure 4-5). In the coastal area it reaches 700 W/m² at 67 m above ground level. In inland parts of islands or continental areas the amount of energy in wind is much smaller. The increase in the mean energy density with increasing altitude is greater over islands and coastal regions. Inner parts of the islands have mean annual energy densities at 67 m height of 300–450 W/m². In most parts of the peninsula energy density value remains between 200 and 350 W/m². The mean energy density is closely related to wind turbulence, therefore it has somewhat smaller differences in territorial and seasonal variation compared to the mean wind speed.

4.1.1.3 Mean annual potential wind energy production (MWh/yr) by Vestas 850 kW, Vestas 2.0 MW and Südwind S70 wind turbines

Using standard power curves of three different wind turbines (850 kW Vestas V52, 1,500 kW Südwind S70 and 2,000 kW Vestas V80) the mean annual potential energy yield was modelled. Vestas V52 and V80 have different capacity but still highly similar power curve characteristics (slope, etc.) and therefore spatial differences in power production are minimal while power output is more than twice higher for V80 wind turbine (Figure 4-6 and Figure 4-14).

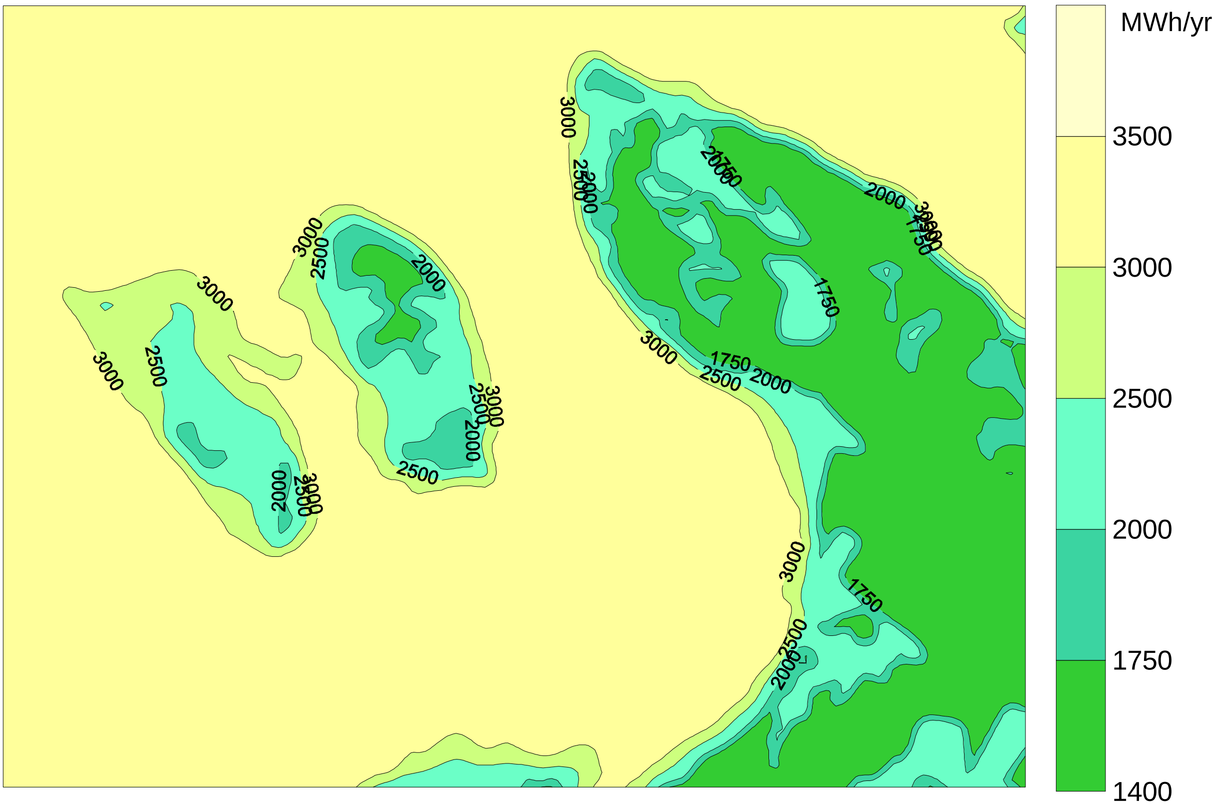

Figure 4-6. Mean annual energy yield (MWh/yr) by Vestas V52 wind turbine at 67 m above ground level

Mean annual energy yield (MWh/yr) by Vestas V52 wind turbine at 67 m above ground level reaches 3,000–3,200 MWh/yr over the off-shore areas, in coastal regions with open appearance the mean annual energy yield remains between 2,000–3,000 MWh/yr and the open areas in inland parts of the peninsula have mean annual energy yield of 1,700–2,500 MWh/yr.

Mean annual energy yield (MWh/yr) by Vestas V80 wind turbine at 80 m above ground level shows only slightly different spatial distribution, caused mainly by less variable wind speed distribution at height of 80 m. Relative differences in potential energy yield between coastal areas and inner part of the peninsula are smaller for V80 with hub height of 80 m than for V52 with hub height of 67 m.

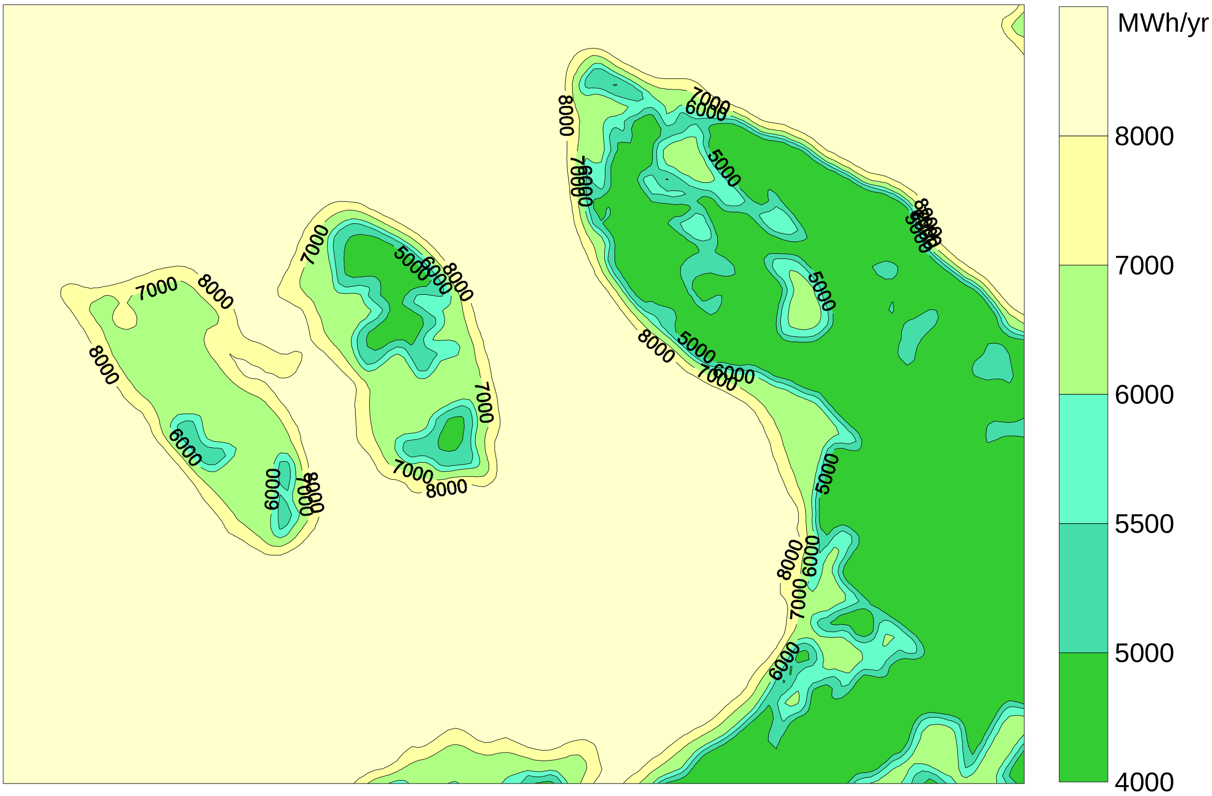

Figure 4-7. Mean annual energy yield (MWh/yr) by Vestas V80 wind turbine at 80 m above ground level

Power curve characteristics for Südwind S70 wind turbines are significantly different than for Vestas turbines and therefore potential annual energy yield is expressed in way of higher spatial variability. Differences between open areas and partly sheltered wooded meadows have stronger gradient than in case of Vestas turbines (Figure 4-7). The potential energy yield by Südwind S70 is highly uniform for off-shore conditions (6,400–6,600 MWh/yr). In coastal zone, especially NW and N coast of the peninsula with higher air turbidity the S70 shows good performance and decrease in energy production from coastal area toward inland part is relatively slow and uniform.

In the coastal area potential annual energy yield reaches 5,000–6,000 MWh/yr at 85 m above ground level. In inland parts of islands or continental areas the amount of potential energy is much smaller and shows clear decrease tendency in West-East direction. In most parts of the peninsula potential annual energy yield remains between 2,500 and 3,500 MWh/yr. Open areas and wooded meadows in inland regions have annual potential for energy production in range of 4,000 to 5,000 MWh/yr.

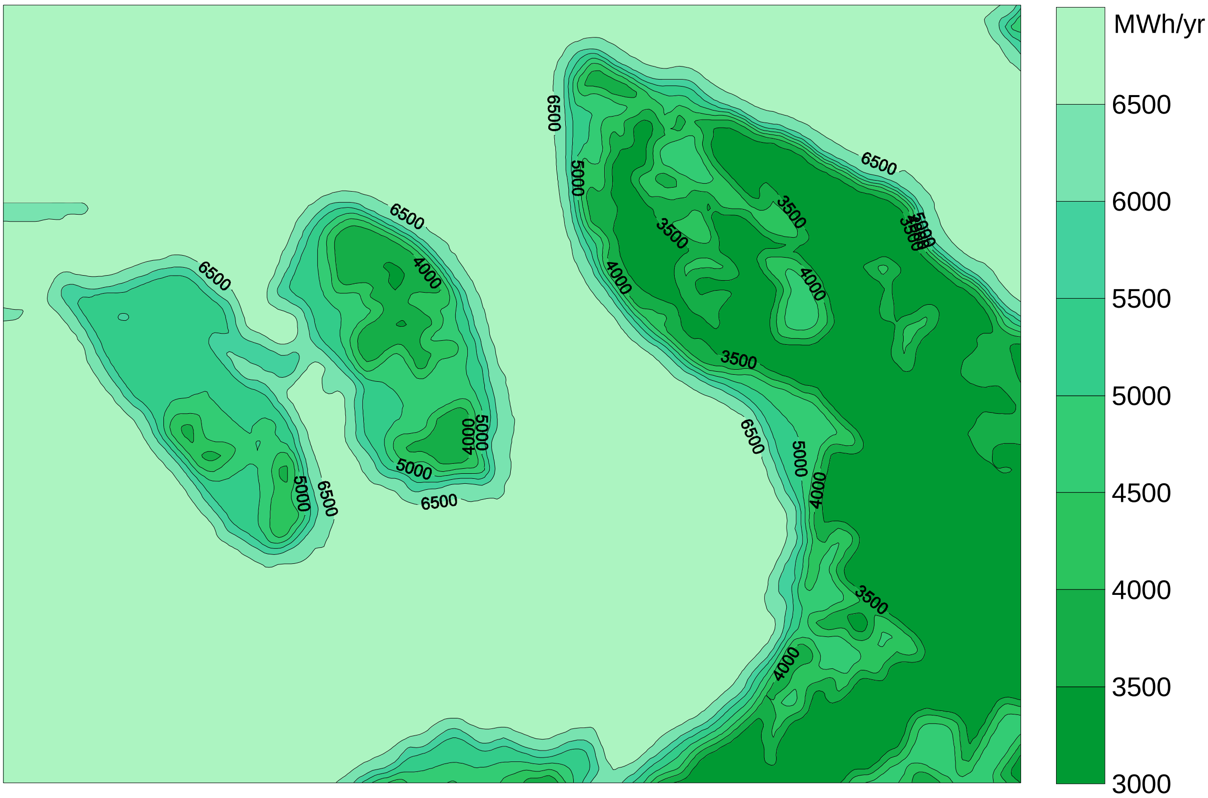

Figure 4-8. Mean annual energy yield (MWh/yr) by Südwind S70 wind turbine at 85 m above ground level

4.2 Physical plan for wind energy utilization and principal elements of EIA in planning process

Pakri region have been used formerly as military area but nowadays "green" lifestyle is promoted. To ensure high efficiency of wind farms and siting of wind turbines according to good practice, most of the elements of EIA (Environmental Impact assessment) were applied when identifying suitable locations for wind turbines.

Beside of requirement set by different laws and acts, also alternative land use scenarios were considered under EIA process. Land use intensity in Pakri region is relatively low, especially in inland part of the peninsula. Coastal areas have high potential for recreation and settlement, therefore those areas are not recommended for wind energy utilization. However, areas with preferably different land use coincide in general with existing restrictions (e.g. landscape protection area, etc.).

Energy consumption and CO_2 emissions for manufacturing wind turbines and in construction of wind farm are estimated to be the same as stated in other reports issued in Europe. In 3 to 4 months a modern wind turbine on an average site will generate as much energy as that used to manufacture it. Energy consumption and CO_2 emission in construction, management and utilization generally do not depend on country, but rather from locality. Due to well developed infrastructure, vicinity of disposal utilities and existing power distribution network the energy demand is lower than in average. No significant additional CO_2 emission will occur during construction as no changes in land use and land cover are necessary.

Strict set of criteria were developed for zonation process. Five different restrictive zones were distinguished according to legislative status and pith. All restrictions were used according to

GIS overlay exclusion method. Thematic maps of limiting factors were overlayed each to other. Areas where no restrictions were applied were considered as regions suitable for wind energy utilization.

The scale of maps was 1:10 000 and basic information was collected from catastrial map, base map and aerial ortophotographies.

4.2.1 Assessment of limiting and restricting factors for building wind turbines

During the assessment different factors were grouped according to their vulnerability to wind energy utilization. Taking into account also legislative background for building activities the following five restrictive zones were developed:

A) Exclusion zone
Any kind of wind engineering in this area is forbidden by law and regulations. This zone includes: area of settlement, households and 300 m buffer for noise and safety purposes; natural and historical monuments and their protection zone in 50 m width; cemeteries, protection zones for electric powerlines, gas pipes, etc.; protection zones for roads.

B) Restriction zone
This zone is divided into two subzones B1 and B2 according to potential influence legislative status and pith.

- B1 is zone of strictly restricted areas where any of wind engineering activities may cause unrecoverable changes. The B1 zone includes natural reservates of national parks, nature reserves, landscape reserves and MAB. If protection area is established to protect birds or animals the full protection area belongs to the B1 zone.
- B2 zone includes natural objects (plants, minerals, fossils) of I, II, and III protection categories; buffer zones of protected areas and programme of Man and Biosphere (MAB); coastal zone with restricted building activities according to law.

C) Reservation zone
Includes aspects which are not enacted or regulated, also subjective aspects are included which may cause conflicts during planning process. This zone includes: 1,000 m buffer for cemetery and outstanding historical monuments (additionally to the zone A); open sector to seaside from lighthouses and navigation signs; 1,000 m buffer around TV-, radio- and mobile transmissionmasts; recreation areas and popular landscapes/views.

D) Naturally unsuitable zone
Areas which are not suitable for erecting wind turbines or their operation. The zone includes lakes, wetlands, islets and forests. These features are partly eliminated also by several regulations.

E) Area without restrictions
Suitable regions where restrictions by laws and acts are not set and no social opposition could be expexted as wind energy utilization do not have any harmful impact.

4.2.1.1 Restrictions by natural environment

Most common uncertainties associated with wind energy are related to wildlife, especially to avifauna. Wind power plants may have a direct influence (injury or death of birds due to collision with blades or tower) and an indirect effect through the disturbance of birds' breeding, nesting and feeding places, but also by affecting their migration behavior. However, several studies carried out in Germany and The Netherlands show that in general mechanical effects on bird life are not very strong. Death of birds occurs only in case of extreme weather conditions (low clouds, dense fog or heavy rainfall with strong wind) and mainly at large wind farms. The small number of injured birds can be explained by the fact that birds avoid wind farms on their migration routes; however, most bird species show fast habituation to wind turbines. Still, t should be considered that a change in birds' migration routes would strongly affect their normal life and therefore the main migration routes, breeding and nesting areas should be excluded from the list of suitable areas for wind power production. The influence of wind turbines on animals and plants is only minor, mainly limited with the construction period and service roads. No change in animal habitation has been observed at wind farms.

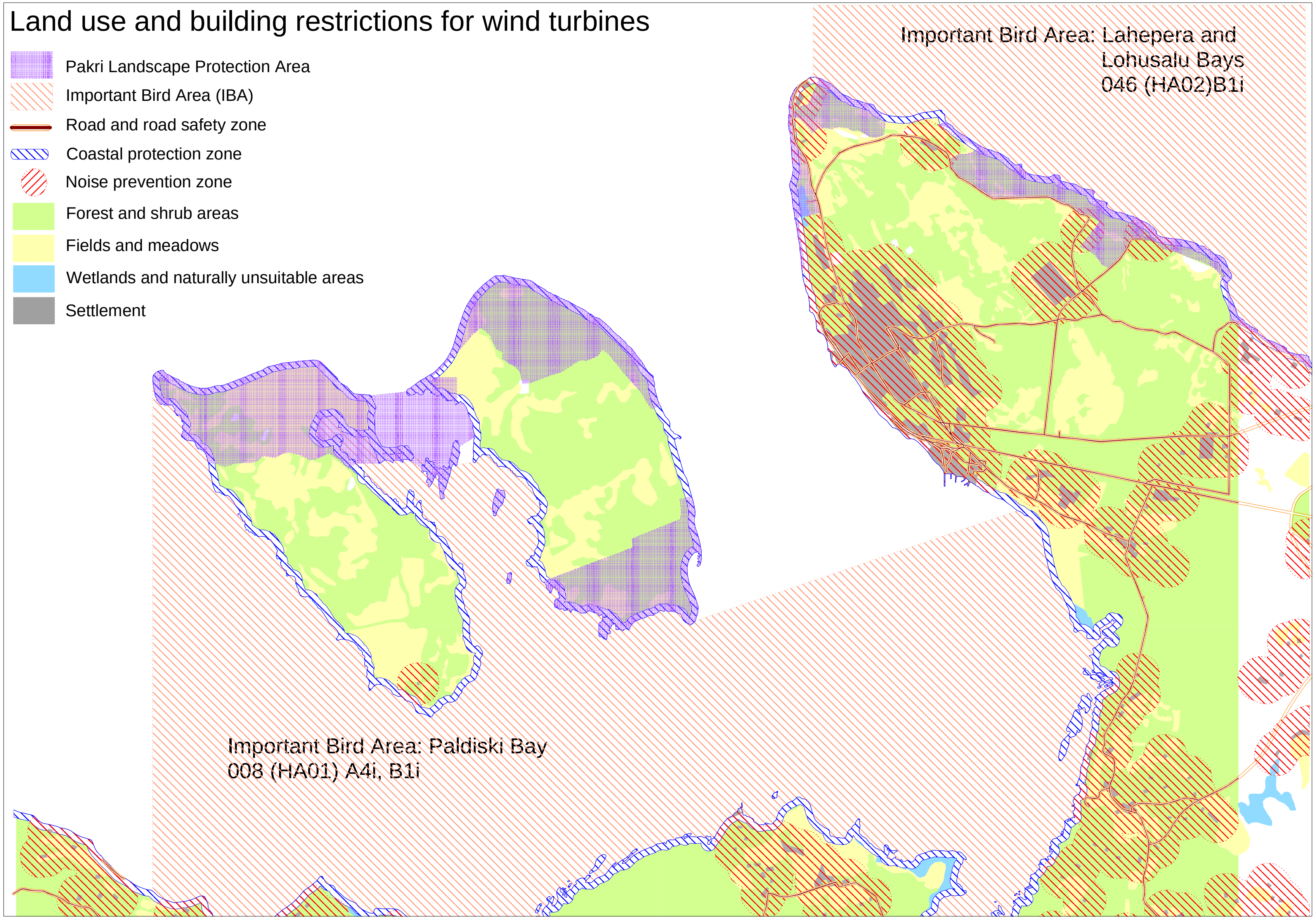
Land use and building restrictions for wind turbines
Pakri Landscape Protection Area
Important Bird Area (IBA)
Road and road safety zone
Coastal protection zone
Noise prevention zone
Forest and shrub areas
Fields and meadows
Wetlands and naturally unsuitable areas
Settlement
Important Bird Area: Lahepera and
Lohusalu Bays
046 (HA02)B1i
Important Bird Area: Paldiski Bay
008 (HA01) A4i, B1i

