出國報告（出國類別：考察）

考察歐盟
既有燃煤鍋爐混燒生質燃料技術及碳權經營

服務機關：台灣電力公司

姓名職稱：李建平 工安環保處副處長

陳清江 發電處火力營運組長

徐豪傑 開發處主管火力

潘文川 核火工處鍋爐課長

派赴國家：荷蘭、瑞典、英國

出國期間：98 年 10 月 27 日~98 年 11 月 05 日

報告日期：98 年 12 月 24 日

行政院及所屬各機關出國報告提要

出國報告名稱： 考察歐盟「既有燃煤鍋爐混燒生質燃料技術及碳權經營」

頁數 83 含附件：☑是□否

出國計畫主辦機關/聯絡人/電話：台灣電力公司

出國人員姓名/服務機關/單位/職稱/電話

1. 李建平/台灣電力公司/工安環保處/副處長/02-23667202
2. 陳清江/台灣電力公司/發電處/火力營運組長/02-23666525
3. 徐豪傑/台灣電力公司/開發處/主管火力/02-23666870
4. 潘文川/台灣電力公司/核火工處/鍋爐課長/02-23229531

出國類別：☑1 考察□2 進修□3 研究□4 實習□5 其他

出國期間：98 年 10 月 27 日至 98 年 11 月 5 日　出國地區：荷蘭、瑞典、英國

報告日期：98 年 12 月 24 日

分類號/目

關鍵詞:生質燃料(biomass fuel)木質顆粒(wood pellet)、焙燒木質碳(torrefied wood)、焙燒（torrefaction)、碳權交易（ECX）

內容摘要:(二百至三百字)

木質顆粒燃料(wood pellet)屬生質燃料為新興再生能源，歐洲佔約 85%的市場，主要發展國家包括荷蘭、瑞典、丹麥、奧地利及英國等歐盟國家；因為木質顆粒燃料具有含水量低的特點，燃燒效率頗佳，但熱質略低於煤，前述歐洲國家為提高生質能源使用率，皆視木質顆粒燃料為高潛力的生質能源，甚至替代部分的燃煤比例。未來溫室氣體減量法通過，本公司將面臨減量壓力，本次考察行程將了解木質顆粒燃料的製程、考察發電鍋爐混燒應用之經驗並實地考察歐洲氣候交易所有關木質顆粒燃料衍生之碳權查証、交易等議題，藉以衡量日後本公司應用木質顆粒燃料等類似生質能源替代部分燃煤發電之可行性，並做為經營碳資產管理之參考。

本文電子檔已傳至出國報告資訊網（http://open.nat.gov.tw/reportwork）

目　　錄

頁次

一、　團員名單、行程紀要及出國目的…… 3

二、　歐盟既有燃煤鍋爐混燒生質燃料技術探討…… 4

1. 生質燃料特性…… 4

2. 生質燃料混燒方式及實務簡介…… 8

3. 政策及法令…… 17

4. 經濟性分析與效益評估…… 18

三、　歐盟碳權經營簡介…… 23

1. Climate Exchange PLC 簡介…… 23

2. ECX 交易產品…… 29

3. 歐洲交易市場現況…… 32

四、　結語與建議…… 35

第一章 團員名單、行程紀要及出國目的

第1節　團員名單

本次出國考察成員詳如下表：

姓　　名	單　　位	職　　稱
李　建　平	工安環保處	副處長
陳　清　江	發電處	火力營運組長
徐　豪　傑	開發處	主管火力
潘　文　川	核火工處	鍋爐課長

第2節　行程紀要

本次出國考察行程概要如下表：

考 察 機 構	國家	城市	日期	詳細工作內容
			10/27	往程（台北 －阿姆斯特丹）
Topell Pellets	荷蘭	阿姆斯特丹	10/28	考察荷蘭 Torrefied Wood 製造廠家，了解 Torrefied Wood 燃料顆粒特性及來源
Vapo Group 及 Fortum Energy	瑞典	斯德哥爾摩	10/29 ∫ 10/30	1.考察瑞典 Wood Pellets 製造廠家，藉以掌握 Wood Pellets 特性及來源 2.參訪 Fortum 電廠之木質與化石燃料混燒技術、周邊設備及對鍋爐效率、煙氣排放及煤灰品質之影響
European Climate Exchange 及 Doosan Babcock Energy	英國	倫敦 Glasgow	10/31 ∫ 11/3	1. 週末準備及整理參訪資料事宜 2. 了解碳權查証、交易等議題，路程（倫敦 － GlASGOW） 3. 考察混燒鍋爐特性，路程（GlASGOW－倫敦）
			11/4~11/5	返程（倫敦 － 台北 ）

第3節　出國目的

木質顆粒燃料(wood pellet)屬生質燃料為新興再生能源，歐洲佔約 85%的市場，主要發展國家包括荷蘭、瑞典、丹麥、奧地利及英國等歐盟國家;因為木質顆粒燃料具有含水量低的特點，燃燒效率頗佳，但熱質略低於煤，前述歐洲國家為提高生質能源使用率，皆視木質顆粒燃料為高潛力的生質能源，甚至替代部分的燃煤比例。未來溫室氣體減量法通過，本公司將面臨減量壓力，本次考察行程將了解木質顆粒燃料的製程、考察發電鍋爐混燒應用之經驗並實地考察歐洲氣候交易所有關木質顆粒燃料衍生之碳權查証、交易等議題，並藉以衡量日後本公司應用木質顆粒燃料等類似生質能源替代部分燃煤發電之可行性，並做為經營碳資產管理之參考。