Figure 4-9. Land use and building restrictions for wind turbines

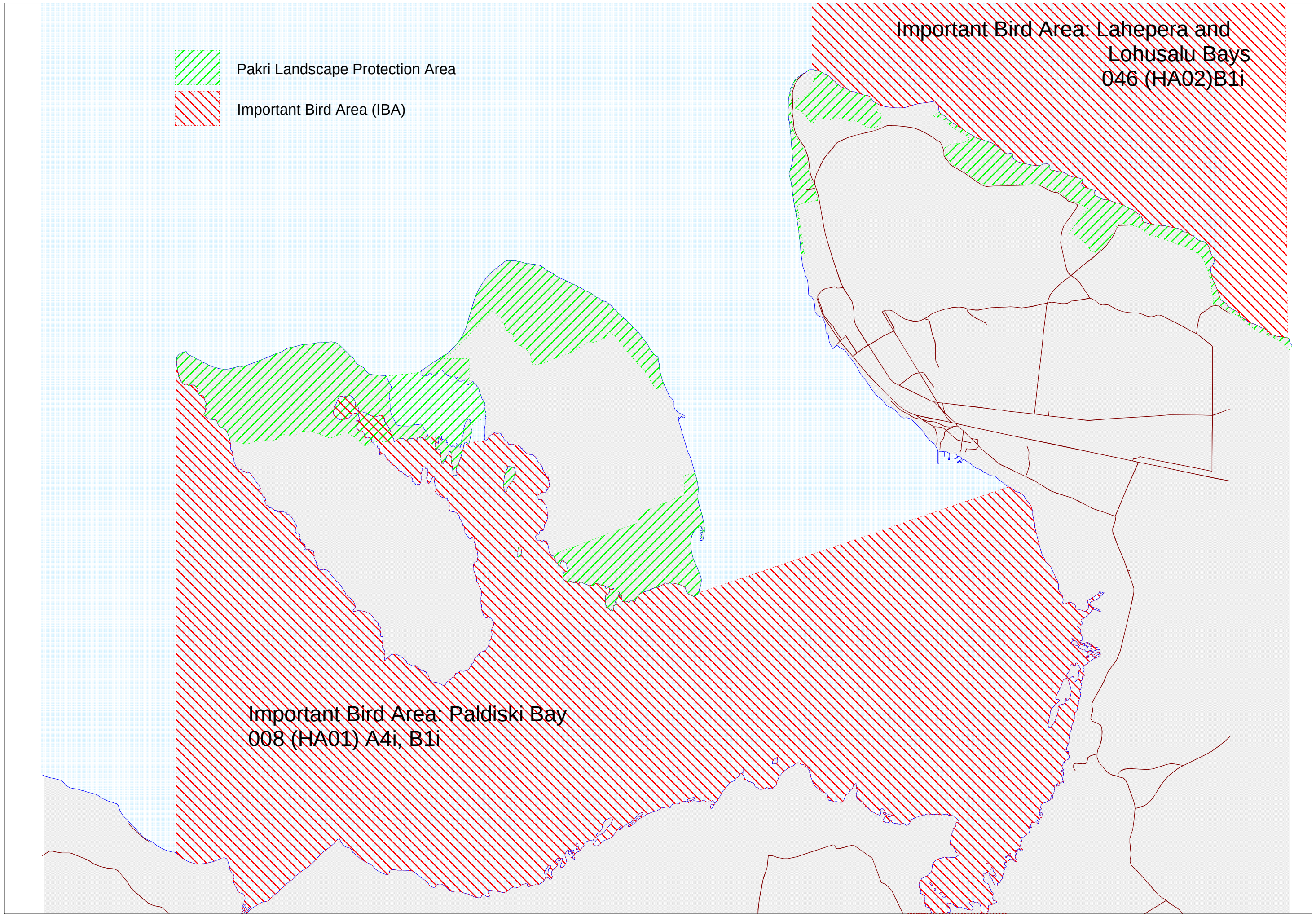

Figure 4-10. Important Bird Area, Pakri Landscape Protection Area

4.2.1.2 Restrictions by human environment

The operation of a wind power plant inevitably brings about noise emission and moving shadows of blades on sunny days. Noise emission is strongly dependent on the size and construction type of the power plant, but disturbance is more important at inland sites than close to the coast, where the sound of the waves and other background noise due to higher wind speed make the noise of the wind turbine less noticeable. To keep the noise level acceptable, the distance between residential buildings and the wind turbine should be not less than 400 m in open land, which corresponds to noise <40 dB(A) that is lower than in a normal living room (50 dB(A)) but louder than the bedroom level (30 dB(A)). Moving shadows of the blades are felt to be disturbing in the morning and evening when sun rays are at a low angle.

The land use intensity by wind turbines is relatively small[58] being determined mainly by the size of the foundation of the plant, the area of the service roads and electric power lines. All the rest of the area can still be left in natural condition or to be used for other purposes. However, one should consider with some restrictions the surroundings of a wind farm or a power plant due to safety reasons. No activities demanding frequent stay of people or having living facilities close to wind turbines can be allowed because of possible damage caused by blades. Also icing of blades is common in winter in Estonian climate and pieces of ice can injure people.

Landscape aesthetics can be regarded as a subjective restriction in wind energy planning because it does not have any harmful results on living beings. Since the most appropriate sites for wind power plants are in wide open areas their visual impact can be a disturbance to the landscape. Thus wind turbines should be fitted into the landscape as well as possible and areas with unique natural landscapes should not be used for this purpose. Also recreational areas should be left out of use for wind power generation because of a combination of questions of landscape aesthetics, land use and safety.

4.2.1.3 Infrastructure

Most common restrictions related with infrastructure are related to safety or operation. In certain circumstances wind turbines can affect the visibility of navigational signs (and lighthouses), therefore some sectors close to these should not be used for siting wind turbines. Also 1,000 meters wide buffer around radar, TV-, radio- and mobile transmission masts is created to avoid any electromagnetic interferrence or reflectance. According to laws protection zones for electric powerlines, gas pipes and roads are enacted.

4.2.2 Selection of suitable sites for wind farm and wind turbines

To ensure high efficiency of wind farms the wind resources were calculated. Siting of wind turbines must be carried out according to good practice and therefore most of the elements of EIA (Environmental Impact Assessment) were applied when identifying suitable locations for wind turbines.

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[58] Freris, L., Inherit the Wind. IEE Review, April 1992.

The highest portion of building restrictions were set in by Pakri Landscape Protection area (cliff, wooded meadows and coastal meadows), building restriction area of coastal protection zone and in off-shore areas by Important Bird Areas (IBA). Several local scale restrictions have caused by settlement (noise prevention zone), safety zones beside roads and power lines. Due to natural reasons (expensive construction or negative effect on wind) wooded areas and wetlands are also considered as unsuitable. Despite of all restrictions there is still 1 134 hectares suitable land for building wind turbines in Paldiski region.

Using the suitable land as intensively as it is technically allowed, the maximum number of wind turbines in 1.5 to 2.0 MW class is 73 (Figure 4-11). Wind farm specification by size of suitable plots follows:

Area for 12 stand alone wind turbines, TOTAL <= 12 wind turbines
Area for 2 wind turbines in 3 wind farms, TOTAL <= 6 wind turbines
Area for 3 wind turbines in 1 wind farm, TOTAL <= 3 wind turbines
Area for 4 wind turbines in 2 wind farms, TOTAL <= 8 wind turbines
Area for 5 wind turbines in 2 wind farms, TOTAL <= 10 wind turbines
Area for 6 wind turbines in 2 wind farm, TOTAL <= 12 wind turbines
Area for 7 or more wind turbines in 3 wind farm, TOTAL <= 22 wind turbines
GRAND TOTAL <= 73 wind turbines

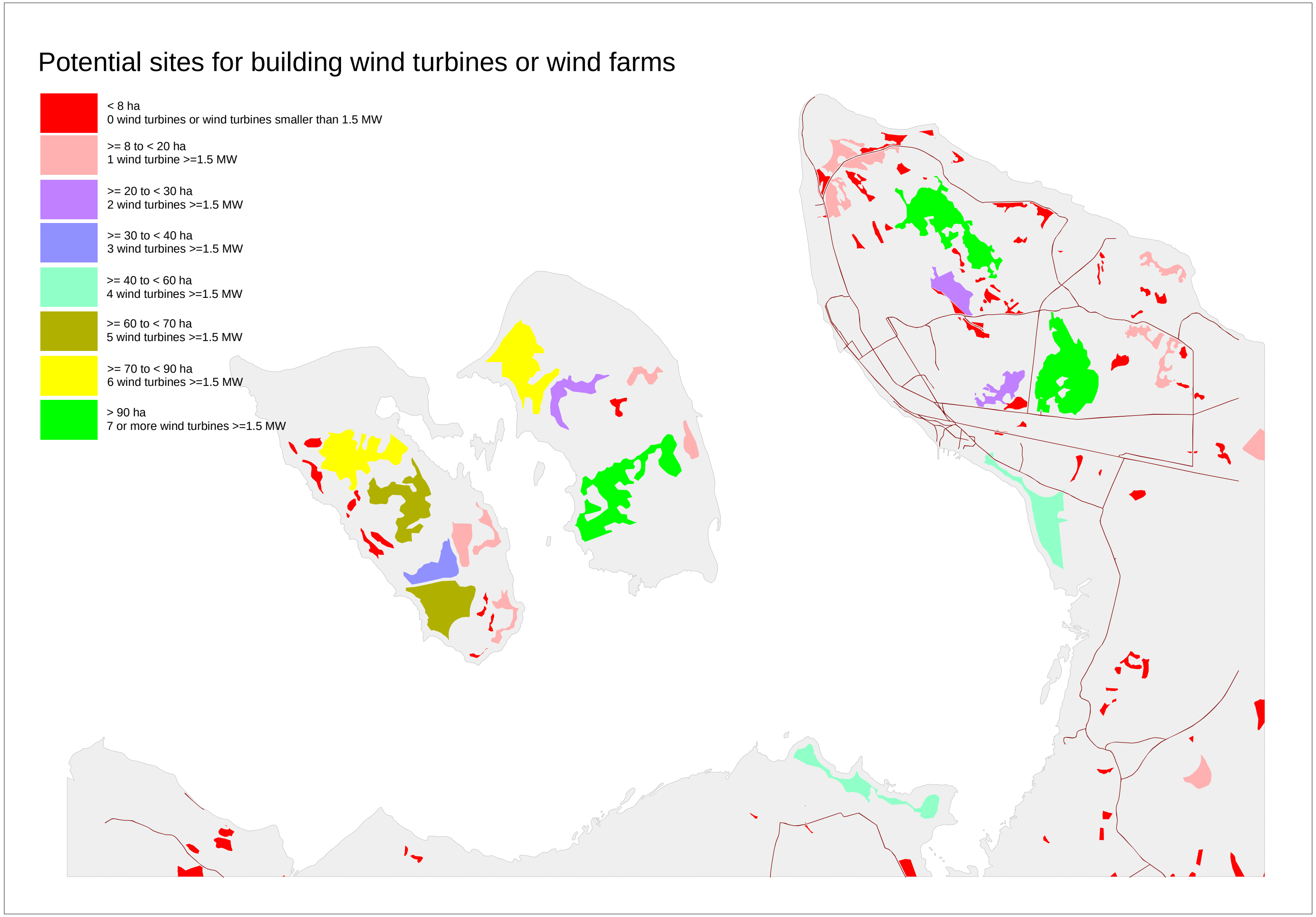

Figure 4-11. Potential sites for wind farms according to possible number of wind turbines with rated power 1.5 to 2.0 MW

4.3 Wind and wind energy characteristics at Paldiski Pilot Project area

Wind resources for Paldiski Pilot Project area are calculated according to EMHI meteostation 10 year observation time series which are validated by 9 months automatic weather station measurement data from Paldiski mast (at 25 m and 40 m a.g.l.) in Paldiski Pilot Project area.

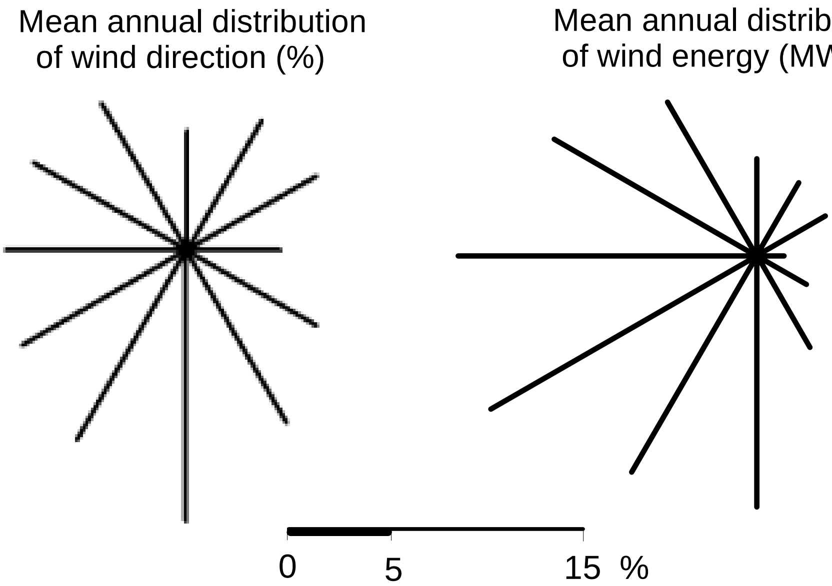

Figure 4-12. Relationship between occurrence of wind and wind energy from different sectors by EMHI Pakri meteostation data

Accordingly to overall atmospheric circulation in Estonia are dominating south-westerly winds. Seasonal changes in atmospheric circulation lead also to seasonal variation of dominating wind speeds. During cold period of the year when wind speed is the highest wind is blowing more frequently from southern and south-western direction, in warm period with the lowest wind speed the wind occurrence from different sectors is more even (Figure 4-12). Mean wind speed is the highest for westerly and south-westerly winds, the lowest wind speed is characteristic for easterly winds. Thereby it is very important to follow openness of westerly sector from wind turbines if planning wind farms.

Wind speed distribution is best described by two parametric Weibull distribution[59] and therefore further detailed description of wind characteristics is given in form of A and k parameters of Weibull distribution.

4.3.1 Selection of pilot project area

The main criteria for selection of Paldiski PP area is that the selected wind farm site should be representative for average wind conditions all over the Pakri WF study area (Figure 4-13). This enables to extrapolate results of the pilot study to wider region while selection of the windiest areas could lead to overestimated economical efficiency.

[59] Stewart D. A, Essenwanger, O. M., 1978. Frequency Distribution of Wind Speed Near the Surface. *Journal of Applied Meteorology,* 17:1633-1164.

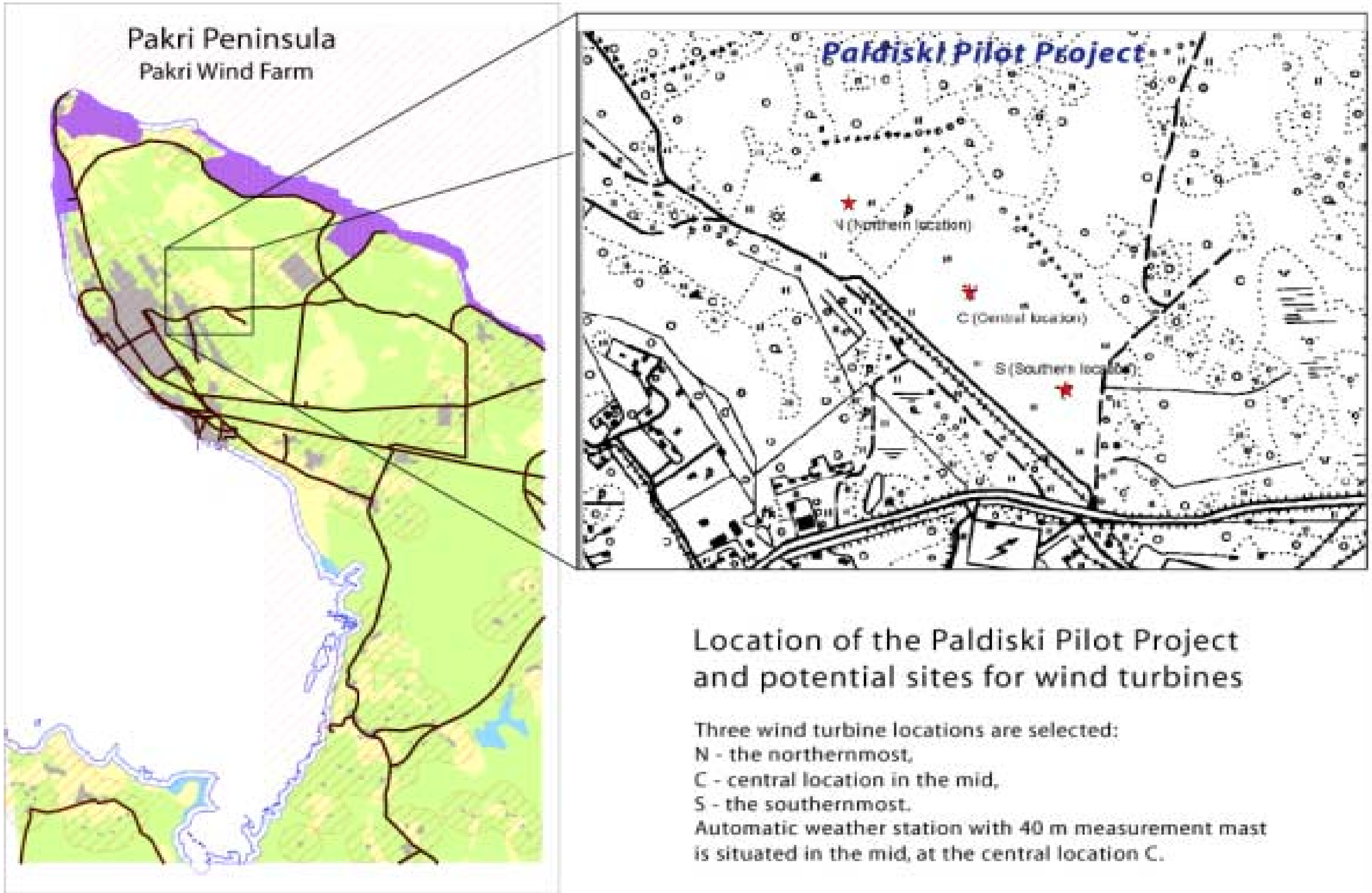

Figure 4-13. Location of the Pakri Wind Farm and Paldiski Pilot Project

To enable calculation of real cost of produced energy or avoided CO_2 emission the pilot project study area should be large enough to fit several wind turbines. Location of wind farm should correspond to average regional conditions in sense of transportation, construction, logistics and infrastructure. Only sites where these conditions are fulfilled can be used as examples for economical calculations in larger area.

Another important consideration is that the pilot project area should serve as example of good practice in sense of minimized environmental impact. The highest performance of the pilot project as example can be achieved if *Best Available Technology* (BAT) is used. Wind farm pilot projects are normally commissioned year or two years ahead of the main wind farm, therefore BAT that is used in pilot project will be the *Business As Usual* technology in time of construction the main wind farm.

In current study an open field in central part of the Pakri Peninsula, 1 km to east from Paldiski city was selected. The selected wind farm enables to fit 3 wind turbines, each of them with rated capacity of 2 MW. Wind farm design for optimal performance requests siting of the turbines in a row that has SSE-NNW direction.

4.3.2 Mean annual wind speed (m/s) at 67 m, 80 m and 85 m

The Paldiski PP wind farm consists of three wind turbines in a row oriented in SSE-NNW direction and therefore wind turbines are marked as follows:

- Location N – the northernmost wind turbine location
- Location C – wind turbine in the mid
- Location S – the southernmost wind turbine location

As shown in Table 4-1 the mean annual wind speed (m/s) shows only minor variation within the pilot project area at the wind turbine hub height.

Table 4-1. Mean annual wind speed at different height by wind turbine locations

Location	67 m a.g.l.	80 m a.g.l.	85 m a.g.l.
N	7.0	7.3	7.4
C	7.2	7.4	7.5
S	7.1	7.3	7.4

Wind speed distribution has significant variation at height of 67 m a.g.l. but on higher level (80 m and 85 m a.g.l.) variation is negligible (Table 4-2).