第二章 歐盟既有燃煤鍋爐混燒生質燃料技術探討

第 1 節 生質燃料特性

一、木材、木質顆粒 Wood Pellet 及焙燒木質碳 Torrefied Wood 之特性：

1、 木材是屬可再生的碳吸存型生質能，常作薪炭用途；木材非石化燃料，雖燃燒將碳素釋放，仍可藉新生林木吸收固定，形成碳循環，具二氧化碳中和概念，京都議定書定義為零排放。 然而木材整塊燃燒速率不穩，影響熱能釋放，

加上樹種與含水率較高之影響，用來做為發電用燃料之價值偏低。

2、 所以經過篩選後，將木材破碎、乾燥、壓縮成型，製成相同大小(pelletizing) 、熱質均勻、儲存期長、易運送與管理的固體燃料(pellet)，在 90 年代由於環保與油價的推波助瀾下在歐洲開始被廣泛使用。

3、 木質壓縮型燃料分為顆粒型(Pellet)與木磚型(Briquette)。

木質顆粒品質標準規範摘要		ÖNorm M7135	DIN51731：
甲、	直徑 mm	4~10	4~10
乙、	長度 mm	5 × 直徑	＜50
丙、	密度 Kg/dm3	＞1.12	1.0~1.4
丁、	熱值 kcal/kg	4300	4181~4659
戊、	水份含量%	＜10	＜12
己、	灰份含量%	＜0.5	＜1.5
庚、	硫含量 %	＜0.04	＜0.08
辛、	氮含量＜%	＜ 0.3	＜0.3
壬、	氯含量＜%	＜0.02	＜0.03

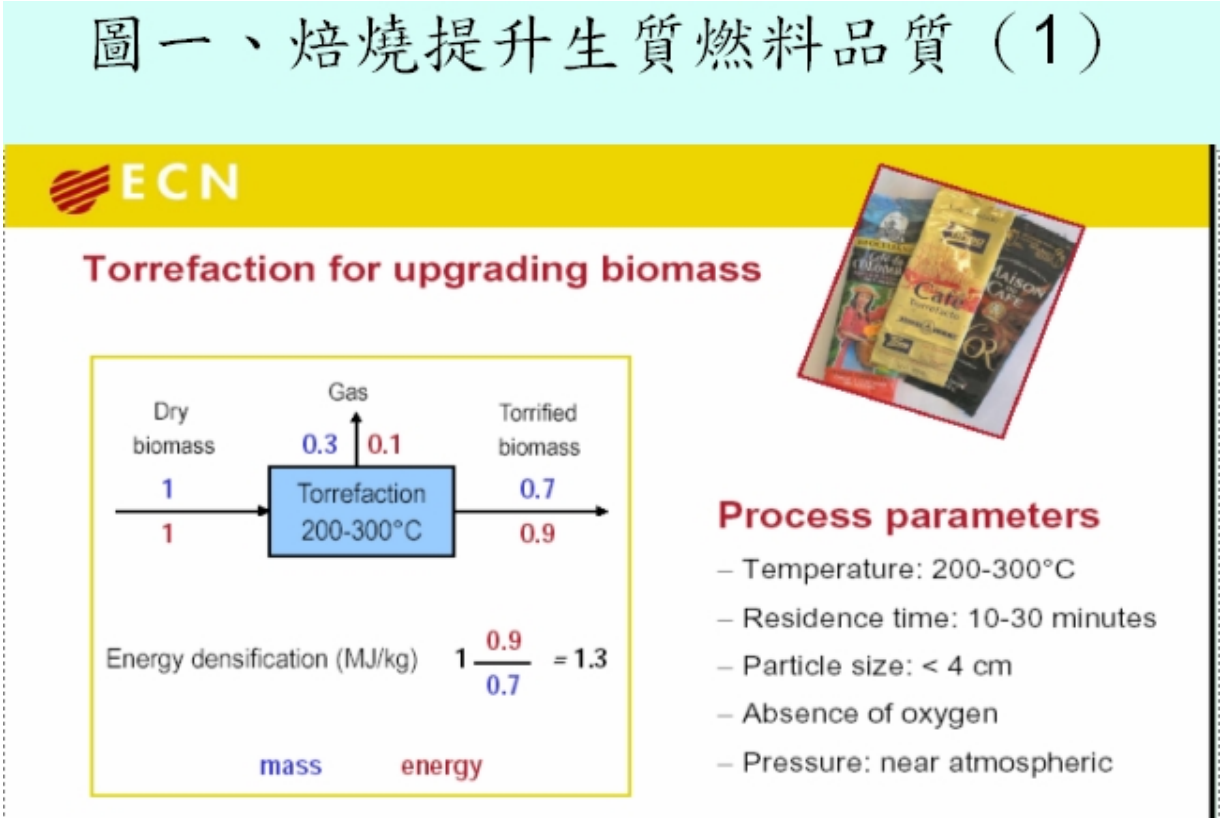
（資料來源：European Commission/DG JRC Institute/2006）

4、 焙燒（Torrefaction）是一種提升生質燃料品質的方法之

一，它是將生質燃料在溫度攝氏 200~300 度並且在缺氧狀態下，經 10~30 分鐘的輕熱裂解的過程。註：荷蘭 TOPELL 公司採用經授權使用生產之 Torbed Reactor 技術，溫度攝氏 320 度，生產時間 90 秒，但目前尚未商業化。

5、 在焙燒的過程中能將生質燃料的半纖維素 、有機揮發物移除，但仍保留 90%的熱值與 70%的重量。(如圖一)

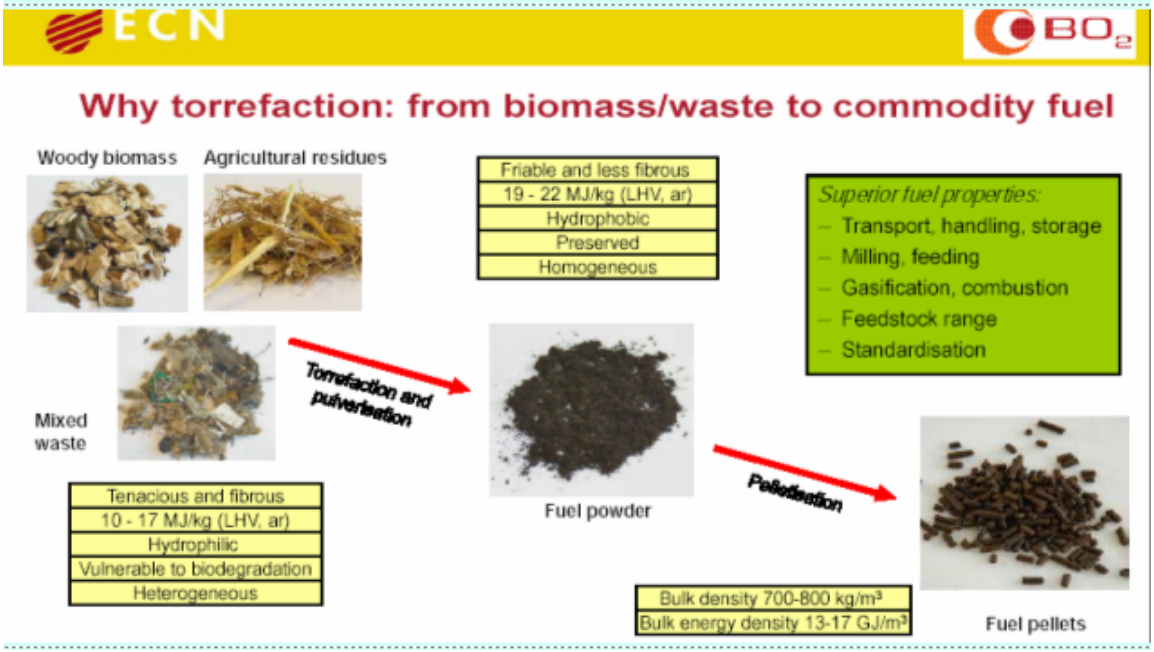
圖一



生質燃料在焙燒後能提高單位的熱值(4539~5256Kcal/Kg，LHV AR)與研磨性（HGI 38~48)，可以降低運費外也更容易與煤混燒(co-firing) 。(如圖二、圖三)