Table 4-2. Mean annual wind speed distribution in form of Weibull distribution *A* and *k* parameters at different height by wind turbine locations

Location	67 m a.g.l.		80 m a.g.l.		85 m a.g.l.	
	A	*k*	*A*	*k*	*A*	*k*
N	7.8	2.10	8.2	2.11	8.3	2.19
C	8.1	2.08	8.4	2.10	8.5	2.17
S	8.0	2.10	8.3	2.12	8.4	2.19

Wind speed distribution shows the higher occurrence of strong wind in C location, both in height of 67, 80 and 85 m. However, the turbulence is the highest for S location and the modest in C location.

Based on wind speed distribution the mean annual energy density was modelled all over the potential pilot study area with grid of 10 m. Such a wind field was used to make any minor corrections to the exact location of potential sites of wind turbines to ensure the highest performance efficiency.

4.3.3 Mean annual energy density (W/m^2) at 67 m, 80 m and 85 m

Mean annual energy density (W/m^2) is a wind energy characteristic that is proportional to the third power of wind speed and describes energy available in a flow of air through a unit area. It is highly dependent of wind speed, but reflects more exactly wind speed distribution and theoretical available energy.

Energy density attains its maximum in late autumn (October, November) when mean monthly values are between 400–450 W/m^2. Once the maximum is attained, the variation between different months is small (30–40 W/m^2). In February and March, the mean monthly energy density is only 60–75% of that in winter. The lowest monthly values are characteristic of late spring and summer, from May to July (160–150 W/m^2). A rapid increase in mean monthly energy density takes place in September. Within three months in autumn (August, September, October) the monthly mean energy density can rise from 200 to 450 W/m2.

Table 4-3. Mean annual wind speed at different height by wind turbine locations

Location	67 m a.g.l.	80 m a.g.l.	85 m a.g.l.
N	385	418	429
C	405	443	460
S	388	423	436

Mean energy density (W/m^2) have higher variation on higher level (Table 4-3) but is not statistically significant. The highest increase of energy is characteristic for core area of the Paldiski PP, while marginal areas close to shrub and forest experience less wind energy as the sheltering effect is still significant. Relatively uniform energy density values leads to conclusion that the air turbulence caused by local roughness has less influence than long distance disturbance and general regional roughness.

4.3.4 Mean annual potential wind energy production (MWh/yr) by Vestas 850 kW V52, Vestas 2.0 MW V80 and Südwind S70 wind turbines

Mean annual energy yield (Table 4-4) shows relatively small difference in energy production by V80 wind turbine in case of hub height of 67 m or 80 m. High efficiency is achieved also with S70 wind turbine both by height of 67 m and 85 m.

Despite of good performance of V52 with hub height of 67 m this turbine is not recommended as the land use intensity will be very low due to low rated power output. Therefore under consideration of sustainable energy production turbines with higher capacity should be preferred.

Table 4-4. Mean annual power yield (MWh/year) at different height by wind turbine locations

Location	67 m a.g.l.			80 m a.g.l.	85 m a.g.l.
	V52	S70k	V80	V80	S70
N	2,200	4,144	5,449	5,801	4,585
C	2,229	4,289	5,540	5,895	4,782
S	2,199	4,211	5,407	5,748	4,639

Mean annual energy yield is calculated for Paldiski PP assuming that there is no need to reduce normal wind turbine noise emission level (101.5 dBA) as is shown by EIA studies. This means that the maximum conversion efficiency is achieved. Sheltering effect of wind turbines could be noticed in case of location C. Wind turbine in southern location S, but also the northernmost turbine reduce potential power production in central location in order of 2–5%. Mean annual expected energy production of 5,800–5,900 MWh/year in Paldiski PP area is higher than average in coastal transition zone where roughness class is set as 2 or 3.

4.3.5 Seasonal and interannual variability of wind and wind energy characteristics

Seasonal distribution of power production by wind turbines at Pakri region is highly correlated with seasonal pattern of energy consumption. The highest energy yield is characteristic for period from October to January (more than 10% of annual energy production in every month) and the lowest energy yield in summer from May to August (Figure 4-14).

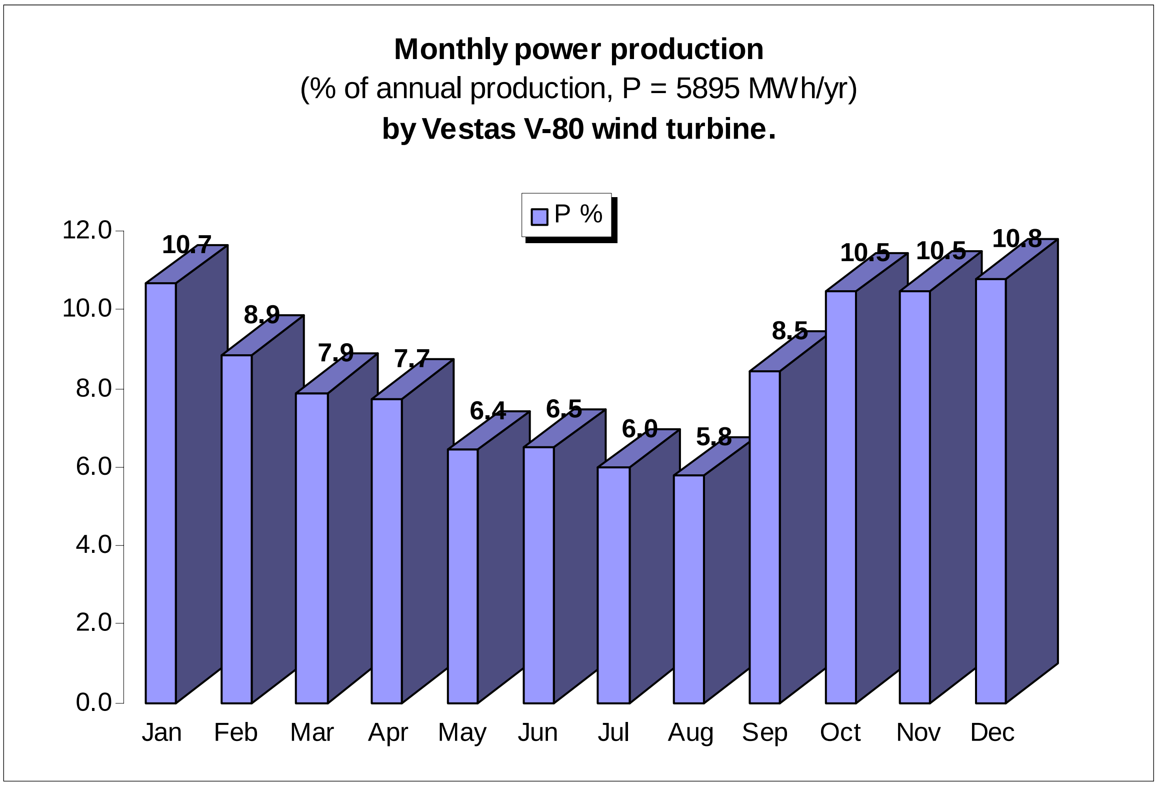

Figure 4-14. Monthly power production (% of annual production, P = 5,895 MWh/yr) by Vestas V80 wind turbine

Similar seasonal distribution of wind energy availability and energy consumption makes wind energy attractive but high short term variability requires effective power management to recover low-production periods. Wind speed and energy availability are the highest in winter but this is associated also with the highest variability (Figure 4-15). The example is taken from February, 2001 as under normal wind climate conditions in winter and its shows average value for mean energy density E = 291 W/m^2 (Std = 343 W/m^2), but this value is associated with high energy fluctuations (E_{max} = 2,325 W/m^2, E_{min} = 0.01 W/m^2). Most of energy yield of that month is given within 10 days and energy recover in at level of 90% is needed in 9 days.

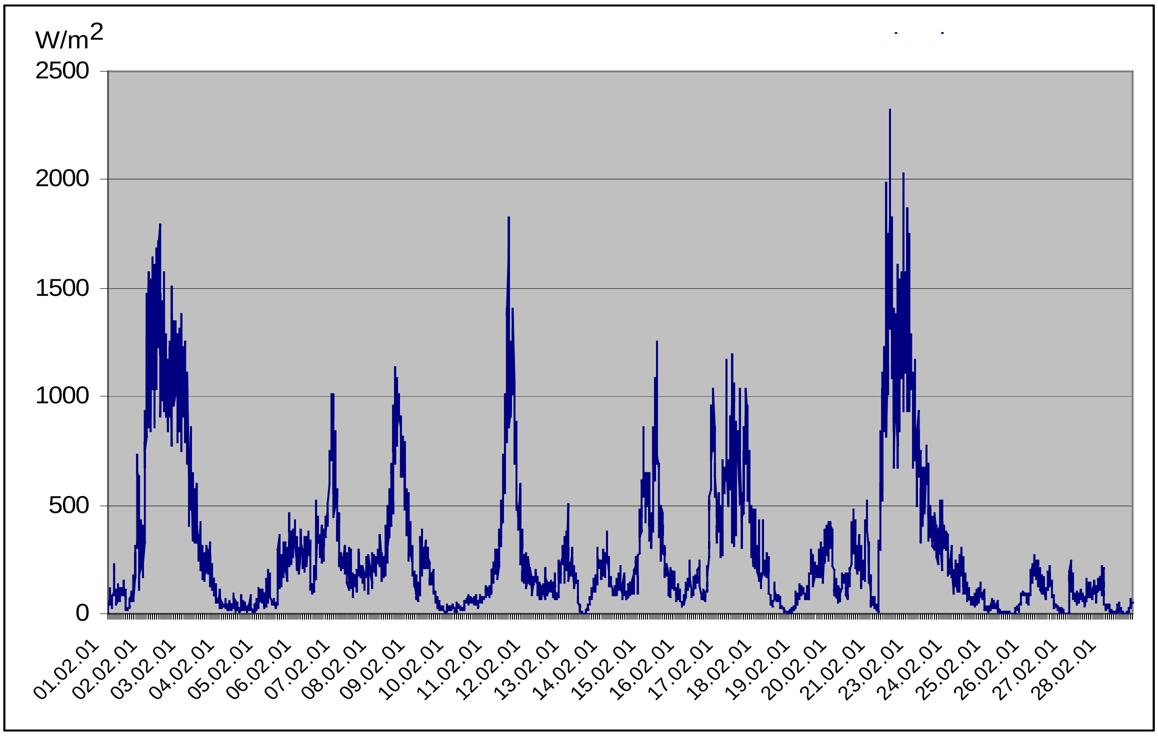

Figure 4-15. Variability of mean energy density (W/m^2) at 40 m. a.g.l. Measurement averaging interval 10 minutes, mean wind speed: 6.7 m/s (Std = 1.09 m/s)

Still, one should keep in mind that high variability in mean energy density do not reflect directly in power production. The highest peaks of wind energy (E > 1,400 W/m^2) are cut off by wind turbines as the nominal performance is achieved at wind speed 14 m/s. Also the lowest droughts (caused by wind lower 4 m/s) are uniform as those are below cut in wind speed.

To study long term variability of energy production and to predict the lowest and the highest possible energy production according to historical measurement data the time series of Pakri meteostation from the period of 1899–1990 is used.

Table 4-5. Variation of mean monthly wind speed (at 10 m a.g.l.) and calculated energy density (W/m^2) according to long-term (1899–1990) wind speed time series from Pakri meteostation

	Wind speed (m/s)			Mean energy density (W/m^2)		
	Mean	Min	Max	Mean	Min	Max
Jan	6.7	2.4	10.7	234	23	1,212
Feb	6.0	2.9	11.0	228	36	1,321
Mar	5.6	2.8	9.9	186	29	1,004
Apr	5.0	2.2	9.0	149	19	786
May	4.6	2.4	7.9	124	22	589
Jun	4.6	1.6	8.8	123	15	711
Jul	4.4	2.5	7.0	108	24	370
Aug	4.9	2.7	8.5	150	27	703
Sept	5.9	3.0	9.5	227	41	887
Oct	6.4	3.5	10.5	298	68	1,102
Nov	6.7	4.1	10.2	340	86	1,052
Dec	6.6	3.4	10.5	332	61	1,099
Year	5.6	3.5	7.9	201	68	579

Compiled data set shows that the lowest expected annual power production (according to the lowest mean annual wind speed) will be not lower than 4,000 MWh/yr (68 % of normal yield) and not higher than 11 000 MWh/yr (186% of normal yield) by Vestas V80 wind turbine. Interannual variation for shorter periods are generally less than 25% and the wind farm life-time variation in energy production will remain between +7% and -5%.

4.4 Conclusions

Wind energy resources and possibilities for wind energy utilization have been studied in Pakri region in general, in Pakri WF and Paldiski PP area. Wind resources have been studied on the basis of the wind data from Pakri meteorological station and wind data measured at 40 m.a.g.l with automatic weather station in Paldiski PP area. All wind field modelling and calculations are performed by WA^{S}P program (Wind Atlas Analysis and Application Program) worked out at Risø National Laboratory, Denmark, using the same methodology as used for the European Wind Atlas. In all calculations the influence of nearby sheltering obstacles, roughness and orography of the surrounding area are taken into account.

The test area Pakri Peninsula is a typical coastal location with moderate to good wind condition and thereby it is very well suitable for feasibility study for wind farms that should represent Estonian coastal conditions. In winter the monthly mean wind speed on islands and on the western coast reaches 7–8.5 m/s, in the inland areas it remains between 4–5 m/s. Mean annual wind speed at wind turbine hub height (80 m a.g.l.) reaches 9.0–9.3 m/s over the off-shore areas, in coastal regions with open appearance the mean annual wind speed remains between 7–8.5 m/s and the open areas in inland parts of the peninsula have mean wind speed of 6.5–7.5 m/s.

Mean energy density (W/m^2) reaches in the coastal area 700 W/m^2 at 67 m height, in inland parts of the islands mean annual energy density remains between 300–450 W/m^2 and in most parts of the peninsula energy density value remains between 200 and 350 W/m^2. Using standard power curves of three different wind turbines (850 kW Vestas V52, 1,500 kW Südwind S70 and 2,000 kW Vestas V80) the mean annual potential energy yield was modelled.

The potential energy yield by Südwind S70 for off-shore conditions estimates 6,400–6,600 MWh/yr. In coastal zone, the S70 shows good performance and potential annual energy yield reaches 5,000–6,000 MWh/yr at 85 m above ground level. In inland parts of islands or continental areas the amount of potential energy is much smaller and counts 2,500 and 3,500 MWh/yr. Open areas and wooded meadows in inland regions have annual potential for energy production in range of 4,000 to 5,000 MWh/yr. Mean annual energy yield (MWh/yr) by Vestas V52 wind turbine at 67 m above ground level reaches 3,000–3,200 MWh/yr over the off-shore areas, in coastal regions with open appearance the mean annual energy yield remains between 2,000–3,000 MWh/yr and the open areas in inland parts of the peninsula have mean annual energy yield of 1,700–2,500 MWh/yr. The highest yield is estimated for Vestas V80 which enables to produce 7,000–8,000 MWh/yr in coastal zone and 4,500–5,500 MWh/yr in woodland areas.

To identify potential sites for wind turbines and wind farms in environmentally sound way most of the EIA elements (Environmental Impact Assessment) were applied in analysis. Areas which according to EIA principles do not conflict in any way to natural or social aspects comprises still 1 134 hectares in Pakri region. This includes only suitable land for building wind turbines and enables to install 73 wind turbines each of them with rated power of 1.5 to 2 MW. Among of these areas a Paldiski PP plot which is suitable for installation of three wind turbines was selected out for detailed analysis. The Paldiski PP have average wind resources for Pakri region and is characteristic for most of the sites within the Pakri wind farm area. Mean annual power yield is estimated at level of 2,200 MWh/yr by Vestas V52 (hub height 67 m), 5,800 MWh by Vestas V80 (hub height 80 m) and 4,600 MWh/yr by Südwind S70 (hub height 85 m).

Seasonal distribution of power production by wind turbines at Pakri region is highly correlated with seasonal pattern of energy consumption. The highest energy yield is characteristic for period from October to January (more than 10% of annual energy production in every month) and the lowest energy yield in summer from May to August (from 6.4% to 5.8%). Each month in spring and autumn contributes with 7.7–8.5% of annual energy production. Therefore wind energy has good perspectives to supplement the overall energy system.

5 Paldiski pilot project and Pakri wind farm cost-efficiency analysis

The chapter is organized in a step-wise movement from a small Paldiski pilot project (Paldiski PP) with 3 wind turbines to the large Pakri Peninsula wind farm (Pakri WF) feasibility study with 36 wind turbines. The first part of the chapter deals with comparative cost-efficiency analysis of wind turbines for the Paldiski PP and selection of the best wind turbine for the Pakri WF. The technical description of wind turbines and their instalment problems together with the analysis of Paldiski PP investment costs are the basis for the prognosticating of Pakri WF investment costs.

The pilot project alternatives and Pakri WF cost calculations are tested with three price policy options – three levels of potential feed-in tariffs for the wind energy based electricity. On the basis of cost-efficiency analysis recommendations are worked out for the Pakri WF investments, grid connection conditions and the wind energy based electricity price policy.

5.1 Paldiski pilot project – technical and economical aspects

5.1.1 Investments for the Paldiski pilot project

5.1.1.1 Wind turbines

Two main wind turbine technology development trends can be seen in the fast-growing wind market.

- An upscaling of 500–600 kW turbines, via 660–750 kW, into present-day 800–900 kW sub-megawatt turbines (e.g Enron, NEG Micon, Nordex, Vestas)
- Improvement of the existing 1,5 MW class machines with larger rotors and upscaling turbines to 1.8–2 MW (Enercon, NEG Micon, Enron, Vestas)

Suppliers claim reduction of energy generation cost as one of the main reasons for continously launching new and bigger wind turbines. But very important are also high energy yields, silent operation, superior grid compatibility and long service life. A number of manufactures offer direct-drive generators with solid-state energy converters. The low content of harmonic distortion, absence of inrush currents and adjustable reactive power make these wind turbines particularly suitable for weaker grids.

Table 5-1. Wind turbines for pilot project alternatives PP1 – PP5

Indicator		Unit	PP1	PP2	PP3	PP4	PP5
Wind turbine			V52	V80	V80	S70	S70
Rated power	RP	kW	850	2 000	2 000	1 500	1 500
Tower height		m	65	67	78	65	85
Power production		MWh	2 209	5 465	5 815	4 215	4 669
Net power production	NP	MWh	2 032	5 028	5 350	3 878	4 295
Mean wind speed		m/s	7.2	7.2	7.4	7.1	7.5

Mean energy density		W/m^2	404	405	443	401	460
Rotor area	RA	m^2	2 124	5 027	5 027	3 846	3 846
Capacity factor		%	27	29	31	30	33
NP / RA		MWh/m^2	0.96	1.00	1.06	1.01	1.12
NP / RP		MWh/kW	2.39	2.51	2.67	2.59	2.86

Examples of new sub-megawatt class turbines are the Enron 900 series, the Vestas V52 (850 kW), NEG Micon NM 900/52, and 800 kW Nordex N-50.

Vestas V63 prototype was developed to V66 1.65 MW machine. In 2000, market leader Vestas made the switch to variable speed operation, the new conversion system with double-fed wound rotor technology Optispeed. The largest turbine fitted with the system is the V80 – 2.0 MW. This machine has, among others, been selected for the prestigious Horns Rev offshore wind farm (80 x 2.0 MW).

For the present feasibility study well proven Vestas V80 with 2.0 MW rated power was chosen as the example of 1.5–2 MW class and Vestas V52 (850 kW) as the example of sub-megawatt class. The third type we analyzed was the 1.5 MW Südwind S70.

Paldiski PP area is 20 ha and therefore three wind turbines was decided to settle in this test site (see the test site map in the 4. chapter).

Five alternative options PP1 – PP5 with wind turbines V52, V80 and S70 were chosen. These five alternatives differ from each other by rated power and wind turbine tower height. Table 5-1 presents the main technical characteristics for each selected for Paldiski PP wind turbine.

The maximum wind power production comes from the wind turbine V80 with 78 m tower used in option PP3. Power production in the Table 5-1 is already decreased by the availability factor (2%). The availability factor includes all standstills connected with wind turbine – maintenance, replacements, repairs.