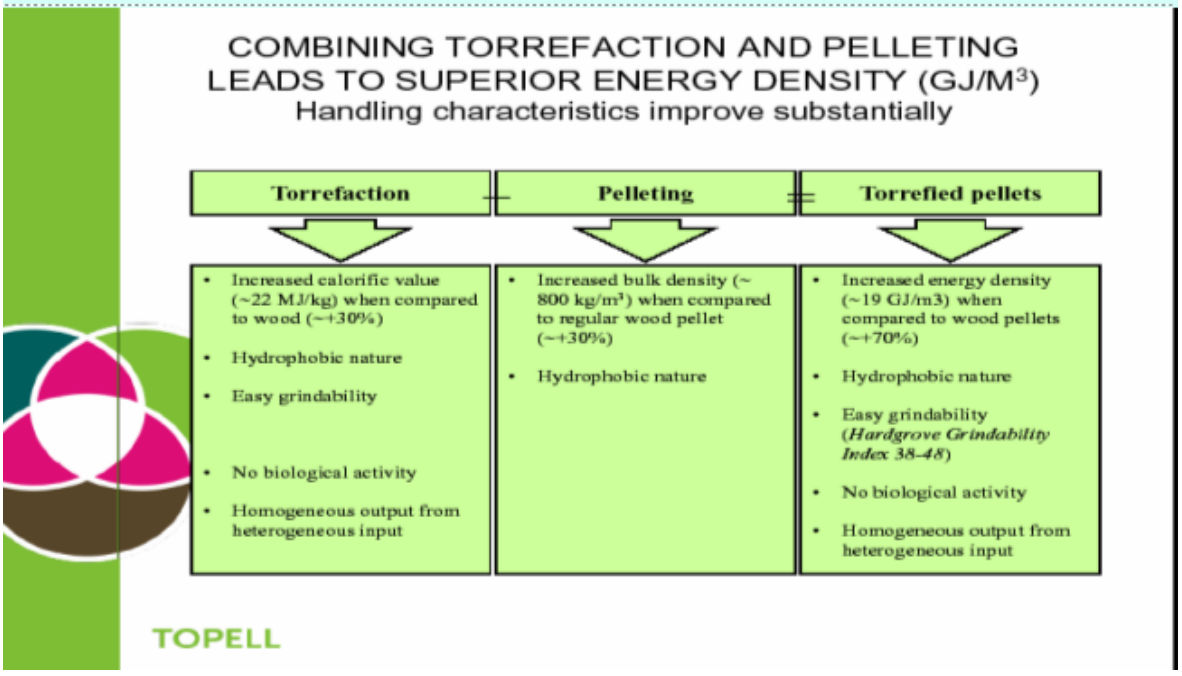
圖二

圖二、焙燒提升生質燃料品質（2）



圖三

圖三、焙燒＋造粒



二、本公司進口煤規範：

總水份% a.r	10（15max）
固有水份% a.d	5
揮發物% a.d	28（24min）
灰份% a.d	14（18max）
硫份% a.d	0.62（1.25max）
熱值 Kcal/Kg a.r	6200（5900min）
研磨性 HGI	50（45min）
固定碳% a.d	60max

三、木質顆粒及焙燒木質碳與本公司進口煤碳之主要差異：

熱值較低

灰份、硫份含量較低

揮發物含量較高，固定碳含量較低

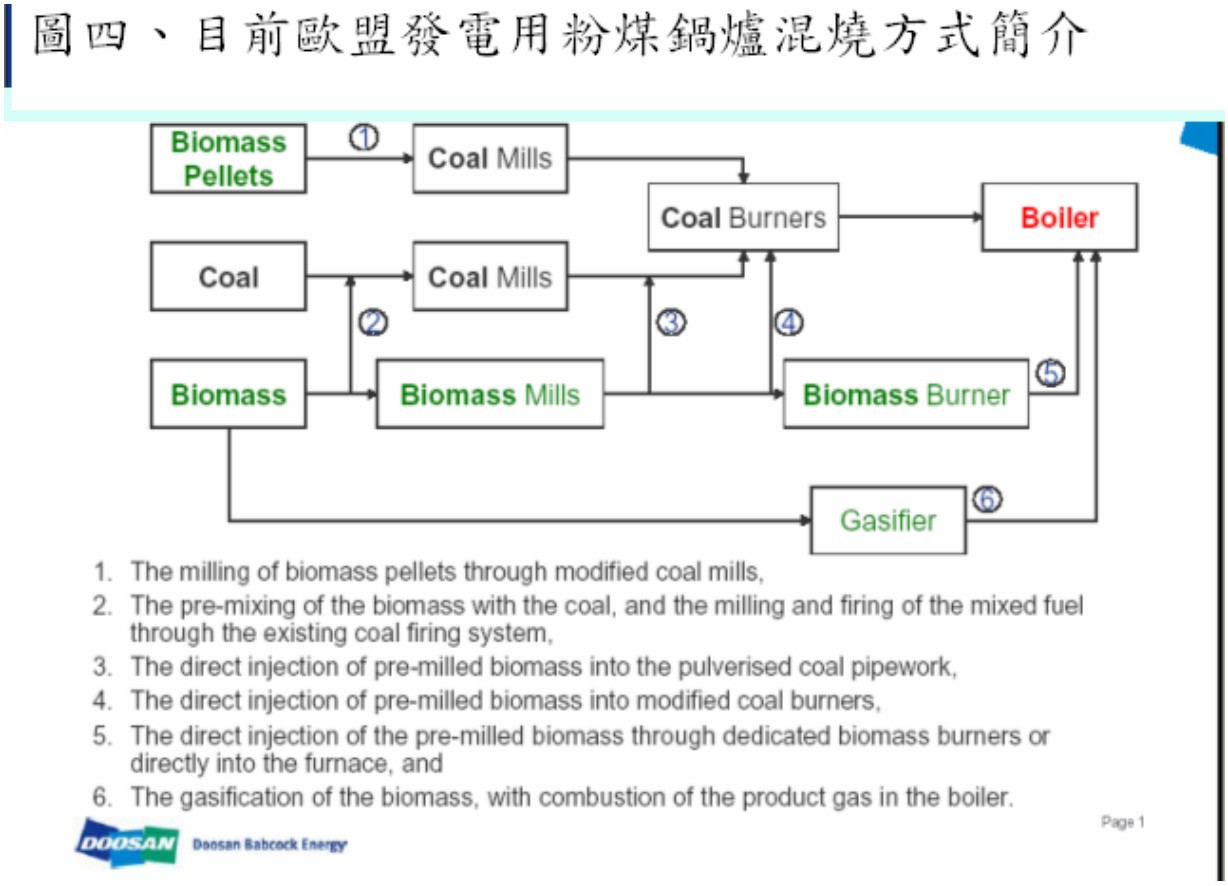
研磨率（HGI）較低，較難研磨

木質顆粒水份含量相當，焙燒木質碳水份含量較低

第 2 節 生質燃料混燒方式及實務簡介

一、 目前歐盟生質燃料混燒方式簡介（如圖四）

圖四



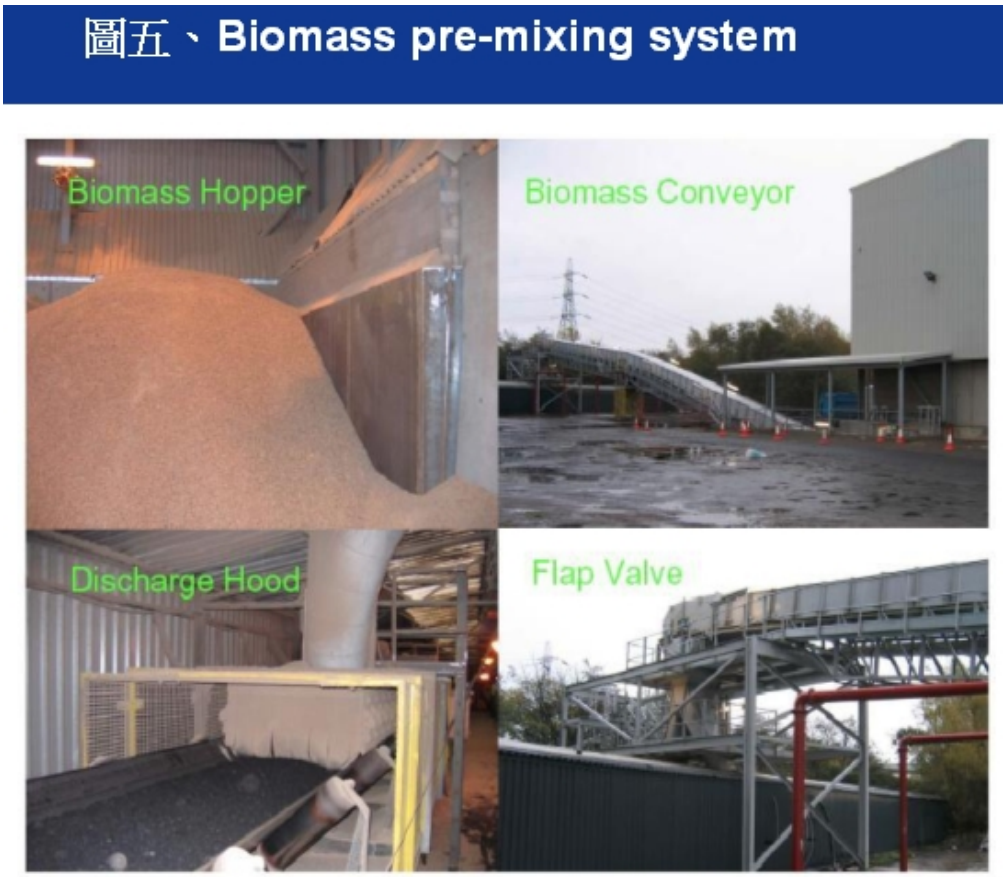
1、直接混燒系統(Direct co-firing system)

①~⑤種為直接混燒：

第①種方式為生質燃料顆粒在既有之粉煤機研磨，粉煤機需修改以適用冷的一次風。這種混燒方式，將使投入鍋爐之熱量大幅下降（若燃用焙燒木質碳僅小幅下降），目前歐洲僅少數電廠採用此種混燒方式（瑞典有一個案例）。

第②種方式為生質燃料與煤預混後（如圖五），經既有之粉煤燃燒系統研磨及燃燒，這種混燒方式因為投資費用少、改

圖五



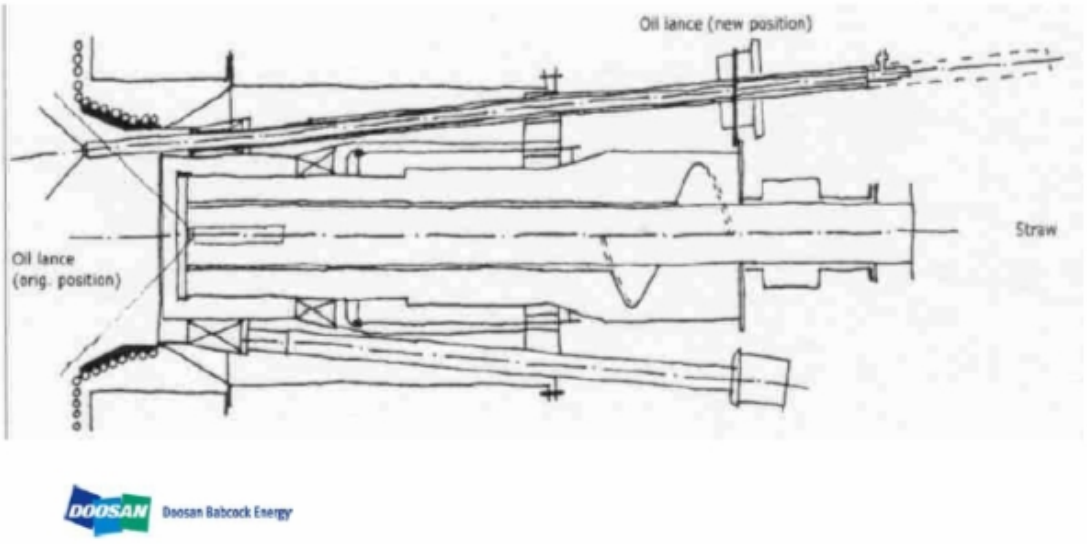
混燒之作業時間能控制在合理範圍，故許多電廠第一次混燒選擇此種方式。這種混燒方式之混燒比例（熱量投入基礎上）最高 5~10%（5~6%或更低更為常見），惟不同特性之燃料一起研磨，需注意控制粉煤機進口一次風溫度，避免自燃或爆燃等安全 問題。