Wind power based electricity cost is calculated on the basis of 8% less net power production NP, which takes into account the losses in two transformers (0.6/20 and 20/100 kV – total about 4%), in wind turbine inner consumption (2%) and in 110 kV grid connection interruptions (2%).

The total calculated net power production decrease compared to the wind turbine mean annual potential wind energy production is 10%.

The wind turbine repairs, grid connection interruptions and other risks may be under- or overestimated, because there are not enough data available for risk prognoses.

Table 5-2. Paldiski pilot project total investments

Indicator	Unit	PP1	PP2	PP3	PP4	PP5
Wind turbine		V52	V80	V80	S70	S70
Rated power	kW	850	2 000	2 000	1 500	1 500
Tower height	m	65	67	78	65	85
Net power	MWh	2 032	5 028	5 350	3 878	4 295

production						
Wind farm Number of turbines		3	3	3	3	3
Rated power	kW	2 550	6 000	6 000	4 500	4 500
Net power production	MWh	6 097	15 083	16 049	11 633	12 886
Wind turbines price	EUR	1 561 402	4 444 360	4 711 022	3 934 401	4 162 182
Erection	EUR	110 765	124 209	131 662	124 209	131 662
Transportation	EUR	106 991	239 096	253 442	239 096	253 442
Foundation	EUR	50 618	95 867	115 041	95 867	115 041
Roads	EUR	25 565	25 565	25 565	25 565	25 565
Grid connection	EUR	162 975	383 470	383 470	287 602	287 602
Project management	EUR	40 366	106 251	112 404	94 135	99 510
Total investments	EUR	2 058 680	5 418 819	5 732 605	4 800 876	5 075 004
TIN / NPn		0.34	0.36	0.36	0.41	0.39

Price estimates of wind turbines include the design, manufacture and supply of complete standard wind turbines with steel foundation sections and steel conical tubular towers. A two year warranty with 5 preventative maintenance visits and remote control equipment are included in the price of turbines. All prices exclude import duties and VAT.

Prices of wind turbines for Paldiski PP in Table 5-2 were estimated in Estonian currency (EEK) and then in European Union currency (1 EUR = 15.6466 EEK).

Real purchase prices of turbines may differ from these price estimates about 10–15%. For example the 36 V80 Pakri windfarm turbines total price may be less than EUR 53 million or more than EUR 63 million (without import duties and VAT). The same 10–15% deviation may occur in all cost calculations, because it is impossible to forecast excat results of the negotiation process between supplier of wind turbines suppliers and it`s client.

5.1.1.2 Foundations of wind turbines

The ground conditions for building the foundations for wind turbines are good in Pakri peninsula. Mostly limestone basis with not high ground water level is dominating.

Foundations could be prepared by local contractor. To ensure fulfilment of the project demands, the contractor has to organize his control program. The excavation has to be done without rooting up the bottom, and without using heavy machinery on the finished excavation level. Bottom of excavation is compacted, and a cleaning layer of minimum 100 mm concrete is laid out

The work begins with setting the bottom reinforcement in the right dimensions. The reinforcement layer is set up 50 mm above the cleaning layer. After that the delivered steel section is to be placed upon the cleaning layer, which has been hardened.

The top of the steel section must be completely horizontal, and adjusting the regulation screws does this. The work must be carried out very carefully, so that there is no risk that the tower is standing unbalanced after the assembling. The contractor is responsible, that the top of the steelsection does not deviate more than 4 mm from horizontal level, and that the circular shape is preserved.

Casting must be done in one work operation. Exceptional great care must shown by casting inside the steel section, to ensure that it does not deviate, but stays in centre of the plate and with horizontal top. At casting vibrator must be used, and the concrete supply under the lowest flange/rolled ring must be complete, so that there is no cushions at any place. The concrete has to be insulated from both loss of heat and loss of moisture for at least 7 days and nights, summer as well as winter.

Filling around and over the foundation must take place before erecting the tower. Soil, which is used for backfilling, must fulfil the demands to effective density, which are mentioned in the project.

At a distance of 500 mm from the pedestal, the filling must be sand or gravel to prevent corrosion of steel section because of possible aggressive soil.

Assuming that ordinary Portland cement is used for the concrete, full strength at normal conditions is achieved after 28 days and nights of hardening.

Wind turbine steel conical tower foundation costs include the geological investigations, excavation, concrete and construction works made under the supervision of wind turbine supplier. Paldiski PP foundation costs are in Table 5-2.

5.1.1.3 Transportation of wind turbines

The wind turbines will be transported to Estonia by ship. Paldiski South Harbour is located about 3 km from the pilot project area. The depth of sea in harbour is 8.5 m, Paldiski harbour can handle the V80 components.

Transportation from the harbour to the site will be performed using special trailer with electric/hydraulic manually controlled turnable rear wheels.

Transportation cost of the wind turbines, towers and foundation sections from place of manufacture to Paldiski is in Table 5-2.

5.1.1.4 Erection of wind turbines

The wind turbine erection can be started up not before than the foundation concrete has achived 28-day strength. To erect the wind turbines rather specific cranes are needed. For example the Finnish crane company have the crane *Liebherr 1600 LR/1*, capable to lift a 100-ton item up to 130 metres.

Erection cost include the provision of the needed cranes, project management, one qualified and experienced working supervisor and experienced service engineers for the duration of the assembly and erection of the wind turbines as well as the tests and commissioning of same. Erection costs are in Table 5-2.

5.1.1.5 Grid connection and transformers

Paldiski town is connected to the main grid through two 110 kV high voltage lines, both able to transfer about 70 MW of capacity. The main 32 MW 110 kV/ 35 kV trasformer station is situated just nearby the Paldiski PP area. For the Pakri WF the existing 32 MW transformer must be enlarged and upgraded but the pilot project could be connected to the existing transformer.

The wind turbine must be connected to medium-voltage grid at 6–33 kV, where 36 kV is the highest equipment voltage. The cable connection is made in the bottom of the tower. For connecting pilot project turbines less than 1 km of 20 kV cables must be installed.

The transformer in the turbine must be adjusted to the grid voltage. When ordering the turbines Vestas needs precise information about grid voltage, with regards to choise of the transformer's nominal voltage and winding connection. As an option, Vestas company offers switch gear.

Estonian electricity utility Eesti Energia AS is going to introduce a company standard to be used as a guidance upon the connection of wind turbine generator systems and wind farms to the electrical network. The time of interruptions per year caused from grid connection will be fixed in the contract with main grid owner.

It is assumed that the turbines power quality characteristics have been measured in accordance with the recommendations of the IEC draft standard IEC 61400-21.

The average cost of grid connection and transformer is estimated by experts about EUR 64,000 per 1 MW of rated power. For the Paldiski PP the grid connection cost may be lower, in case the existing transformer can be used. But for the Pakri WF the new 100–200 MW transformer and new 100 kV cables are needed. These capacity figures depend on the development plans for the Paldiski town, the harbour and the whole Pakri peninsula. These development plans are not yet available.

5.1.1.6 Roads, land use and other investment costs

Load capacity per axle of the roads should never be less that 15 ton/metric per axle. The minimum bend radius of the roads must correspond requirements of 47 m long blade trailer.

Wind turbines are located near the existing local roads and about 100–400 m of new roads or the average road construction cost of EUR 8,500 are estimated for each wind turbine.

Land purchase is not included into the investment costs, because it is not clear right now how much, mainly state-owned land is needed for each wind turbine and for the roads. Land lease is included into the annual operational costs.

Most of the land under Pakri WF area belongs to the State.

Use of the state-owned land is regulated with State Assets Act.[60] State land may be subjected to a commercial lease without a public auction or tender with preliminary negotiations only with the consent of the Estonian Government.

Project management costs include the costs needed for the wind farm project and management of all client`s activities during the preparatory and construction period. These costs were assessed as 2% of the investment costs (Table 5-2).

5.1.2 Selecting the best wind turbine for the Paldiski pilot project and Pakri wind farm

The comparison of wind power production NPn and TIN/NPn (Table 5-2) indicated that the best wind turbine for the Paldiski PP is Vestas V80 (PP2 and PP3).

Wind turbine V52 has a bit better TIN/NPn ratio (Table 5-2 – 0.34), but almost three times less wind power production. It is not recommended as the land use intensity will be very low due to low rated power output. The V52 NP/RA and capacity factor are also less than for the V80 (wind turbine capacity factor is the ratio between the annual net power production and the theoretically maximum power production when working all the year with maximum rated power. Usually the capacity factor is 20–35%).

Wind turbine S70 has a bit better capacity factor and NP/RA ratio, but other characteristics, for example NPn and TIN/NPn are worse than for the wind turbine V80.

Later we can see that the wind power based electricity cost calculations for the Paldiski PP wind turbine options PP1 – PP5 will confirm this choice, because the capital costs are proportional to total investments.

There are no difference in investment efficiency ratio TIN/NPn (0.36) between the option PP2 – V80 with 67m tower and PP3 – V80 with 78 m tower. If the installment costs for PP3 are higher than in our estimates, then the PP2 may be more cost-effective than PP3. The authentic installment costs will be available after the negotiations have started between the wind turbine supplier and Pakri windfarm developers.

According to power production criteria NPn, investments efficiency criteria TIN/NPn and land use intensity criteria we recommend as the best alternative for thePaldiski PP and for the Pakri WF the VESTAS WIND SYSTEMS wind turbine Vestas V80 with 78 m tower.

5.1.3 Wind turbine Vestas V80 technical description

The Vestas V80 – 2.0 MW is a pitch regulated upwind turbine with active yaw and a rotor with three blades. The rotor diameter is 80 m and it operates with Optispeed system. This feature enables the rotor to rotate with variable speed 9–19 RPM. Rotor swept area is 5,027 m^2.

[60] State Assets Act, RT I 1995, 22, 327

All V80 – 2.0 MW turbines are equipped with OptiTip, the special pitch regulating system. With OptiTip, the angles of the blades are constantly regulated so they are always at the optimal angle for the current wind conditions. Therefore the power production and noise levels are always at optimal level.

The blades are made of glass fibre reinforced epoxy. Each blade (ca 6,500 kg weight) consists of two blade shells, bonded to a supporting beam. Special steel root inserts connect the blades to the blade bearing. The blade bearing is a 4-point ball bearing, which is bolted to the blade hub.

The main shaft transmits the power to the generator through the gearbox. The geargox is a combined planetary and helical gearbox. From the gearbox, power is transmitted via a maintenance-free composite coupling to the generator. The generator is a special asynchronous 4-pole generator with wound rotor.

At higer wind speeds, the OptiSpeed and the pitch regulating system keep the nominal power, regardless of the air temperature and density. At lower wind speeds, the OptiTip system and the OptiSpeed optimise the power output by selecting the optimal RPM and pitch angle.

The wind turbine brakes by full feathering the blades. A parking brake is mounted on the gearbox high speed shaft.

All functions of the wind turbine are monitored and controlled by microprocessor-based control units. This control system – including a transformer – is placed in the nacelle. Changes in the pitch of the blades are activated by a hydraulic system, which enables the blades rotate 95 degrees. This system also supplies the pressure for the brake system.

The glass fibre reinforced nacelle cover protects all the components inside the nacelle against rain, snow, dust, sun, etc. A central opening provides access to the nacelle from the tower. Inside the nacelle, there is an 800-kg service crane, which can be changed to lift the main components up to 6 400 kilograms.

The steel tubular tower (3-parted 67m, 4-parted 78 m) is delivered painted. The top diameter is 2.3 m and the bottom diameter 4 m. As an option, Vestas offers a service lift in the tubular tower.

OptiSpeed, also named Vestas Converter System (VCS), ensures a steady and stable electric power from the turbine.

VCS consists of an effective asynchronous generator (2 MW, 690 VAC, 50/60 Hz, 1,680–2,016 RPM) with wound rotor and slip rings. A power converter VCS enables variable speed in a range of approx. 60% of nominal RPM. VCS together with the pitch control ensures energy optimisation, low noise operation and reduction of loads on the gearbox and other vital components.

VCS controls the value of current in the generator rotor circuit. This gives precise control of the reactive power, and gives an exact connection of the generator to the grid.

Weights:

	67 m	78 m
Tower	135.0 t	190.0 t
Nacelle	61.2 t	61.2 t
Rotor	37.2 t	37.2 t

The wind turbines can be placed in wind farms with the distance of at least 5 rotor diameters (400m between the wind turbines). If the wind turbines are placed in one row, perpendicular of the predominant wind direction, the distance between the wind turbines must be at least 4 rotor diameters i.e. 320 m.

Vestas Remote Panel for Windows (VRPW) is a computer software for remote monitoring and control of Vestas wind turbines. The program is running on standard Personal Computers with Windows 95/98/ME or Windows NT 4/2000 and enables easy access to wind turbine data via a modem. By means of VRPW it is possible to monitor essential turbine functions and to receive production data and alarms.

5.2 Pakri wind farm

5.2.1 Pakri wind farm investments

Pakri WF investments are calculated on the basis of Paldiski PP option PP3 (Table 5-2 and Table 5-3). The real total investments may be somehow less than EUR 68 million, depending on contract negotiations between the Pakri WF developers and the wind turbine supplier. But on the other hand the grid connection and land lease or purchase costs may be much higher. The task of this feasibility study is to present only preliminary expert estimates.

Table 5-3. Pakri WF investments

			Unit	Pakri WF
2	Wind turbine			V80
3	Rated power	RP	kW	2 000
4	Tower height		m	78
5	Net power production	NP	MWh	5 350
6	*Wind farm*			
7	Number of turbines	n		36
8	Rated power	RPn	kW	72 000
9	Net power production	NPn	MWh /y	192 593
10	Wind turbines price		EUR	56 532 263
11	Erection		EUR	1 579 941
12	Transportation		EUR	3 041 300
13	Foundation		EUR	1 380 492
14	Roads		EUR	306 776
15	Grid connection		EUR	4 601 639
16	Project management		EUR	1 348 848
17	Total investments	TIN	EUR	68 791 258

The cost of roads and cables depend on the exact location of the Pakri WF wind turbines that is not yet determined. The wind energy based electricity production and therefore the annual costs per 100 kWn depend also on the number and location of wind turbines.

5.2.2 The wind power based electricity price policy and capital costs

The main barrier to the much wider use of wind energy in Estonia is the lack of confidence in local electricity market conditions, the vague state of national energy strategy and the electricity price policy. The grid connection conditions for the RES – feed-in tariffs and other technical conditions are not yet determined for the next 10–20 years period. At the same time the new EU directives request the opening of electricity market, RES based electricity production significant increase etc.

The political, legal and economical uncertainty in RES price policy was described in chapters 2 and 3. This uncertainty is handled in this chapter by the variable feed-in tariff estimates and variable capital costs according to the different RES price policy options.

In the following sections we compare three RES price policy options using very simple wind farm cost models without inflation. We are interested only in the *relative* efficiency of these different price policy options. If inflation is ignored in all these options then the relative efficiency estimates are more or less correct.

These wind turbines cost models demonstrate the advantages and shortcomings of high or low feed-in tariffs and help us to work out the rational strategies for the wind farm developments.

5.2.2.1 Wind energy based electricity price policy options

In our feasibility study we compare three different options for the wind energy based feed-in tariffs.

A. High feed-in electricity tariff, at least 5.75 EUR (90 EEK) per 100 kWh excluding VAT, that creates strong incentives for the private investments. The results are hopefully rapid growth of wind energy sector, but also the increasing capital costs and electricity prices. It may create some social problems in Estonia, because electricity prices are already relatively high for the consumers. The high cost of the rapid development of wind electricity sector is paid by electricity consumers.

B. Medium feed-in electricity tariff 4.48 EUR (70 EEK) per 100 kWh excluding VAT with certain premiums for the wind power developers (loans with low or zero interest rate, cheap land and grid connection etc). Capital costs and electricity prices are at lower rates compared to first option.

C. Low feed-in electricity tariff 4.00 EUR (63 EEK) per 100 kWh excluding VAT with rather low or zero interest rate on the capital invested. It is the low-profit option with international financial aid, co-operative or state equity capital involved. The wind energy sector growth will not be so fast as in the first case, but consumers and enterprises enjoy electricity prices that are not higher than in neighbouring markets. The wind turbines prices and instalment costs are decreasing in the future and then it will be easier to develop the wind energy sector.

5.2.2.2 Option A – high feed-in electricity tariff

This option presents the situation that the government will decide to stimulate the profit-oriented wind energy based electricity production and the feed-in tariff is about two times higher than existing oil shale based electricity producer price. It is the case when the consumers must pay the difference between these two price levels. It is likely it will be politically very unpopular decision and connected with high political risks. The decision is above all cost-efficient for the wind energy developers and investors, not for the consumers. Therefore, the introduction of it may be questionable from the practical point of view.

The basic assumptions on what the option A is built up are:
1/3 TIN – equity capital with 8% interest rate per year (20 years);
2/3 TIN – 6% loan paid back in 10 years;
depreciation 8% during the 11–20 years;
electricity feed-in tariff – 5.75 EUR (90 EEK)/100 kWh, VAT excluded, tariff valid for 20 years (without inflation);

Table 5-4. Electricity cost calculations with high feed-in tariff (A)

			PP3	Pakri WF
2	Turbine		V80	V80
3	Number of turbines		3	36
4	Tower height	m	78	78
5	Rated power	kW	6 000	72 000
6	Net power production	MWh	16 049	192 593
7	Total investments TIN	EUR	5 735 024	68 820 288
8	2/3 TIN	EUR	3 823 349	45 880 192
9	1/3 TIN	EUR	1 911 675	22 940 096
10	Maintenance	EUR	153 926	1 847 118
11	Land lease	EUR	2 558	63 939
12	Capital cost 2/3 TIN 6% 1–10y	EUR	509 364	6 112 370
13	Capital cost 1/3 TIN 8% 1–20y	EUR	152 934	1 835 208
14	Depreciation 11–20y TIN 8%	EUR	458 802	5 505 623
15	Annual cost 1–10y	EUR	818 782	9 858 634
16	Annual cost 11–20y	EUR	768 220	9 251 887
17	Annual cost / 100kWh 1–10y	EUR	5.10	5.12
18	Annual cost / 100kWh 11–20y	EUR	4.79	4.80
19	100kWh feed-in tariff	EUR	5.75	5.75
20	Annual earnings	EUR	922 841	11 074 086
21	Annual income 1–10y	EUR	104 058	1 215 452

22	Annual income 11–20y	EUR	154 621	1 822 199
23	Payback period	y	6.2	6.2

The wind farm 20-year period is divided into two equal parts because it is very complicated to get loans for the periods of more than 10 years.

The depreation in option A is chosen 8% for 11–20 years to decrease annual cost deviations between 1–10 and 11–20 year periods. If the depreciation is for example 4% during the 1–20 years then the wind energy based electricity 1–10 year annual cost (row 17 in Table 5-4) is remarkably higher than during the next 10-year period (row 18). The option A demonstrates that there are no problems to increase wind farm investments, because the payback period is 6.2 years and the average annual income is about 10–15% from the annual earnings.

5.2.2.3 Option B – medium feed-in electricity tariff

Options B creates the incentive to decrease the cost of wind power based electricity. Capital costs are lower, when the proportion of equity capital is higher – the debt ratio (long-term liabilities/equity) is lower. Instead of paying back huge loans and interest rates to the investors we can use international aid, create favourable grid connection conditions and positive incentives for the local governments or co-operative members.

Wind power based electricity investment assumptions for the option B:
1/3 TIN – equity capital (state) with 0% interest rate;
2/3 TIN – 3% (subsidised) loan for 10 years;
depreciation 8% during the 11–20 years:
electricity feed-in tariff – 4.48 EUR (70 EEK) /100 kWh (20 years);

Table 5-5. Electricity cost calculations with medium feed-in tariff (B)

			PP3	Pakri WF
2	Turbine		V80	V80
3	Number of turbines		3	36
4	Tower height	m	78	78
5	Rated power total	kW	6 000	72 000
6	Net power prod, 92%	MWh	16 049	192 593
7	Total investments TIN	EUR	5 732 605	68 791 258
8	2/3 TIN	EUR	3 821 737	45 860 839
9	1/3 TIN	EUR	1 910 868	22 930 419
10	Maintenance	EUR	153 926	1 847 118
11	Land lease	EUR	2 558	63 939
12	Capital cost 2/3 3% 1–10y	EUR	442 836	5 314 028
13	Capital cost 1/3 0% 1–20y	EUR	0	0
14	Depreciation 11–20y TIN 8%	EUR	458 608	5 503 301
15	Annual cost 1–10y	EUR	599 320	7 225 084
16	Annual cost 11–20y	EUR	615 092	7 414 357
17	Annual cost / 100kWh 1–10y	EUR	3.73	3.75
18	Annual cost / 100kWh 11–20y	EUR	3.83	3.85
19	100kWh feed-in tariff	EUR	4.48	4.48
20	Annual earnings	EUR	719 013	8 628 157

21	Annual income 1–10y	EUR	119 693	1 403 073
22	Annual income 11–20y	EUR	103 921	1 213 801
23	Payback period	y	8.0	8.0

This option has the payback period 8 years – more than in option A.