第③種方式需增設生質燃料 Mill，研磨後之生質燃料粉末，經氣動輸送設備直接噴入既有粉煤機至既有燃燒器間之粉煤管路。這種混燒方式，將使投入鍋爐之熱量不受影響（英國 Drax 電廠 2005 年夏天起，已成功採用此種混燒方式，目前正擴大混燒規模中）。

第④種方式比第③種成本及風險較高，同樣需增設生質燃料 Mill，但因部份生質燃料性質特殊，有淤塞阻礙粉煤管路的風險，故採此方式將需研磨後之粉末，經氣動輸送設備直接噴入經修改的燃燒器（如丹麥 Studstrup 電廠 coal-straw 燃燒器，如圖六）。

圖六

圖六、丹麥Studstrup電廠燃燒器修改實例



第⑤種方式同樣需增設生質燃料 Mill，又因欲維持既有燃煤能力，故需增設專用之生質燃料燃燒器。將研磨後之粉末，經氣動輸送設備直接噴入增設之生質燃料燃燒器。總體而言，安裝專用的生質燃料燃燒器，被視為是一種昂貴和相對高風險的混燒方法。

2、間接混燒系統(Indirect co-firing system)

第⑥種為間接混燒系統，主要的方式是將生質燃料汽化（gasification） 然後將產生的 syngas 與燃煤鍋爐一起混燒，但汽化爐、syngas 的清潔設備與焦油的處理都較前者昂貴。

二、 一般來說，目前發電用粉煤鍋爐與 wood pellet 生質燃料混燒的比例約 5-10%。

但須考慮幾項主要條件：

甲、 是否能取得穩定、充足的生質燃料。

乙、 儲存時自燃等安全問題

木質顆粒具親水性，必須儲存於室內（如圖七），且必須做好

圖七

圖七、Biomass storage shed

防範自燃的安全措施（如偵測及防火），以免引起安全、環保、健康及民情問題。

丙、混燒技術及混燒對鍋爐上、下游設備的影響問題。

丁、灰的去化問題

戊、經濟效益

三、 英國 Drax 電廠及瑞典 Fortum 電廠改混燒生質燃料簡介

英國 Drax 電廠：

6 部 660MW 燃煤機組，每部機 10 台粉煤機，每台每小時磨煤能力 36 噸，滿載時只需運轉 8 台，2 台備用。

2005 年夏天起，成功的以第三種混燒方式混燒生質燃料（即增設生質燃料 Mill，經研磨後之生質燃料粉末，經氣動輸送設備直接噴入既有粉煤機至既有燃燒器間之粉煤管路，如圖八、圖九），

圖八

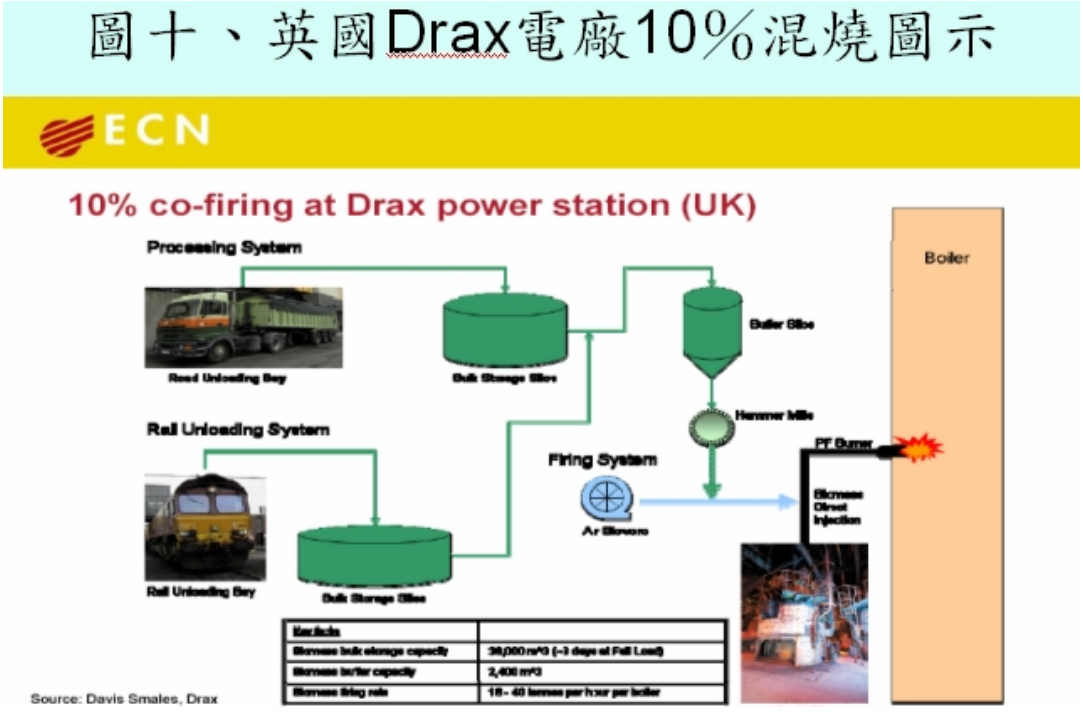
圖九

圖九、英國Drax電廠直接混燒
生質燃料管路及噴入點

目前正擴大混燒規模（6 個鍋爐各配置 2 台生質燃料 Mill），混燒比例目標 10%（如圖十）。

圖十

圖十、英國Drax電廠10%混燒圖示



僅使用原有之蒸汽吹灰器，即可處理結渣、積灰等問題。

瑞典 Fortum 電廠：

甲、3 部 100MW 機組（1959 年運轉，燃用油、煤），1970 年代石油危機後以燃煤為主。1990 年代初期瑞典開始課收碳稅後，停止燃煤改以燃用木質顆粒為主、燃油為輔。（另有 1 部較新較大燃油機組，正計劃改燃木質顆粒中）