More complicated is also to find equity with 0 interest rate and the loan with 3% interest rate. This wind farm cost model can be modified by decreasing the annual income (rows 21–22) and increasing the interest rates.

5.2.2.4 Option C – low (normal) feed-in electricity tariff

There are no arguments against the wind energy based electricity, if the wind energy feed-in tariff is equal to the normal, liberal electricity market price. Chapters 2 and 3 described electricity markets, prices and feed-in tariffs in some EU countries and in Estonia. According to this information the feed-in tariff in Estonia must not be higher than 4 EUR/100kWh without VAT. Wind electricity is then more cost-effective than the oil shale based electricity if we calculate external costs correctly. For example introducing only the CO_2 tax into the oil-shale based electricity prices at the same level as it is done in Sweden the oil-shale based electricity producer price will be 6.57 EUR/100 kWh (see the remarks concerning external costs for oil shale in 3.3.3).

Wind power based electricity cost calculations for the option C:
½ TIN – equity capital with 8% interest rate per year (20 years);
½ TIN – equity capital with 0% interest rate;
depreciation 4% (20 years)
electricity feed-in tariff – 4.00 EUR (63 EEK) /100 kWh (20 years).

Table 5-6. Electricity cost calculations with low feed-in tariff (C)

			PP3	Pakri WF
2	Wind turbine		V80	V80
3	Number of turbines		3	36
4	Tower height	m	78	78
5	Rated power total	kW	6 000	72 000
6	Net power production	MWh	16 049	192 593
7	Total investments, TIN	EUR	5 735 024	68 820 288
8	Maintenance	EUR	153 926	1 847 118
9	Land lease	EUR	2 558	63 939
10	Depreciation 4% TIN	EUR	229 401	2 752 812
11	Annual cost	EUR	385 885	4 663 868
12	Annual cost / 100kWh	EUR	2.40	2.42
13	Interest rate 1/2 TIN 8%	EUR	229 401	2 752 812
14	Total costs	EUR	615 286	7 416 679
15	Prod. price / 100 kWh	EUR	3.83	3.85
16	100 kWh feed-in tariff	EUR	4.00	4.00
17	Annual earnings	EUR	641 976	7 703 712
18	Annual income	EUR	26 690	287 033
19	Payback period	y	8.9	8.9

The Table 5-6 actually presents two alternatives of the option C. If the Pakri WF investments include only equity with 0% interest rate then the wind electricity annual cost is 2.42 EUR/100 kWh (row 12).

The second alternative is more feasible – equity has the 4% interest rate or ½ equity has the 8% rate. At least ½ equity with 8% interest rate can be collected from co-operative members, the second part from the state and from other sources. Then the wind electricity cost is 3.85 EUR/100 kWh (row 15) and annual income (row 18) is 4% of the annual earnings. The payback period is 9 years.

5.2.3 Maintenance costs

Maintanance costs include service on site, consumables, repair, wind turbine insurance, rent of site, administration, etc. Consumables, such as oil for gearboxes, brakes and clutches are replaced at fixed intervals of three years. Particular details of the yaw system are replaced at intervals of five years.

Annual maintenance costs are estimated as 0.15 EEK/kWh or 9.59 EUR/MWh. Insurance costs are about half of the maintenance costs.

Land lease is estimated by the local government experts in all price policy options EUR 64,000 for Pakri WF and EUR 2,600 for Paldiski PP. In European countries the land value in wind energy based electricity cost is usually much more significant than in our estimates. It depends on the shortage and ownership of usable land. Pakri WF land is mainly state-owned and therefore the land lease or price policy is more flexible.

Maintenance costs and land lease are presented in (Table 5-4 – Table 5-6).

5.2.4 Relative feasibility of the price policy options

High wind energy feed-in tariffs used in Germany, Denmark and in some other countries are already decreasing. What is the best solution for Estonia: option A, B or C? Table 5-7 and Table 5-8 present an overview of RES price policy options for the Paldiski PP and Pakri WF.

If we use in Paldiski PP (PP3) only equity capital with 0% interest rate then the wind electricity cost is 2.40 EUR / 100 kWh (see the column D in the Table 5-7). It includes only 4% depreciation and maintenance costs. If to take into account only maintenance costs then the wind energy based electricity selling price is 0.96 EUR / 100 kWh (column E). Without insurance the wind electricity marginal maintenance cost is only about 0.50 EUR (8 EEK) / 100 kWh. These marginal maintenance costs are really very low and demonstrate the main advantage of wind energy based electricity. The same is true for the Pakri WF.

Table 5-7. Paldiski pilot project (PP3) price policy options

	Wind electricity price policy		A	B	C	D	E
1	Wind el. feed-in tariff/100 kWh	EUR	5.75	4.48	4.00		

2	Wind el. cost / 100 kWh 1–10y	EUR	5.10	3.73	3.83	2.40	0.96
3	Wind el. cost / 100 kWh 11–20y	EUR	4.79	3.83	3.83	2.40	0.96
4	Equity / TIN ratio		0.33	0.33	0.50	1.00	1.00
5	Equity interest rate		8.00	0.00	8.00	0.00	0.00
6	Debt / TIN ratio		0.67	0.67	0.50	0.00	0.00
7	Debt interest rate		6.00	3.00	0.00	0.00	0.00
8	Annual capital cost / 0.04*TIN ratio 1–10y		2.89	1.93	1.00	0.00	0.00
9	Annual capital cost / 0.04*TIN ratio 11–20y		0.63	0.00	1.00	0.00	0.00

Pakri WF wind energy based electricity cost calculations for the options A, B and C are presented in the last columns WF of the Table 5-4 – Table 5-6. These tables are useful for the comparisons between PP3 and WF. For example the wind electricity annual costs per 100 kWh are slightly different, but less than 1%.

The main factors in annual wind electricity costs per 100 kWh are capital costs that are determined by the proportion of the owners` equity (or debt ratio) and the interest rates of loans and equity. Therefore the only way to adapt to the wind electricity low (normal) feed-in tariffs is to diminish the capital costs, which means to find out most favourable conditions for getting the needed capital.

The proportion of annual capital costs in different price policy options can be compared through the ratio to the annual depreciation costs (rows 8 and 9 in Table 5-8). The lowest capital costs are in option C – about 2–3 times less than in option A.
The income/earnings ratio is 4–16% (rows 11,12).

Table 5-8. Pakri wind farm price policy options

	Wind electricity price policy		A	B	C
1	Wind el. feed-in tariff/100 kWh	EUR	5.75	4.48	4.00
2	Wind el. cost / 100 kWh 1–10y	EUR	5.12	3.75	3.85
3	Wind el. cost / 100 kWh 11–20y	EUR	4.80	3.85	3.85
4	Equity / TIN ratio		0.33	0.33	0.50
5	Equity interest rate	%	8.00	0.00	8.00
6	Debt / TIN ratio		0.67	0.67	0.50
7	Debt interest rate	%	6.00	3.00	0.00
8	Annual capital cost / 0.04*TIN ratio, 1–10y		2.89	1.93	1.00
9	Annual capital cost / 0.04*TIN ratio, 11–20y		0.63	0.00	1.00
10	Payback period	y	6.2	8	8.9
11	Income / annual earnings, 1–10y		0.11	0.16	0.04
12	Income / annual earnings,11–20y		0.16	0.14	0.04

The lowest acceptable for the developers feed-in tariff is 4 EUR (63 EEK) / 100 kWh – price policy C with normal maintanence costs, 4% depreciation and 4% equity capital interest rate. More effective for the wind energy based electricity developers are options A and B.

Wind electricity feed-in tariff over 6 EUR/100 kWh is not acceptable for the electricity consumers in Estonia.

The most cost-effective for the Estonian economy and for all electricity consumers is the wind electricity price policy option C with normal (low) feed-in tariffs. The main financial instruments to develop the wind energy sector in Estonia are not the abnormally high wind energy based electricity feed-in tariffs, but the state or co-operative investments into the wind farms with low or zero interest rate. The state must provide for the wind farms favourable grid connection conditions.

5.3 Conclusions

The wind energy based electricity cost calculations of the five wind turbine alternatives proved that the most feasible wind turbine for the Pakri WF is Vestas V80 with 78 m tower. Only a bit less cost-effective was the same wind turbine with 67 m tower. More detailed analysis of wind turbine erection and installment costs will help us to determine the best alternative.

The Pakri WF cost-efficiency depends on Estonian electricity market liberalization and wind energy based electricity feed-in tariffs. The price policy options A, B and C analysis proved that the feed-in tariff less than 4 EUR per 100 kWh is not cost-effective for the wind electricity developers. The feed-in tariff more than 6 EUR per 100 kWh is not acceptable for the electricity consumers in Estonia.

Environmental expenses in oil shale-based electricity production price still remain very low compared with the actual damage to the environment. Pollution charges in the developed Nordic countries exceed those used in Estonia by tens and even hundreds of times. Considering, for example, only pollution charge for CO_2 emission on the basis of rates established in Denmark or Sweden, the oil shale-based electricity production price would be at least 6.60 EUR/100 kWh. But a sharp enforcement of such regulations is not actually possible in the short term considering the level and possibilities of our economy and purchasing power of consumers.

The high wind electricity feed-in tariffs, options A and B, represent the case when the *political* decisions are made to stimulate artificially wind power production, not the natural *economical* signals about high demand. These political decisions are favourable to inefficient decisions, for example to use loans with high interest rate. If the political climate changes and high wind electricity feed-in tariffs will be abolished the wind farm owners will be in great difficulties to pay back their loans. Estonian wind energy sector must avoid these political risks.

The most cost-effective for the Estonian economy is the wind electricity price policy option C with normal (low) feed-in tariffs. The wind energy sector needs not the abnormally high wind energy based electricity feed-in tariffs, because these price distortions create false incentives and wind farms with low efficiency. The feasible strategy is the state or co-operative equity investments into the wind farms with low or zero interest rate. The state must provide for the wind farms favourable grid connection conditions.

Table 5-9. Investment calculations

	Unit	PP1	PP2	PP3	PP4	PP5	WF
Wind turbine		V52	V80	V80	S70	S70	V80
Rated power	kW	850	2 000	2 000	1 500	1 500	2 000
Tower height	m	65	67	78	65	85	78
Power production	MWh	2 209	5 465	5 815	4 215	4 669	5 815
Net power production	MWh	2 032	5 028	5 350	3 878	4 295	5 350
Mean wind speed	m/s	7.2	7.2	7.4	7.1	7.5	7.4
Mean energy density	W/m^2	404	405	443	401	460	443
Rotor area	m^2	2 124	5 027	5 027	3 846	3 846	5 027
Capacity factor	%	27	29	31	30	33	31
NP / RA per annum	MWh/m^2	0.96	1.00	1.06	1.01	1.12	1.06
NP / RP per annum	MWh/kW	2.39	2.51	2.67	2.59	2.86	2.67
Number of turbines	N	3	3	3	3	3	36
Rated power	KW	2 550	6 000	6 000	4 500	4 500	72 000
Net power production	MWh /y	6 097	15 083	16 049	11 633	12 886	192 593
Wind turbines price	EUR	1 561 402	4 444 360	4 711 022	3 934 401	4 162 182	56 532 263
Erection	EUR	110 765	124 209	131 662	124 209	131 662	1 579 941
Transportation	EUR	106 991	239 096	253 442	239 096	253 442	3 041 300
Foundation	EUR	50 618	95 867	115 041	95 867	115 041	1 380 492
Roads	EUR	25 565	25 565	25 565	25 565	25 565	306 776
Grid connection	EUR	162 975	383 470	383 470	287 602	287 602	4 601 639
Project management	EUR	40 366	106 251	112 404	94 135	99 510	1 348 848
Total investments	EUR	2 058 680	5 418 819	5 732 605	4 800 876	5 075 004	68 791 258
TIN / NPn		0.34	0.36	0.36	0.41	0.39	0.36

Table 5-10. Option A

		PP1	PP2	PP3	PP4	PP5	WF
Turbine		V52	V80	V80	S70	S70	V80
Number of turbines		3	3	3	3	3	36
Tower height	M	65	67	78	65	85	78
Rated power	KW	2 550	6 000	6 000	4 500	4 500	72 000
Net power prod, 92%	MWh	6 097	15 083	16 049	11 633	12 886	192 593
Total investments TIN	EUR	2 059 549	5 421 106	5 735 024	4 802 902	5 077 145	68 820 288
2/3 TIN	EUR	1 373 033	3 614 070	3 823 349	3 201 934	3 384 763	45 880 192
1/3 TIN	EUR	686 516	1 807 035	1 911 675	1 600 967	1 692 382	22 940 096
Maintenance	EUR	58 474	144 662	153 926	111 574	123 591	1 847 118
Land lease	EUR	2 558	2 558	2 558	2 558	2 558	63 939
Capital cost 2/3 TIN 6% 1-10y	EUR	182 922	481 483	509 364	426 576	450 934	6 112 370
Capital cost 1/3 TIN 8% 1-20y	EUR	54 921	144 563	152 934	128 077	135 391	1 835 208
Depreciation 11-20y TIN 8%	EUR	164 764	433 688	458 802	384 232	406 172	5 505 623
Annual cost 1-10y	EUR	298 874	773 265	818 782	668 785	712 473	9 858 634
Annual cost 11-20y	EUR	280 716	725 471	768 220	626 441	667 711	9 251 887
Annual cost / 100kWh 1-10y	EUR	4.90	5.13	5.10	5.75	5.53	5.12
Annual cost / 100kWh 11-20y	EUR	4.60	4.81	4.79	5.38	5.18	4.80
100 kWh feed-in tariff	EUR	5.75	5.75	5.75	5.75	5.75	5.75
Annual earnings	EUR	350 568	867 296	922 841	668 921	740 970	11 074 086
Annual income 1-10y	EUR	51 694	94 030	104 058	136	28 497	1 215 452
Annual income 11-20y	EUR	69 852	141 825	154 621	42 480	73 259	1 822 199
Payback period	Y	5.9	6.3	6.2	7.2	6.9	6.2

Table 5-11. Option B

		PP1	PP2	PP3	PP4	PP5	WF
Turbine		V52	V80	V80	S70	S70	V80
Number of turbines		3	3	3	3	3	36
Tower height	M	65	67	78	65	85	78
Rated power total	KW	2 550	6 000	6 000	4 500	4 500	72 000
Net power prod, 92%	MWh	6 097	15 083	16 049	11 633	12 886	192 593
Total investments TIN	EUR	2 058 680	5 418 819	5 732 605	4 800 876	5 075 004	68 791 258
2/3 TIN	EUR	1 372 454	3 612 546	3 821 737	3 200 584	3 383 336	45 860 839
1/3 TIN	EUR	686 227	1 806 273	1 910 868	1 600 292	1 691 668	22 930 419
Maintenance	EUR	58 474	144 662	153 926	111 574	123 591	1 847 118
Land lease	EUR	2 558	2 558	2 558	2 558	2 558	63 939
Capital cost 2/3 3% 1-10y	EUR	159 030	418 596	442 836	370 861	392 037	5 314 028
Capital cost 1/3 0% 1-20y	EUR	0	0	0	0	0	0
Depreciation 11-20y TIN 8%	EUR	164 694	433 506	458 608	384 070	406 000	5 503 301
Annual cost 1-10y	EUR	220 061	565 815	599 320	484 992	518 186	7 225 084
Annual cost 11-20y	EUR	225 725	580 725	615 092	498 201	532 149	7 414 357
Annual cost / 100kWh 1-10y	EUR	3.61	3.75	3.73	4.17	4.02	3.75
Annual cost / 100kWh 11-20y	EUR	3.70	3.85	3.83	4.28	4.13	3.85
100 kWh feed-in tariff	EUR	4.48	4.48	4.48	4.48	4.48	4.48
Annual earnings	EUR	273 138	675 736	719 013	521 176	577 313	8 628 157
Annual income 1-10y	EUR	53 077	109 921	119 693	36 184	59 127	1 403 073
Annual income 11-20y	EUR	47 413	95 012	103 921	22 975	45 164	1 213 801
Payback period	y	7.5	8.0	8.0	9.2	8.8	8.0

Table 5-12. Option C

		PP1	PP2	PP3	PP4	PP5	WF
Turbine		V52	V80	V80	S70	S70	V80
Number of turbines		3	3	3	3	3	36
Tower height	m	65	67	78	65	85	78
Rated power total	kW	2 550	6 000	6 000	4 500	4 500	72 000
Net power production	MWh	6 097	15 083	16 049	11 633	12 886	192 593
Total investments, TIN	EUR	2 059 549	5 421 106	5 735 024	4 802 902	5 077 145	68 820 288
Maintenance	EUR	58 474	144 662	153 926	111 574	123 591	1 847 118
Land lease	EUR	2 558	2 558	2 558	2 558	2 558	63 939
Depreciation 4% TIN	EUR	82 382	216 844	229 401	192 116	203 086	2 752 812
Annual cost	EUR	143 413	364 064	385 885	306 247	329 235	4 663 868
Annual cost / 100kWh	EUR	2.35	2.41	2.40	2.63	2.55	2.42
Own. income 1/2 TIN 8%	EUR	82 382	216 844	229 401	192 116	203 086	2 752 812
Production price	EUR	225 795	580 908	615 286	498 363	532 320	7 416 679
Prod. price / 100 kWh	EUR	3.70	3.85	3.83	4.28	4.13	3.85
100kWh feed-in tariff	EUR	4.00	4.00	4.00	4.00	4.00	4.00
Annual earnings	EUR	243 874	603 336	641 976	465 336	515 458	7 703 712
Annual income	EUR	18 079	22 428	26 690	-33 027	-16 863	287 033
Payback period	y	8.4	9.0	8.9	10.3	9.8	8.9

6 Analysis of CO2 abatement cost-efficiency

The present chapter analyses the potential of the Pakri Peninsula wind farm (Pakri WF) as a climate change mitigation project in the frame of Joint Implementation (JI). The naturally good preconditions for wind energy wider introduction are used for construction of a first large-scale wind energy based power generator unit in Paldiski region. Estonia has a good wind potential, however, up till present time only one wind turbine on the western island Hiiumaa has been working for longer period, it was erected in 1997 (see Figure 6-1). It's rated power is small compared with nowadays wind turbines – 150 kW only, and accordingly annual power production reached approximately 320 MWh during recent years. The second turbine with the capacity of 300 kW started functioning in February 2002 only and no statistical data on the power production is available yet. The turbine is the first one out of the small-size planned wind farm located in the south-west of island Saaremaa. Single wind turbine does not allow to make solid conclusions about the costs and efficiency of power production from the point of view of climate change mitigation activities.

In the current chapter the GHG mitigation costs are calculated on basis of the results of financial calculations performed in the Chapter 5 varying depending on three investment options. The actual RES promotion policy in the host country actually impacts on the cost-efficiency of climate mitigation. As a lot of issues connected with the financial options of investment to wind energy depend on the current formation of state's energy policy, no long-term fixed assumptions could be taken for the basis. An element of life cycle analysis, CO_2 emission due to manufacturing, erection and maintenance will be taken into consideration. The cost of CO_2 mitigation is finally calculated for Pakri wind farm life span.

6.1 The number of wind turbines in feasibility study area

In Estonia, wind energy could be considered the second-important renewable energy source after the biomass, therefore the potential of wind in Estonia is carefully studied today. The theoretical potential of the wind energy could reach the benchmark of 10 TWh a year[61]. This could give approximately twofold yearly electricity consumption – 5.2…5.3 TWh – of recent years in the country. One should still take into the consideration the real economic and technical restrictions dominating at present time. The actual production at present is about 0.32 GWh during recent years. So, there is a long way to go.

Paldiski region, including Pakri Peninsula and two neighbouring islands is the area with one of the most high mean energy density after two biggest western islands Saaremaa and Hiiumaa. Compared to those islands, still the number of restrictions posed by natural environment is relatively much smaller, which allows far bigger scale of development of wind farms and single wind turbines on the western and south-western coastline of Estonia.

[61] This figure has been recently assessed by the Institute of Energy by Tallinn Technical University and was under the discussion in the roundtable on RES potential in Estonia.