乙、上述 3 部 100MW 機組改燃木質顆粒增設設備：Hammer Mill、底灰再燃之輸送帶、儲存場所增設處理或防範自燃設備。

丙、木質顆粒研磨後之 Particle 100%＜3 mm，30%＜0.5 mm。

丁、若 100%木質顆粒，經原有 Ball Type Mill，須加 10%油才能滿載

戊、若 70%木質顆粒，經原有 Ball Type Mill，另 30%經新增設之 Hammer Mill 則可滿載

己、改燃進口木質顆粒後：

出力及效率並未下降（與鍋爐原設計之燃料品質有關）

SO_2、CO_2、NOx 下降。

庚、因為木質顆粒之氯含量低，燃用後鍋爐並無結渣、積灰及腐蝕問題。

辛、燃用木質顆粒，未燃碳比例高，故增設底灰再燃之輸送

帶，將未燃物再送回鍋爐燃燒，產生之灰則作為肥料使用。

四、 生質燃料混燒技術問題

1、生質燃料 Mill 及粉煤機問題：大多數生質燃料之研磨性較差，可能影響混燒比例。且因其揮發物含量高，具易燃特性，若溫度高於攝氏 180 度即會釋放大量可燃性揮發物質，故混燒時需要注意 Mill 操作程序並調整進口一次風溫度，避免 Mill 自燃爆燃等安全問題。

2、生質燃料揮發物含量高但固定碳含量低，需謹慎調整及操作燃燒相關設備，以確保燃燒穩定度。

3、部份生質燃料水份含量高，致鍋爐績效降低，出力也可能下降，故需提升生質燃料的品質（成份、特性、熱值、研磨性等），如採木質顆粒及焙燒木質碳混燒方式，並繼續再提升其品質，以減少對鍋爐效率及出力之衝擊。

4、生質燃料中的化學成分，可能會降低灰熔點溫度並導致爐管結渣(特別是燃燒器附近區域爐管結渣)，需藉加強吹灰等方式處理。

5、生質燃料燃燒，可能增加 SCR catalysts 表面積灰而影響性能。

6、若生質燃料氯含量高，將產生高溫氯化物（氯化氫），造成

鍋爐熱回收區爐管表面的積灰及腐蝕，亦會影響 FGD 除硫效率及石膏之品質。

7、生質燃料混燒，將增加煙氣中極細微的 aerosols，可能影響 ESP 收集效率。

8、生質燃料燃燒後的灰，其化學成份與煤灰有很大的不同，它們不是鋁矽酸鹽，而是簡單的無機物質矽、鉀、鈣、磷、硫的混合物。故混燒產生的灰，因其性質與煤灰有所差異，可能影響飛灰再利用於水泥業。

9、通常生質燃料的硫、氮、汞含量比煤低，故 SO_2、NOx、Hg 排放下降。

第 3 節 政策及法令

一、政策

英國 2002 年 4 月起推出再生能源義務法，並提供包含生質燃料混燒在內的再生能源發電財政獎勵，致生質燃料混燒機組大幅增加(如圖十一)。此外，歐洲甚多國家亦已提出了具體的政策，鼓勵生質燃料混燒。

二、灰再利用法令修改

歐盟已修法（Fly Ash For Concrete EN-450）准許生質燃料飛灰部份比例可用於水泥業：最高 20%（mass）fuel based 及 10%（mass）ash based（混燒之生質燃料種類亦已定義）。