Figure 6-1. Tahkuna 150 kW wind turbine in Hiiumaa

In the present study the evaluation of whole Paldiski region from the point of view of wind energy potential has undertaken, see Chapter 4 and appropriate map of potential sites for building wind turbines or wind farms (see Figure 4-11). The option of off-shore wind farm has not considered as the issue is not of high priority at present time in Estonia. However, considering the practice of Denmark, for example, it may occur that the further development of large-scale wind farms will be towards using shallow sea areas in the coastline of western Estonia. The whole Paldiski area which includes two neighbouring islands could host up to 73 towers for wind turbines erection. In case the 2 MW turbines will be foreseen to be used, the relevant yearly production of wind power reaches 390 GWh, which should be considered rather significant output (amount) of electricity in the scale of small country. As the including of two Pakri islands to the frame of present feasibility study was not planned in the phase of application for present study, the technical, economic and environmental restrictions analyses were carried out to Pakri Peninsula only.

The overall number of wind turbine towers to be located in the study area was evaluated in the Chapter 4. It is assessed on the basis of EIA, taking into consideration the various restrictions set by nature conservation, buildings, Important Bird Area (IBA) limitations, etc. aspects. Additionally the restrictions caused by the location of local roads was considered. All in all – the 36 wind turbines as a maximum for the planned Pakri WF with the rated power of 2.0 MW each could be located on the peninsula, which is the actual feasibility study area.

The number of towers corresponds to maximum number which could be located using the step-wise elimination of particular zones under certain restrictions on peninsula. In case the rated power of the turbine is smaller the number of towers could be increased somehow and vice-versa. Slightly bigger turbines could be installed at the same number of towers or the number of towers must be slightly decreased. In present case the maximum capacity of turbines, 2.0 MW engine was chosen, as it is desirable that the suitable areas on the peninsula could be used for generating maximum quantities of electricity. For the time being in Europe the international consortium Vestas Wind Systems A/S with it's 2.0 MW Vestas V80 turbines have won leading position compared to many other turbine producers. Still, this could not be taken as the absolute value. In case some other wind turbine producers with somehow higher rated power of turbines' will be chosen, the maximum yield of electricity could be increased appropriately. This is an aspect which must be considered in a comprehensive way together with the requirements of EIA.

Also, the option to change the lower capacity turbines with those of higher rated power in the future, should be considered when the huge investments designed for the long term are under way. The land use restrictions would be mostly the same. The idea would be to get higher energy yield of wind power using the same territories. Such a practice is under way in some countries in Europe, e.g. in Denmark.

6.2 GHG emission reduction potential of the feasibility study area

6.2.1 Baseline data for oil shale based power production

The total rated power of 36 wind turbines equals to 72 MW. Yearly power production of the wind turbines according to the wind potential in the Pakri WF area allows to produce in average 192 593 MWh/year of electricity, see the calculations performed in the Chapter 5 and appropriate comprehensive tables (5-4 – 5-8).

To make an assessment of possible quantities of avoided GHG emission, the baseline figures for oil shale based power production must be used. The year 2000 has been taken for the basis. For the purpose of the study, the amount of emissions per produced quantity of electricity is the key factor. This value is used for calculating the avoided tonnes of CO_2 as a result of functioning of wind turbines. There exist several options of assessment of CO_2 emission factor in oil shale based power industry. In the following the net electricity production is used, which means the electricity own use by power plants (in-plant consumption) is excluded.

In the calculations the statistical data from power producer, Eesti Energia AS on electricity production, the use of oil shale and appropriate emissions of CO_2 have been taken for the basis to derive the value of the CO_2 emission factor.[62] In 2000 the net production of power in two oil shale based power stations (Narva Power Plants) in

[62] Environmental Report. (2000). Eesti Energia AS, Tallinn.

North East of Estonia was 6,572 GWh, and their total CO_2 emission was 8,996 thousand tonnes.

The numerical value of the CO_2 emission factor is thus: 8,996 thous. t / 6572 GWh = 1.3688 kg/kWh or t/MWh.

Based on the literature on oil shale combustion technologies[63] value of the coefficient has been referred – 1.35 ... 1.4 kg CO_2/kWh. This is in good coherence with the calculations based on the statistical data from the year 2000. The value of the CO_2 emission factor – 1.37 kg/kWh as a mean value was recently recommended by Tallinn Technical University.

6.2.2 Calculation of CO_2 emission reduction compared to baseline

The avoided emission of GHG, considering CO_2 only, could be calculated based on the yearly output of electricity by 36 wind turbines in the Pakri wind farm, Pakri WF. In the result of normal functioning of wind turbines in Pakri WF, the electricity which is worked out is going to replace a share of electricity generated on the basis of oil shale in existing power plants. Mean annual power yield is estimated at level 5,800 MWh by Vestas V80 (hub height 80 m). In case the business as usual is assumed, the appropriate to produced electricity CO_2 emission will take place. Data from the Chapter 5 are taken for the basis.

The amount of CO_2 emission to be emitted in oil shale power plants during a year to generate 192 593 MWh of electricity is:

192 593 MWh * 1.3688 t/MWh = **263,621** tonnes.

For the life span, equal to 20 years, the value of avoided CO_2 emission for the whole Pakri WF is calculated as following:

263 621 * 20 = **5 272 426** tonnes.

The average yearly amount of avoided CO_2 per one wind turbine is:

263 621.3 /36 = **7 322.8** tonnes.

The value as for single wind turbine during whole life span is appropriately

7,322.8 *20 = **146 456** tonnes of CO_2.

As a result of straightforward evaluation of GHG mitigation, the avoided emission reaches to 5.27 million tonnes for Pakri WF during life span. This could be considered quite a significant amount of avoided CO_2 tonnes for Pakri Peninsula.

[63] Possible Energy Sector Trends. Context of Climate Change. Ed by T. Kallaste, O. Liik and A. Ots. SEI-Tallinn, Tallinn Technical University. Tallinn 1999.

In hypothetical case, when two Pakri islands could be included to Pakri WF as well, the total amount of avoided CO_2 emission could be considered approximately twice as much, i.e. could reach the value of

$$73/36 * 5.27 = 10.7 \text{ million tonnes}$$

These results could be defined as straight effects of wind energy introduction in the country replacing certain amount of electricity by wind generated power.

As it is common in case of comparison of different energy production technologies, including wind turbines the wide spectrum of burdens, externalities could be taken into consideration in cost and effect calculations. In the following an elementary attempt is made to include one externality only to the costs related to wind power generation.

6.2.3 Consideration of the environmental externalities

In case one would like to include the life cycle analysis (LCA) type approach to assess also the GHG emission related global warming effect, which is caused by construction (manufacturing), erection and maintenance of wind turbines, the carbon or carbon dioxide based calculations must be additionally included. It is not the aim of the present feasibility study to analyse various aspects of the LCA, the relevant detailed references could be found in the recent European Communities performed work on externalities. In the following some of rather approximate evaluations of relevant coefficients will be used. In principle, including the emissions of CO_2 to climate mitigation calculations, it may give somehow better idea about the total GHG releases to environment from point of view of LCA connected with wind turbines manufacturing and operation. In the literature some of the values of carbon or CO_2 emission per unit power produced from different electricity generation technologies, including the renewable energy, are given.

Externalities in general are defined as benefits or costs generated as an unintended by-product of an economic activity, that do not accrue to the parties involved in the activity. Environmental externalities are benefits or costs that manifest themselves through changes in the physical-biological environment.[64] Pollution emitted by oil shale based power plants during power generation may result in causing harm to people and environment, it is usually not included to power utility's costs. To the extent that electricity industry does not pay these environmental costs, or does not compensate people for harm or damage done to them, consumers do not face the full cost of electricity they purchase and therefore energy resources will not be allocated efficiently. For the first results in the frame of present work it is referred to Section 3.3.3.

The quantification of burdens in the form of various emissions to atmosphere, is a topics which is well qualified to the internalisation of externalities in using so called wind fuel. There exist quite a number of studies in world as well in Europe which are devoted to different energy production technologies comparison from the various

[64] Owen, A.D. (2001). The Economics of Renewable Energy Technologies in the Context of Australia. Newsletter of the International Association for Energy Economics. Second Quarter, pp.10-14.

aspects, including the burden to environment.[65] Professor Owen, e.g. gives a very good comparison of environmental externalities in different electricity generation technologies.[65] He concludes that on the basis of CO_2-imposed externalities alone it is proved that damage costs resulting from combustion of fossil fuels, if internalised into the price of the resulting output of electricity, would clearly render a number of renewable technologies (specifically wind and biomass) financially competitive with coal-fired generation.[66]

From the other side, in case the wind energy is used for power production, certain externalities should be considered. In the following only one wind turbines related externality, CO_2 emission is taken into consideration based on several references to literature.

Atmospheric emissions occur mainly in the manufacturing and installation phase of wind turbines. Emissions of CO_2, SO_2, NO_x, CH_4, particulates, N_2O etc., result from the energy used in the manufacturing stages of the materials used for the wind turbines. Using data on energy use and emissions caused by the production of materials from the GEMIS database, the total atmospheric emission per wind turbine could be calculated. In doing this way, the so-called wind fuel cycles could be calculated.

Wind is actually a natural energy source, occurring directly at the point of its' use. Thus, there is no fuel cycle with fuel extraction, fuel transportation and processing in connection with a wind farm. The wind fuel cycle consists only of the presence of the wind turbines, their operation and connection to the electric grid.

Characteristic for the wind fuel cycle is the lack of pollution connected directly to the wind turbine functioning (operating). Still, there is chemical pollution connected to the manufacturing of materials for the turbine itself and the materials used for the electrical transmission equipment. In order to include this type of pollution the wind turbines are considered for a more detailed analysis from a life cycle analysis (LCA) point of view. It is commonly accepted that the LCA has the following stages, as shown in the following Figure 6-2.

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[65] ExternE – Externalities of Energy. Community Research Studies (1998). European Commission. Brussels.

[66] Owen, A.D. (2001). The Economics of Renewable Energy Technologies in the Context of Australia. Newsletter of the International Association for Energy Economics. Second Quarter, p.10-14.

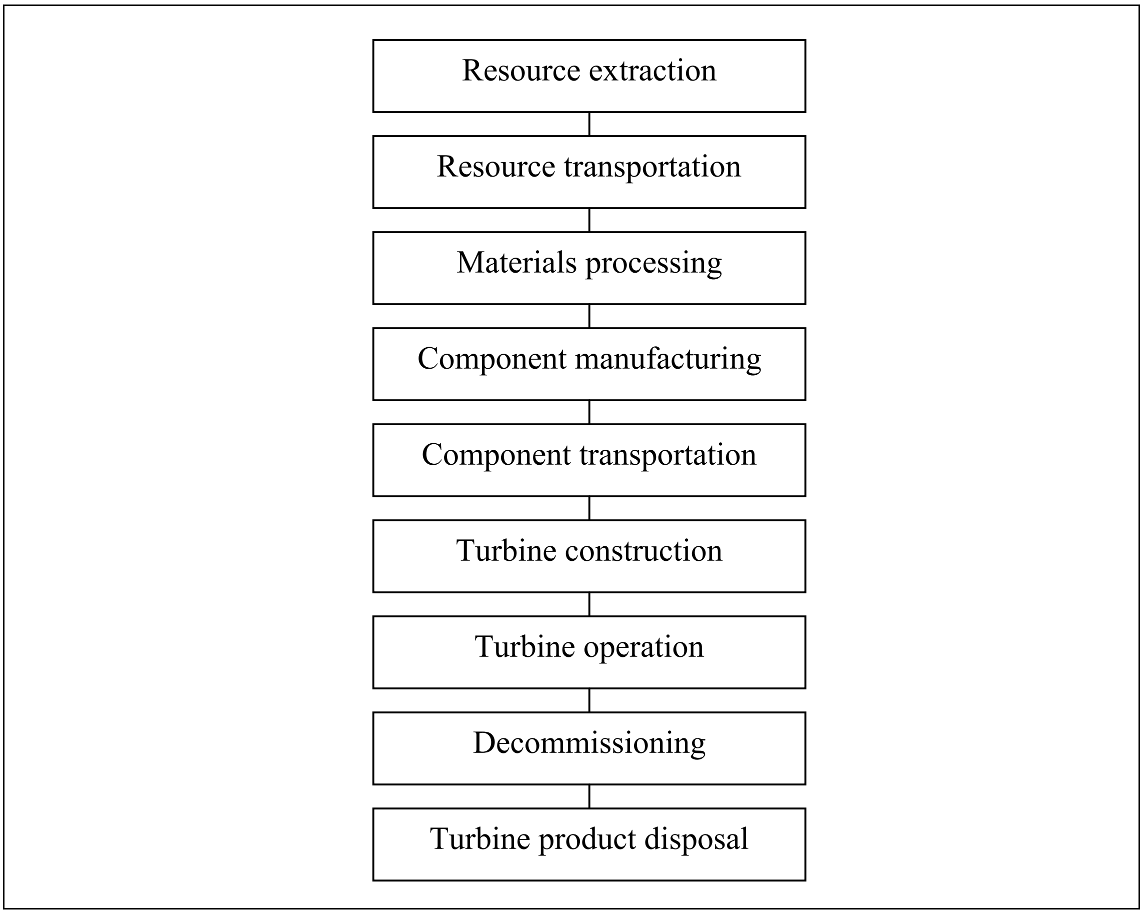

Figure 6-2. Life cycle of the wind turbine fuel cycle

The internalisation of other environmental externalities in general is rather voluminous work. Including costs associated with, e.g. the emissions of CO_2, SO_2, NO_x, CH_4, particulates, N_2O etc., in case of wind turbines manufacturing and maintenance is relatively very small compared to coal or oil shale based power production.

6.2.4 CO_2 emission due to construction, erection and maintenance of wind turbines in Pakri WF analysis

As assumed in case of Pakri WF GHG mitigation analysis CO_2 aspect alone is considered as the most important from the point of view of climate change. LCA as for manufacturing wind turbine is rather straightforward in case the abovementioned single externality only will be considered.

To standardise the CO_2 emissions to a unit output of electricity they are related to the expected electricity production during the life span of the single wind turbine and also, the whole wind farm. The net GHG emission reduction would be less than calculated in the paragraph above according to following results. The following coefficients referred in GEC manual[67] are used for life-cycle analysis type calculations:

[67] GEC Manual

1. Amount of carbon emitted in the process of manufacturing and constructing wind turbines and other related equipment equals to 19.55 (g-C/kWh).

2. Amount of carbon emitted calculated from the energy consumed for the maintenance and repair of wind farms equals to 6.39(g-C/kWh).

To convert the value of given coefficient from carbon to CO_2 one has to use the appropriate ratio of molecular weights, which is:

$$M_{CO2} / M_C = 44/12 = 3.666 \sim= 3.67$$

As a result the relevant coefficients have the following values:

$$19.55 \text{ g-C/kWh} * 3.67 = 71.68 \text{ kg } CO_2\text{/MWh and}$$

$$6.39 \text{ g-C/kWh} * 3.67 = 23.45 \text{ kg } CO_2\text{/MWh.}$$

The amount of CO_2 emitted in the process of manufacturing and constructing of wind turbines and other related equipment for single 2.0 MW capacity turbine is:

$$71.68 \text{ kg } CO_2\text{/MWh} * 5{,}349.8 \text{ MWh} = 383{,}474 \text{ kg}$$

For the Pakri WF total annual amount of CO_2 emitted is:

$$383{,}474 \text{ kg} *36 = 13{,}805 \text{ t.}$$

For the life span of 20 years it makes rather a value – **276,101 t**.

Using the another value of the coefficient, 6.46 kg CO_2/MWh experienced in Germany,[68] when the turbines with rated power of 250 kW were used, the appropriate calculations for Pakri WF lead to more than tenfold less value:

$$6.46 \text{ kg } CO_2\text{/MWh} * 5{,}349.8 \text{ MWh} * 20 *36 = \mathbf{24{,}883} \text{ t.}$$

The third reference value for CO2 emissions[69] by manufacturing 7 t CO_2/ GWh gives no significant difference compared to former option – 26 960 tonnes. It must be considered, however, that the value of this type of coefficient could have significantly different value depending of the value of turbines rated power.

Following the logic of LCA accounted amount of CO_2 emission will be reduced from the amount of avoided CO_2 emission.

The CO_2 emissions released due to maintenance, could be calculated in the following way. According to yearly power production the following amount of CO_2 due to maintenance is emitted:

[68] ExternE – Externalities of Energy. Community Research Studies (1998). European Commission. Brussels.

[69] Environmental Emissions from Energy Technology Systems: the Total Fuel Cycle (1998). Proceedings of IEA/OECD Expert Seminar, Paris, 12-14 April 1989. International Energy Agency.

192,593 MWh * 23.45 kg CO2/MWh = 4,516,498.4 kg = **4,516.5** tonnes.

For the Pakri WF life span, i.e. for 20 years it makes:

4,516.5 t * 20 = **90,326** tonnes.

To summarize the LCA connected CO_2 emissions both from manufacturing and maintenance two options according to given values of coefficients could be differentiated.

1. GEC Manual option.

The values of the coefficients used are those referred to in GEC manual.

The sum of the LCA connected CO_2 emissions both from manufacturing and maintenance is:

276,101 t + 90,326 t = **366,427** t and

the appropriate total CO_2 emissions reduction for Pakri WF for the life span is:

5,272,426 – 366,427 = **4,905,999** t.

2. The combined option – GEC Manual + ExternE study referred values of coefficients.

The values of the coefficient of CO_2 emissions connected with manufacturing used in GEC Manual, also the one as for CO_2 emissions connected with the maintenance for Germany referred in ExternE work.

The sum of the LCA connected CO_2 emissions both from manufacturing and maintenance is:

24,883 + 90,326 = **115,209** t.

The appropriate total CO_2 emissions reduction for Pakri WF for the life span is:

5,272,426 – 115,209 = **5,157,217** t.

Table 6-1. Cost options for GHG mitigation assuming different investment policies

Indicator	Unit	Option A	Option B	Option C
		1/3 TIN equity, 8%	**1/3 TIN equity, 0%**	**1/2 TIN equity, 8%**
		2/3 TIN, 6% loan	**2/3 TIN, 3% subs-d loan**	**1/2 TIN, 0% loan**
		high tariff, 5.75 EUR/100kW	medium tariff, 4,48 EUR/100kW	low tariff, 4,00EUR/100kW
Pakri WF FS analysis results				
Total investments, TIN	EUR	**69,657,904**	**69,657,904**	**69,657,904**
Maintenance cost / year	EUR	**1,847,118**	**1,847,118**	**1,847,118**
Life-span	Years	**20**	**20**	**20**
Pakri WF electrical capacity	MW	**72**	**72**	**72**
Pakri WF yearly power production	MWh	**192,593**	**192,593**	**192,593**
Annual costs, 1–10 years	EUR/y	**9,858,634**	**7,225,084**	**4,663,868**
Annual costs, 10–20 years	EUR/y	**9,251,887**	**7,414,357**	**4,663,868**
Life span costs for Pakri WF	EUR	**191,105,210**	**146,394,410**	**93,277,360**
LCA CO2 related aspects				
CO2 emission factor for oil shale	t/MWh	**1.37**	**1.37**	**1.37**
Pakri WF -avoided CO2 /year	tonnes	**263,621**	**263,621**	**263,621**
Pakri WF Life span avoided CO2	tonnes	**5,272,426**	**5,272,426**	**5,272,426**
Avoided CO2 /year for single turbine		**7,323**	**7,323**	**7,323**
Life span avoided CO2 for 1 turbine		**146,456**	**146,456**	**146,456**
LCA manufacturing (GEC coefficient value)	t CO2/MWh	**0.0717**	**0.0717**	**0.0717**
LCA manufacturing (Germany coefficient value)	t CO2/MWh	**0.0065**	**0.0065**	**0.0065**
LCA manufacturing, total 1-st option (GEC coeff.)	tonnes	**276,101**	**276,101**	**276,101**
LCA manufacturing, total 2-nd opt (Germany coeff.)	tonnes	**24,883**	**24,883**	**24,883**
LCA maintenance (GEC coefficient value)	kg CO2/MWh	**0.02345**	**0.02345**	**0.02345**
LCA maintenance, total	tonnes	**90,326**	**90,326**	**90,326**
Life-cycle aspects, total. 1-st option	tonnes	**366,427**	**366,427**	**366,427**
Life-cycle aspects, total. 2-nd option	tonnes	**115,209**	**115,209**	**115,209**
Pakri WF LCA incl. CO2 reduction 1-st opt	tonnes	**4,905,999**	**4,905,999**	**4,905,999**
Pakri WF LCA incl. CO2 reduction 2-nd opt	tonnes	**5,157,217**	**5,157,217**	**5,157,217**
GHG mitigation issues				
CO2 reduction cost, 1-st option	**EUR/tonne**	**39.0**	**29.8**	**19.0**
CO2 reduction cost, 2-nd option	**EUR/tonne**	**37.1**	**28.4**	**18.1**
CO2 reduction cost not considering LCA	**EUR/tonne**	**36.2**	**27.8**	**17.7**

As for the in-plant consumption, this aspect has taken into consideration in the process of evaluation of mean annual energy yield by wind turbines in the Chapter 4. Mean annual energy production represents net power production where in-plant consumption is already extracted. The in-plant consumption makes less than approximately 2% of the net annual production. Additional aspects of shading, grid connection interruption, availability factor in Pakri WF, losses in transformers, etc. have considered. The net power consumption, which is 92% of mean annual production has taken for the basis while performing the Pakri WF power production calculations Thus, as a result, the final value of the factor decreasing the theoretical potential of wind energy yield makes 10%.

6.3 Cost options for GHG mitigation

The investments to 72 MW Pakri wind farm could be evaluated as very costly compared to Estonia's economy in general. The investments based on Vestas V80 80 metres 2.0 MW wind turbines reach in average EUR 69 million which makes more than EEK 1 billion (the state budget for 2000 was EEK 28.5 billion and for 2001 – EEK 30.5 billion. Compared to neighbouring Finland nowadays state of art in the field of wind energy introduction, it could be said that the closest to Estonia neighbours have stopped with the total installed capacity of wind turbines at the figure 39 MW (see for more detailed information The European Wind Statistics[70]). If one have a look on their wind based power development in ten years time frame the following could be noticed. Finland had developed 2.4 GWh wind power production to year 1992 and thereafter increased exponentially the output of electricity to ~77 GWh in 2000.

The different options (see for detailed description in Section 5.2.2) of investment and energy policies in Estonia are taken for the basis of the cost calculations of the climate change mitigation in the frame of international climate co-operation. Those options actually will finally impact most drastically on the total CO_2 emission reduction costs as the way of getting relevant huge investments for Pakri WF will emphasise the mitigation efficiency in the most significant way.

According to options A, B and C avoided CO_2 emission considering the relevant LCA related externality, present a total value of 4.9 and 5.2 million tonnes according to two LCA related CO_2 emission options according to different coefficients values. The third option including no LCA related GHG aspect could be introduced just for comparison. This makes the costs of CO_2 mitigation for investment option A (see Section 5.2.2) as following:

1.option.
The relevant cost is **39.0** EUR / t avoided CO_2 emission. See for detailed calculations in Table 6-1.

2.option

[70] The European Wind Statistics EUWINet (http://euwinet.iset.uni-kassel.de/)

The relevant cost is **37.1** EUR / t avoided CO_2 emission.

3. option. The relevant cost is **36.3** EUR / t avoided CO_2 emission.

For better view on the final results based on Table 6-1 they are presented in the following Table 6-2.

Table 6-2. Cost options for CO_2 emission reduction depending on investment policies, EUR/t

LCA related CO_2 emission options	Total avoided CO_2 emission, t	Investment option A	Investment option B	Investment option C
1. GEC Manual	4,905,999	39.0	29.8	19.0
2. ExternE + GEC Manual	5,157,217	37.1	28.4	18.1
3. Zero option	5,272,426	36.3	27.8	17.7

Comparing the numerical results of the present study for Pakri WF with the Joint Implementation pilot phase projects average in the frame of EAES AIJ programme results in heating sector (see the Section 1.4.3) on can conclude that the results have relatively good coherence. The preliminary calculations gave the cost level of avoided CO_2 emission per tonne about 20 EUR/t as an average over all project categories. The costs of avoided CO_2 emissions, of course, have rather different basis and structure in heating and electricity sectors.

6.4 Concluding remarks

One can conclude from the variety of different options the significant dependence of GHG mitigation costs from various wind farm investment policies which in their turn depend on relevant governmental RES policy in Estonia. As it was said in the former chapter, the governmental policy plays the key role in the further development of RES based power generation and wind energy sector in particular.

There is no doubt that all the figures include certain probability factor. At present time the most unsure variable to shift from one option to another could be considered the state strategy and policy in the field of further development of electricity generation sector. In case Estonia will take an active development strategy of power sector towards including the strong promotion of RES based electricity generation, including wind energy, all options analysed in the study will benefit. And vice-versa, in case the RES policy will be still fairly modest, the investment climate to wider promotion of RES will be hindered and the capital flows will be influenced.

The cost of wind power technology is continuously decreasing. Over the next couple of decades the cost of all renewable energy technologies is likely to decline as technical progress and economies of scale will be combined to reduce the unit costs of power generating. The most recent European Council directive (EC/77/2001)[71] on further promotion of renewable energy sources based electricity generation in EU Member States will for sure play a remarkable triggering role also in the candidate countries to EU energy policy updating.

However, construction of huge wind farm in Pakri Peninsula using the latest technological developments in wind turbine sector, still requests considerable amount of investments. The investments could be made possible under the international climate change mitigation co-operation, in particular – in the frame of Joint Implementation. This may happen with the help of relying on international financing institutions co-operation in the overwhelming up-wards wave of all-European RES promotion oriented policy campaign.

One of the most promising could be considered the climate co-operation in Baltic Sea Region – BASREC Joint Implementation Testing Ground, which will be launched in 2003. Appropriate preparations have launched in 2000 already. It foresees the involvement of three Baltic States, Russia and Poland as host countries in the implementation of JI. Wind farms will have significant perspective for many potential donor countries to reach their Kyoto targets.

[71] Directive of the European Parliament and of the Council on the promotion of electricity from renewable energy sources in the internal electricity market (2001/77/EC), 27.09.2001.

7 Capacity Building and Public Participation for Pakri Wind Farm Study

7.1 The need and goals for capacity building and public participation of Pakri Wind Farm project

Wider use of renewable energy resources (RES) is one of the major political goals of the Estonian environmental and energy policy. Estonia has expressed its desire to join European Union and has adopted basic legal acts and principles, which are valid in the member countries. According to the EU policy the extensive use of RES is prescribed. EU Directive on promotion of RES based electricity production (2001/77/EC) foresees increasing the share of electricity generated from RES in the EU as an average of Member States up to 22.1% by 2010. As an accession country Estonia will take all steps to meet these requirements.

To implement the tasks set up by the Estonian Government and to meet the EU standards not only technological and economical measures should be taken but also general awareness on renewal energy sources should be raised. Internationally accepted climate change mitigation policies encourage RES promotion policies in Estonia and give more possibilities for introducing wind energy use here.

As shown in the study (Chapter 4) wind has notable potential in Pakri peninsula. This area is considered as one of the most feasible sites for wind energy production in Estonia.

In connection to Pakri peninsula wind farm project the local community needs appropriate and detailed information about planned activities since the very early phases of the project. Informing local people about all sides of planned activities as soon and competently as possible the conflicts and misunderstandings can be avoided.

As a result of the long-term influence of the Soviet military forces Paldiski city and its surrounding area has a number of special economical and social features like high rate unemployment. At the same time, good geographical location, harbours, railway network, accessibility by roads and a functional infrastructure of Paldiski town, offer a notable potential for socio-economic development. The area has initiated the interest of several developers. The planned extension of harbours brings along establishment of new enterprises that increase the energy use in the region. The economic development in the region creates a number of new jobs and opens new opportunities for the local people. Building and widening of the wind park increases the demand for more or less qualified labour force and most hopefully provides jobs for local people in construction works of foundations, roads and lines.

It is notable that there are no wind turbine management companies in Estonia yet and therefore the qualified companies from Germany and Denmark should be ordered. When widening the wind energy production in Estonia it is reasonable to establish the local management companies that would take care of the turbines all over Estonia.

It is important to note that establishment of the wind park in Pakri peninsula is totally supported by the local authorities and therefore the investments to the explanatory work and persuasion are minimal. In connection to the discussions of the development strategy of this area a special program on sustainable development issues – Green Paldiski – has been initiated.

To meet successfully all these developments a wide range of awareness rising activities targeted to all groups of the local community should be undertaken. Concluding the circumstances pointed out above, the goals for capacity building and public participation within Pakri peninsula wind farm project can be listed as following:

- to inform local people (Paldiski city, Pakri peninsula) about the designing of the wind park;
- to give to people an opportunity to participate in decision making process;
- to provide appropriate information to the technical, environmental and economical experts, but also to the representatives of the government and local authorities;
- to raise the general knowledge in Estonia about renewal energy resources, to introduce wind energy related RES possibilities, and to promote its´ wider use;
- to encourage the favourable social and economic changes like increase of the employment rate, integration of the non-Estonian people to the society etc in the community of Paldiski region when raising general awareness and knowledge of local people.
- to promote the implementation of the Estonian and EU energy policy in Estonia.

7.1.1 Determination of the target groups

The target groups for public participation and capacity building regarding Pakri WF project are reasonable to define on the basis of their interest in relation to the wind power use. To some extent it includes also geographical aspects. The following target groups can be differentiated:

1. Group directly influenced by the project implementation activities, i.e. inhabitants of Pakri peninsula and local authorities.

Local community members need a special attention from the point of view of capacity building and adult education. This is a mainly Russian-speaking group with several social problems like high rate of unemployment, low-level language skills and low integration into the Estonian society.

Regarding the developments in Pakri new labour force should be educated and trained. For this purpose the adult education units are to be involved. Involvement of the local people and rising of their knowledge stimulate them to be integrated into the Estonian society.

Regular information exchange between local authorities and the project developers is of great importance. As mentioned before Paldiski City Government is very open and positive towards the new developments in Pakri peninsula and totally supports the establishment of wind farm in this area.

Within the course of environmental impact assessment the sites without any limits for instalment of the wind turbines were specified (Chapter 4). These spots have no population living directly in the area neither land in private properties.

On this reason there is a low probability for conflicts with local people and local authorities. However a close cooperation with Paldiski City Government is important during the project. The participation of the local people in the project will be implemented according to the corresponding legal acts (7.3.1).

7.1.1.1.1 **2. Group influenced indirectly by the activities.** Entrepreneurs, farmers, landowners, fishermen, people oriented to recreation, or business in Paldiski region, etc are considered to belong into this group.

7.1.1.1.2 **3. People from public, also experts in their field,** who have professional interest towards nature and nature conservation objects in the area of project implementation, like experts on nature conservation and environmental protection, green movement, experts on energy, NGOs, teachers, students, academic staff, journalists, etc.

The members of this group need detailed information on legislation, legislative and technical procedure, technical details, economic arguments etc. While the instalment of the wind energy turbines is usually connected with relatively high investment need, information about funding institutions is also reasonable.

Because of two important bird areas and one landscape protection area, the region is in interest of naturalists and NGOs. As one of the most feasible areas for wind energy production in Estonia, the area offers interest to the power engineers, experts on renewal energy, NGOs, journalists etc.

A close cooperation within this expert group where different sides inform each other about the details of their expert area could be established.

4. General public of Estonia. General public of Estonia should be informed about the course and experience of this novel project for our country.

5. Public in neighbouring countries like Finland, Sweden, other Baltic States and Russia. Since air pollution from the existing power stations seriously affects not only the environment of Estonia, but also the air quality of the neighbouring countries and contributes global warming, the general public of the neighbouring countries are entitled to know about the current situation and future developments of energy sector in Estonia.

7.2 Methods for information dissemination and public participation

Results and effectiveness of whatever information dissemination depend on the right and reasonable use of methods. Different methods for information dissemination vary within different target groups.

Meetings

Breefing is aimed to a small and selected group of the people, usually for the key persons of the project. For example it might be the very first meeting between representatives of local authorities (Paldiski City Government) and the project developers. The main parts of the breefing are presentation of the project plan and discussion (in form of questions and answers). The handouts, publications and leaflets can be distributed to the participants. Breefing can never replace the further information dissemination process.

Information day – the objective of the information day is to provide general information about the establishment of wind park. Lecturers present different sides (useful and unfavourable) and aspects of the project to the audience.

Training – provides detailed information about the planned activities having usually more practical character. Training is organized according to a special program aimed to a certain target group. Objective of the training is to raise professional skills and knowledge of the audience about RES including wind energy production and its use. A certification could be issued to the participants after passing the training.

Workshop – this is a place for linking information and ideas, presentations, discussions and asking questions. Workshop should be led by a professional moderator who guarantees equal possibility for everyone to express opinion, directs the discussion, asks questions and concludes the workshop. Decisions should not be made during the workshops. There are no performers and listeners in the workshop – all participants are expected to be active co-actors. The course of the workshop should be recorded.

Public meeting – this is an important method of public participation envisaged in legal acts. The aim of the public meeting is to introduce the project and link information, not to make decisions. The project will be introduced to general public and people can give their opinion immediately during the meeting. Meeting should take place according to the agenda (including opening address, introduction of the issue, presentations, discussion, questions-answers, resume). A neutral speaker or certain person pointed by the developer will lead the meeting. Local people can initiate the public meeting as well, but in this case the project developer should be present.

Cooperation with media

Media – news in newspapers, radio and TV – is a powerful instrument to inform people and influence their attitudes. TV as the most visualized (but expensive) mean of media has a great power to influence people of different age, education, nation etc. On this reason any TV appear should be carefully prepared and worked out.

Articles in local newspaper are the main sources from where local people get information about the activities in their home place. The importance of local media is emphasized in the regulations as well. For example according to the Planning and Building Act. The local government is obliged to inform the public about planning process through the local or county media.

Press release can be made by institutions, which are closely connected with the project: local authorities, developers, state institutions etc. The typical moments to make a press release are the starting of the project, after the completion of the most important steps of the project, after concluding the results of the project.

Internet will take more and more important role when informing people on several issues. Different levels could be considered here starting from a short introduction of the project on the web page of the project developer or local municipality up to a special web site on wind energy and other renewal energy sources. For example a web page for European Wind Energy Association (http://www.ewea.org) indicates to the several other web sites related to RES.

An obstacle is that the Internet is not available to everyone yet limiting the group mostly with the younger people and experts. However, the round of the users is growing from day to day.

Official Publications should be published according to the certain order and be paid by decision makers (local authorities). If the environmental impact assessment is required for the instalment of the wind turbines, the public should be informed through the Official Publications by Paldiski City Government according to the Environmental Impact Assessment and Environmental Auditing Act.

Publications

Articles in professional issues – articles providing special and detailed technical data could be presented and distributed inexpensive way.

Leaflets and posters provide mostly general information about the topic. Publishing leaflets is usually expensive and time-consuming activity. For this reason information provided in it could be more popular and targeted to the wider public to be used for longer period.

Other

Public display could be presented in public places like shopping center, bus station, club, school etc. It could be in form of a small exhibition being clear, attractive, and easy readable.

Public display is an instrument for the public participation that is regulated by Planning and Building Act. According to this act the local government will make a decision on the adoption of the plan and will organize the public display of this. The duration of the public display should be at least two weeks.

Objective of the public display is to provide general information about the project and wake people's interest. It is important to indicate contact addresses and phone numbers of the project leaders.

This method can bring out new groups of interested parties, which the project developers have not considered yet.

Site visit. This method can be used in conflict situation to convince somebody. Also it is useful to visit already working wind turbines to be introduced with the existing experience, positive and unfavourable sides of the use of wind power energy.

Different methods suitable for capacity building and public participation are concluded in the table below. The matter of the table is quite conventional while different topics can be linked with each other. Actual use of methods listed in the table depends on the resources (time, people, finances) of the project.

Table 7-1. Methods for capacity building and public participation

Method	**Capacity building**		**Public participation**
	Experts	**Group with wide interest**	
Meetings			
Breefing	++	+	+
Information day	++	++	+
Training	++	++	
Workshop	++	++	
Public meeting		+	++
Cooperation with media			
Press release	+	++	+
Articles in newspapers	+	++	++
Radio, TV	+	++	+
Internet	++	++	+
Official Publications			++
Publications			
Articles in professional issues	++	+	
Posters and leaflets	+	++	+
Other			
Public display		+	++
Presentations	+	++	++
Visiting the object	++	++	

\+ - *suggested to this target group*
++ - *strongly suggested to this target group*

7.3 Public participation process for Pakri Peninsula Wind Farm Project

The public has the right to participate in making decisions that influence their life. From the other side the active participation is in interest of the developers and the state as well: this is a possibility to consider public opinion and use its experience through democratic process. The following principles apply to any public participation process:

- The public shall be involved in the process as early as possible;
- Information about participation possibilities shall be communicated to the public;
- A reasonable term shall be set for the participation;
- The public shall be given the opportunity to acquaint themselves with the basic documentation; all relevant information needed to make a decision shall be presented;
- Justification shall be given to any refusals not to make information public;
- If necessary, interested groups of the public shall be identified and incentives shall be found to facilitate their participation;
- The public shall be given an opportunity to present their opinions and to influence the planning and implementation of projects;
- The public shall be informed of the final decision immediately.

7.3.1 Legislative basis for public participation in Estonia

Accessibility to the environmental information, public participation in the environmental decision-making process and the right to bring an action are the main rights of citizens provided for by the **Arhus Convention**. Estonia ratified this convention in 2001. The Estonian Government adopted a **Public Information Act** (2001), which also supports these basic rights.

There are number of important elements of public participation foreseen by the **Environmental Impact Assessment and Environmental Auditing Act** (2000).

In Pakri WF feasibility study main steps of EIA have been taken (Chapter 2) except the phase of public participation while the building activities have not started in fact. However, close contact with Paldiski local authorities was kept during the study.

If the environmental impact assessment is required it will fell under the scope of the Environmental Impact Assessment and Environmental Auditing Act. Regarding the public participation the act sets out that the decision-maker (local authorities) is obliged to inform the public through the **Official Publications**. The public must be notified within 10 days of the decision on carrying out an EIA and within 10 days of the report on the EIA. The relevant environmental department (inspectorate) will also be informed in writing. The public will be informed of any issuance of permits.

Individual notices will be sent to the organizations and persons whose interests are directly influenced by the planned installation of wind generators.

The developer will organize a **public meeting** to introduce the planned activity after the EIA program and report are finalized. Submissions of those participating in the discussion will be taken into account and recorded. Any refusals to take the submissions into account must be justified in writing.

By the **Planning and Building Act (1995)** the involvement of public in the decision-making process is enacted regardless of the type of plan. In the context of the Pakri peninsula wind farm project the local government is obliged to inform the public through the local or county media. The local government will make a decision on the adoption of the detail plan and will organize **a public display** of the plan in the center of the city or municipality. The public display must have duration of at least two weeks. All the submissions have to be recorded and the local government will respond to written submissions by registered mail within four weeks after the end of a public display. The outcome of a public display will be communicated through the local or county media.

After that, a public meeting will be held to communicate the outcome of the public display. In case the amendments resulting from a public display and public meeting bring along changes to the fundamental objectives of a plan, another public display and public meeting shall be held after the amendment of the plan.

7.3.2 Plan for public participation

The public participation phase of the project should be carefully prepared and designed, because in some cases the conflicts and misunderstandings with publicity can cause notable loss in finances or even fail of the project.

When planning the public involvement it is relevant to proceed from the legislation that gives a base for minimal action plan. The Environmental Impact Assessment and Environmental Auditing Act and the Planning and Building Act determine the procedure and time for public display, public meetings, Official Publications etc. It is reasonable not to limit the activities only with procedures enacted in the legal acts, but “leave space “ for more activities to secure success and flexibility when working with general public.

In planning the public participation process for a project it is useful to follow the next check list and answer the questions:

- Which legal acts determine the public participation process of this project?
- What procedures are enacted by the legal acts?
- Who are the interested parties of the project?
- Which are the target groups for public participation?
- What is the time frame for the public participation activities?
- What kind of information shall be provided to the public?
- Which are the most reasonable methods for public participation process?
- Is the project related information easily accessible for the public?
- Can the representatives of all interested groups and individuals express their opinion equally?
- Can the representatives of all interested groups and individuals influence the planning and implementing of the project equally?
- Are there enough resources (time, money, people) for public participation process?

Final steps for the fully implemented public participation process are analyses and reporting of the results and feedback - assessment of the process.

The levels of the public involvement are informing, participation and consensus. On the lowest level of public participation the project developers only inform people about the decisions.

On the second level of participation people can express their opinion and influence the course of the project. It is a minimal objective for the public participation and is guaranteed by the legal acts.

The highest level of participation is consensus where the specialists outside the project management group provide expert opinion and therefore they support making final decisions. In the present case it is possible when the third target group for public participation (subsection 7.1.1) will provide knowledge and consultancy to the project developers.

7.3.3 Resources for public participation

The public participation process must be carefully planned and budgeted. The developer who is responsible for the sufficient human, time and financial resources should allocate a special budget for public participation process for the project. Expenses for public participation usually cover 5–7% of the total budget.[72]

When lacking of human, time and financial resources the cooperation with the interested groups like NGOs, students, and voluntaries could be considered.

7.4 Conclusions

The local community needs appropriate information about planned activities on wind energy potential further possible use in Paldiski region since the very early stage of the investment project. The target groups for public participation regarding the Pakri WF project are determined on the basis of their interest in relation to the wind power use. The target groups are defined on the ground of their relationship to the activities planned in the project. The following target groups could be differentiated:

- group what is directly influenced by the project implementation activities, i.e. inhabitants of Pakri peninsula and local authorities;
- group what is influenced indirectly by the activities entrepreneurs, farmers, landowners, fishermen, people oriented to recreation, or business in Paldiski region, etc.;
- people from public, also experts in their field, who have the professional interest towards the nature and nature conservation objects in the area of project implementation like experts on nature conservation and environmental

[72] Merisaar, M., Simonsen, J. H., Tingas, K., Veinla, H. (2001). Keskkonnainfo kättesaadavaks tegemine ja üldsuse kaasamine keskkonda mõjutavate otsuste langetamisse. EV Keskkonnaministeerium. Tallinn, 165 p. (in Estonian)

protection, green movement, experts on energy, NGOs, teachers, students, academic staff, journalists, etc.;
- the general public of Estonia;
- public in neighbouring countries like Finland, Sweden, other Baltic States and Russia

Local community habitants in Paldiski town and Pakri Peninsula often are considered as a socially vulnerable group having social problems like high rate unemployment, difficulties on integrating to Estonian society, problems based on lacking of local language skills, etc. This target group needs a special attention from the point of view of capacity building and adult education. The economic development in this area; extension of the Paldiski harbor, establishment new enterprises, starting the tourism and recreation, starting the wind farms or beginning the production of wind turbines parts, also being involved in construction of turbines foundations and roads, etc. creates very probably a number of new jobs, also opens new opportunities for the local people.

Some other target groups like nature conservationists and environmentalists need particular attention as they may pose a source of conflicts between developers. There are the Important Bird Areas and a landscape protection area what are in focus of mentioned groups. Considering different levels of those groups in early planning stages, also the general public involvement with informing, participation and consensus, the highest level of the public participation – consensus – could be achieved here in a reasonable way. On this level the people outside the project management team could give their advice and support to the project developers and assist in relevant manner the decision-making process.

Steps and procedures for public participation process are envisaged mainly on the regulations like Environmental Impact Assessment and Environmental Auditing Act (adopted by the Estonian Government in 2000), the Planning and Building Act (1995) and Public Information Act (2001).

There is number of different methods suitable for capacity building and public participation process for wind park project. The use of them depends on the specific character of target groups, however; also the human, time and financial resources should be allocated for the public participation process for the wind farm development project.

8 Conclusions

The Joint Implementation pilot phase efficient implementation has played a significant role in country's meeting the Kyoto Protocol targets. It has been a preparatory phase for Estonia as a party to UN FCCC to take an active part in international climate co-operation to elaborate the mitigation of global warming. The important precondition of increasing the scope and variety of Joint Implementation projects is the capacity building at various levels of decision making and also at various recipient levels. At present the awareness on climate issues in general and in Joint Implementation particularly has raised significantly since the first AIJ projects in Estonia were launched.

The task of selection, verification, monitoring and reporting on JI projects should be elaborated by the Estonian Government belongs mostly to two ministries, the Ministry of Economic Affairs and the Ministry of Environment. Institutional capacity has improved within recent years. Still, further supporting activities must be foreseen for enlivenment of the work in climate and energy related sphere. The financing of governmental institutions also the research and development institutions dealing with climate mitigation and RES oriented problems should be improved to have more experts involved to related work.

Monitoring, reporting and verification of the future JI projects should be well defined at the start-up phase of each particular project, this will give a good basis for following reporting procedure to UN FCCC Secretariat as well for further emission trading activities. The JI principles rules and regulations should be discussed openly and fixed in relevant documents available to investors, donor country representatives and local entrepreneurs. The procedure of selection and approval of JI projects must be public, should be prepared by the relevant experts in the Ministry of Environment and the Ministry of Economic Affairs. All stakeholders must have access to project planning in the initial stage. Public opinion must be more strongly considered according to recently enforced Arhus Convention ratified by Estonia in 2001, also adopted by the Government the Public Information Act.

Private sector is increasingly being involved and activated in JI related energy projects. It is actively looking for RES wider introduction in energy sector. The major barrier is still finding partner countries and enterprises to initiate next JI projects. As a result a number of potential activities, co-operation projects and also JI projects are not developed to the phase of practical implementation. The work towards opening up new contacts with next possible donor countries is under way at present.

The Estonian Government recently launched the compiling of national programme for GHG emission reduction (climate programme) the draft of it will be prepared by experts from various institutions. Implementation of the flexible mechanisms, foreseen in Kyoto Protocol, has an important role to play in this programme. It is foreseen the adoption of the programme in the second half of 2002.

The appropriate legislative basis should be worked out to prepare good investment climate to donor countries to start any other type of JI projects in Estonia. The conditions should assure the donors with all needed guarantees and relevant information. The work has started with building up the capacity in government. Hopefully in the frame of national climate programme the relevant proposals towards JI promotion will be worked out to formulate the appropriate legislative basis in the country.

The further development of JI projects in Estonia should be oriented towards the widening of the scope of potential donor countries, also the variety of different categories of projects. This will allow to gather valuable knowledge for the implementation also of other mechanisms, like emissions trading in frame of the Kyoto Protocol. This all is very significant concerning feasibility studies like the Pakri Peninsula Wind Farm (Pakri WF) project.

The substantial experience what Estonia as a successful host country has gathered since the start of first AIJ projects in the frame of the Swedish EAES Programme in 1993 should be generalised, relevant methodological guidelines elaborated, the set of criteria for next JI projects compiled. Estonia as host country in JI will have enough attractiveness and translucency for the donor countries to be approached.

Legislative and promotive measures for supporting wind energy

Planning to take measures for addressing barriers and introducing effective incentives to support the use of wind electricity in Estonia has to take use of relevant experience of countries with successful policy in this field. Due to the wide range of possible measures taken in other countries the need and possibility of inventing completely new incentives is very small. However, local situation and all peculiarities of national economy and energy system should be taken into account when introducing new measures.

There are several options for grouping of possible measures for supporting wind energy use. In the project (feasibility study) the following measure groups were analysed (Chapter 2):

- general national policy (especially towards energy and environment);
- pricing and taxation, e.g.:
  - of fossil fuels;
  - of renewables, particularly of wind-generated electricity;
  - internalisation of external costs;
- measures related to electricity market, e.g.:
  - grid connection conditions;
  - guaranteed purchase obligation;
  - liberalization of market;
- support to investments;
- environmental norms and standards (particularly on usage of fossil fuels);
- promotional and demonstration activities;
- voluntary agreements.

The renewable generated electricity will require two essential elements:

- a moderate price support mechanism that enables renewables producers of renewable energy to enter the market and to make a reasonable profit, and
- a stable regulatory environment such that investors can enter the market without concern that the price support mechanism will be modified in a manner likely to make their investment unprofitable.

The authors of the current study have reached the consensus that the minimum programme for Estonia's wind energy development in near-term future should include initiating the following supportive measures:

- introduction of fixed feed-in tariff for wind-generated electricity supplied to national grid (transmission or distribution network); the continuation of purchase obligation for networks is assumed;
- providing the long-enough duration of the feed-in tariff (e.g. for the first 10 years from the installation of wind turbine);
- restructuring electricity sector of Estonia to avoid monopolistic character of electricity market based on a vertically integrated utility:
    - unbundling generation, transmission and distribution into separate enterprises.

The mid-term measures should include:

- the substantial increase of pollution charge rates, in particular the rate on CO_2 emission;
- use a part of proceeds from pollution charges for supporting renewable energy research and development (e.g. design of wind farms, mapping of wind resources, preparing technical infrastructure, assistance in grid connection, etc.).

The target to be reached in long-term future should be the complete internalization of externalities for all energy resources.

In general the legislation related to planning and building or environmental issues in Estonia stimulates the introduction of wind energy. The administrative processes in relation to obtaining permissions either to acquire or lease land, for building and operating wind turbines are moderately easy and several initiatives are going on to ease it further. The public participation in planning processes is enabled and additionally guaranteed by request of EIA.

External costs for oil shale

Although the results of forecasting received in Chapter 3 indicate that environmental cost elements/components in the oil shale-based electricity (dominating in Estonia) production price will rise by 2010 compared with 2000, over two times, this still very poorly reflects the actual damage caused by the oil shale-based electricity production to the environment. Due to the still modest possibilities of Estonian economy the insufficient consideration of the environmental costs in the oil shale-based electricity price represents certain political and social compromise to control the electricity price.

Unfortunately, not for advantage of the environment. Nevertheless Estonia has done the first steps towards internalisation of external costs for energy resources (introducing pollution charge for CO_2, attempts to rise pollution charges 20% annually etc.), but the level is still very low compared to developed European countries.

To demonstrate how strongly the oil shale-based electricity price can be influenced by introducing externalities a hypothetical calculation has been done for 2000. For the simplicity only one externality – CO_2 was considered using the pollution charge rate introduced in developed Nordic countries.

For the simplicity only one externality – CO_2 was considered. Using the relatively modest, compared to Sweden, the Danish rate (242 DKK/t, it is about 500 EEK/t which exceeds the rate used in Estonia by hundred times) for the CO_2 emission from oil shale-based electricity production in Estonia (8,996 thous. t in 2000) the environmental costs will increase very significantly. In particular case – the value increases from 0.05 EEK/kWh (0.32 EUR/100 kWh) to 0.73 EEK/t (4.65 EUR/100 kWh) and the total oil shale-based electricity production price from 0.35 EEK/kWh (2.25 EUR/100 kWh) to 1.03 EEK/kWh (6.57 EUR/100 kWh), i.e. about 3 times. Comparing this result with the calculations of the wind energy based electricity prices it can be concluded that introducing only one externality, with rates accepted in neighbouring Nordic countries, for power generation based on oil shale will give obvious advantages to wind energy based electricity production.

Fast and strong enforcement of such changes in legislative basis in the form of regulations is not actually possible in the short term considering the level and possibilities of country's present economy and purchasing power of consumers. However, the government has to find the best available strategy for curbing the environmentally harmful electricity production, also for the development of significant increase of using local renewable energy sources in coherence with the requirements of the most recent EC Directive (2001/77/EC) on wider promotion of RES in Europe.

Wind energy resources

Wind energy resources and possibilities for wind energy utilization have been studied in Pakri region in general, in Pakri WF and Paldiski Pilot Project (Paldiski PP) area (Chapter 4). Wind resources have been studied on the basis of the wind data from Pakri meteorological station and wind data measured at 40 m a.g.l. with automatic weather station in Paldiski PP area. All wind field modeling and calculations are performed by WA^{S}P program (Wind Atlas Analysis and Application Program) worked out at Risø National Laboratory, Denmark, using the same methodology as used for compiling the European Wind Atlas. In all calculations the influence of nearby sheltering obstacles, roughness and orography of the surrounding area are taken into account.

The test area Pakri Peninsula is a typical coastal location with moderate to good wind condition and thereby it is very well suitable for feasibility study for wind farms that should represent Estonian coastal conditions. In winter the monthly mean wind speed on islands and on the western coast reaches 7–8.5 m/s, in the inland areas it remains between 4–5 m/s. Mean annual wind speed at wind turbine hub height (80 m a.g.l.) reaches 9.0–9.3 m/s over the off-shore areas, in coastal regions with open appearance the mean annual wind speed remains between 7–8.5 m/s and the open areas in inland parts of the peninsula have mean wind speed of 6.5–7.5 m/s.

Mean energy density (W/m^2) reaches in the coastal area 700 W/m^2 at 67 m height, in inland parts of the islands mean annual energy density remains between 300–450 W/m^2 and in most parts of the peninsula energy density value remains between 200 and 350 W/m^2. Using standard power curves of three different wind turbines (850 kW Vestas V52, 1,500 kW Südwind S70 and 2,000 kW Vestas V80) the mean annual potential energy yield was modeled.

The potential energy yield by Südwind S70 for off-shore conditions is estimated to be 6,400–6,600 MWh/y. In coastal zone, the S70 shows good performance and potential annual energy yield reaches 5,000–6,000 MWh/y at 85 m above ground level. In inland parts of islands or continental areas the amount of potential energy is much smaller and counts 2,500 and 3,500 MWh/y. Open areas and wooded meadows in inland regions have annual potential for energy production in range of 4,000 to 5,000 MWh/y. Mean annual energy yield (MWh/y) by Vestas V52 wind turbine at 67 m above ground level reaches 3,000–3,200 MWh/y over the off-shore areas, in coastal regions with open appearance the mean annual energy yield remains between 2,000–3,000 MWh/y and the open areas in inland parts of the peninsula have mean annual energy yield of 1,700–2,500 MWh/y. The highest yield is estimated for Vestas V80 which enables to produce 7,000–8,000 MWh/y in coastal zone and 4,500–5,500 MWh/y in woodland areas.

To identify potential sites for wind turbines and wind farms in environmentally sound way most of the EIA (Environmental Impact Assessment) elements were applied in analysis. Areas which according to EIA principles do not conflict in any way to natural or social aspects comprises still 1 134 hectares in Pakri region. This includes only suitable land for building wind turbines and enables to install 73 wind turbines, each of them with rated power of 1.5 to 2 MW. Among of these areas a Paldiski PP plot which is suitable for installation of three wind turbines was selected out for detailed analysis. The Paldiski PP has average wind resources for Pakri region and is characteristic for most of the sites within the Pakri WF area. Mean annual power yield is estimated at level of 2,200 MWh/y by Vestas V52 (hub height 67 m), 5,800 MWh/y? by Vestas V80 (hub height 80 m) and 4,600 MWh/y by Südwind S70 (hub height 85 m).

Seasonal distribution of power production by wind turbines at Pakri region is highly correlated with seasonal pattern of energy consumption. The highest energy yield is characteristic for period from October to January (more than 10% of annual energy production in every month) and the lowest energy yield in summer from May to August (from 6.4% to 5.8%). Each month in spring and autumn contributes with 7.7–8.5% of annual energy production. Therefore wind energy has good perspectives to supplement the overall energy system.

Wind farm cost-efficiency analysis

The cost calculations for wind energy based electricity made in Chapter 5 of the five wind turbine alternatives proved that the most feasible wind turbine for the Pakri WF is Vestas V80 with 78 m tower. Only a bit less cost-effective was the same wind turbine with 67 m tower. More detailed analysis of wind turbine erection and instalment costs will help us to determine the best alternative.

The Pakri WF cost-efficiency depends on Estonian electricity market liberalization and feed-in tariffs for wind energy based electricity. The different price policy options A, B and C analysis proved that the feed-in tariff less than 4 EUR per 100 kWh is not cost-effective for the wind electricity developers. The feed-in tariff more than 6 EUR per 100 kWh is not acceptable for the electricity consumers in Estonia.

The high wind electricity feed-in tariffs, options A and B, represent the case when the *political* decisions are made to stimulate artificially wind power production, not the natural *economical* signals about high demand. These political decisions are favourable to inefficient decisions, for example to use loans with high interest rate. If the political climate changes and high feed-in tariffs for wind electricity will be abolished the wind farm owners will be in great difficulties to pay back their loans. Estonian wind energy sector must avoid these political risks.

The most cost-effective for the Estonian economy is the wind electricity price policy option C with normal (low) feed-in tariffs. Wind electricity is then more cost-effective than the oil shale-based electricity if we consider external costs correctly (introducing only the CO_2 tax for example at the level of developed Nordic Countries will increase the oil shale-based electricity price at least to 6.60 EUR/100 kWh). The wind energy sector needs not the abnormally high wind energy based electricity feed-in tariffs, because these price distortions create false, misleading incentives and wind farms with low efficiency. The feasible strategy should be is the state or co-operative equity investments into the wind farms with low or zero interest rate. The state must provide for the wind farms favourable grid connection conditions.

Calculated in Chapter 6 the total avoided CO_2 emission for the whole life span of the Pakri WF is about 4.9 million tonnes considering the relevant LCA externality and 5.3 million tonnes without considering LCA externality. According to the different price policy options A, B and C it makes the costs of CO_2 as following:

	Considering LCA externality	Not considering LCA externality
Option A	39.0 EUR/t	36.3 EUR/t
Option B	28.9 EUR/t	27.8 EUR/t
Option C	19.0 EUR/t	17.7 EUR/t

Comparing the numerical results of the present study for Pakri WF with the Joint Implementation pilot phase projects average in the frame of EAES AIJ programme results in heating sector on can conclude that the results have relatively good coherence. The preliminary calculations gave the cost level of avoided CO_2 emission per tonne about 20-25 EUR/t as an average over all project categories. The costs of avoided CO_2 emissions, of course, have rather different basis and structure in heating and electricity sectors.

One can conclude from the variety of different options the significant dependence of GHG mitigation costs on various wind farm investment policies, which in their turn depend on relevant governmental RES policy in Estonia.

There is no doubt that all the figures include certain probability factor. At present time the most uncertain variable to shift from one option to another could be considered the state strategy and policy in the field of further development of electricity generation sector. In case Estonia will take an active development strategy of power sector towards including the strong promotion of RES based electricity generation, including wind energy, all options analysed in the study will benefit. And vice-versa, in case the RES policy will be still fairly modest, the investment climate to wider promotion of RES will be hindered and the capital flows will be influenced.

The cost of wind power technology is continuously decreasing. Over the next couple of decades the cost of all renewable energy technologies is likely to decline as technical progress and economies of scale will be combined to reduce the unit costs of power generating. The most recent European Council directive (2001/77/EC) on further promotion of renewable energy sources based electricity generation in EU Member States will for sure play a remarkable triggering role also in the candidate countries to EU energy policy updating.

However, construction of huge wind farm in Pakri Peninsula using the latest technological developments in wind turbine sector, still requests considerable amount of investments. The investments could be made possible under the international climate change mitigation co-operation, in particular – in the frame of Joint Implementation. This may happen with the help of relying on international financing institutions co-operation in the overwhelming up-wards wave of all-European RES promotion oriented policy campaign.

One of the most promising forms of climate co-operation could be considered the Baltic Sea Region – BASREC Joint Implementation Testing Ground, which will be launched in 2003. Appropriate preparations have started in 2000 already. It foresees the involvement of three Baltic States, Russia and Poland as host countries in the implementation of JI. Wind farms will have significant perspective for many potential donor countries to reach their Kyoto targets.

Capacity building measures

The local community needs appropriate information about planned activities on wind energy potential further possible use in Paldiski region since the very early stage of the investment project. Major conflicts and misunderstandings by general public and in particular by local community could be avoided in case the relevant capacity building measures are planned in advance. Close contact between project developers and local authorities is also important.

The aims of public participation and capacity building in the frame of the Pakri Peninsula WF project could be listed in the following:

- to encourage the favourable social and economic changes like increase of the employment, integration of the non-Estonian people to the society, to increase the tax base, etc. in the community of Paldiski region;
- to inform local people about the designing of the wind farm project;
- to give to people an opportunity to participate in decision making process;
- to provide appropriate information to the technical, environmental and economical experts but also to the representatives of the government and local authorities;
- to raise the general knowledge in Estonia about renewable energy resources, to introduce wind energy related RES possibilities and promote its' wider use;
- to promote the implementation of the Estonian and EU energy policy in Estonia.

Local community habitants in Paldiski town and Pakri Peninsula often are considered as a socially vulnerable group having social problems like high rate unemployment, difficulties on integrating to Estonian society, problems based on lacking of local language skills, etc. This target group needs a special attention from the point of view of capacity building and adult education. The economic development in this area; extension of the Paldiski harbor, establishment new enterprises, starting the tourism and recreation, starting the wind farms or beginning the production of wind turbines parts, also being involved in construction of turbines foundations and roads, etc. creates very probably a number of new jobs, also opens new opportunities for the local people. Some other target groups like nature conservationists and environmentalists need particular attention as they may pose a source of conflicts between developers.

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