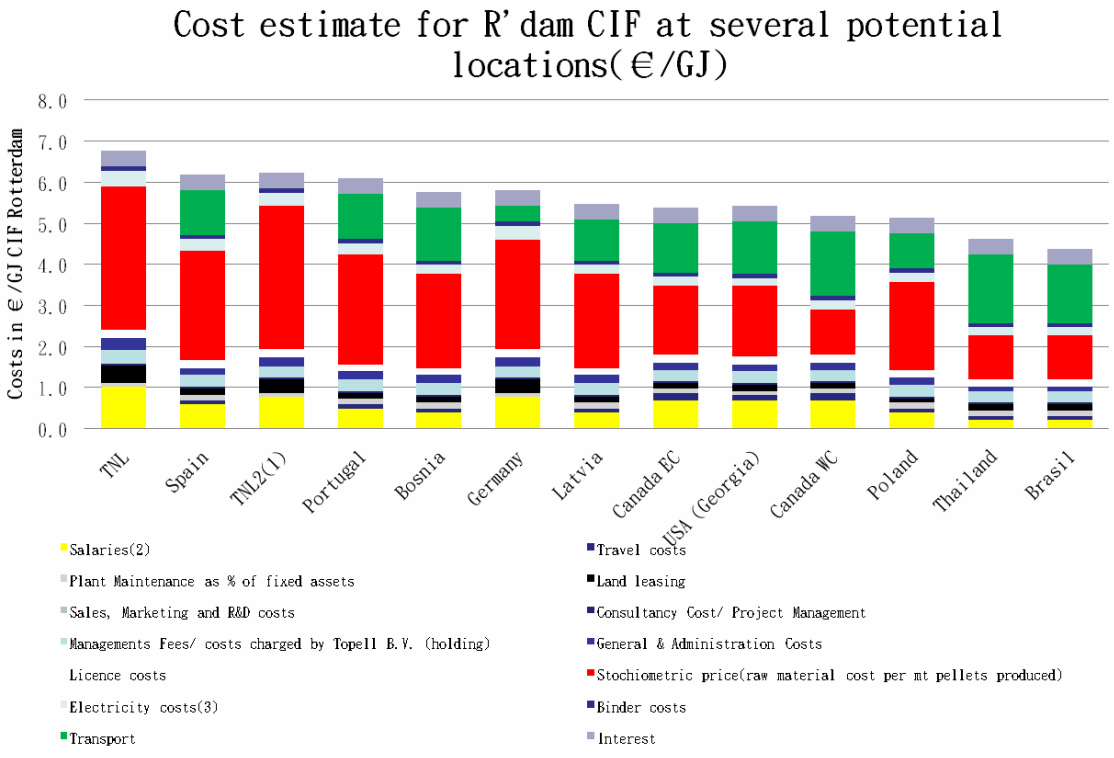
圖十一

圖十一、Current status of biomass co-firing at the large central coal-fired stations in Britain (April 2002-April 2009)

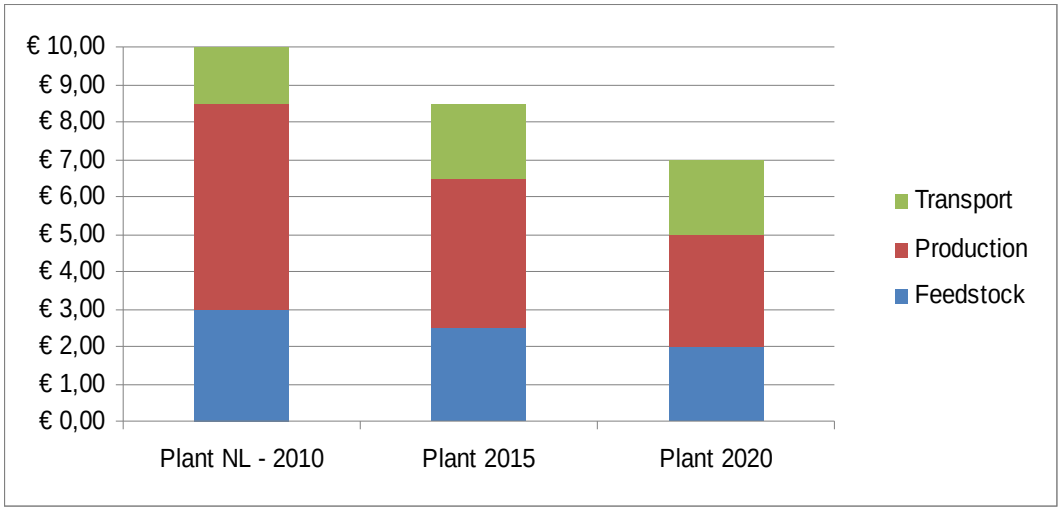
Station	Capacity (MW_e)	Generator	Cumulative GWh
Aberthaw	1,455	RWE npower	431
Cockenzie	1,200	Scottish Power	217
Cottam	2,000	EdF	571
Didcot	2,100	RWE npower	417
Drax	4,000	Drax Power	2,263
Eggborough	1,960	British Energy	742
Ferrybridge	2,035	SSE	2,132
Fiddlers Ferry	1,995	SSE	1,409
Ironbridge	970	E.on UK	178
Kingsnorth	2,034	E.on UK	769
Longannet	2,400	Scottish Power	680
Ratcliffe	2,010	E.on UK	38
Rugeley	1,000	Int. Power	337
Tilbury	1,085	RWE npower	100
West Burton	1,980	EdF	392
		Total MWh	10,676

第 4 節 經濟性分析與效益評估

Wood Pellets 生質燃料目前價格大約 150～200 美元/噸（依據產地與品質有所差異），熱值大約為 4000～4500 Kcal/Kg，單位熱值成本約 5～6 歐元/GJ，不同來源 Wood Pellets 之 CIF 價格分析詳如下表。



Torrefied pellets 生質燃料由於焙燒方式不同，Torrefied pellets 價格也有差異，以本次考察 Torrefied pellets 製造商 TOPELL 為例，每噸價格大約 200～250 美元，單位熱值成本約 10 歐元/GJ。Torrefied pellets 製造商正積極發展焙燒技術，未來隨著焙燒技術成熟後，Torrefied pellets 的價格將大幅下降，預估 2020 年單位熱值成本下降 30%，達 7 歐元/GJ，Torrefied pellets 各項成本分析（木料、焙燒、運輸）及未來成本趨勢詳如下表。

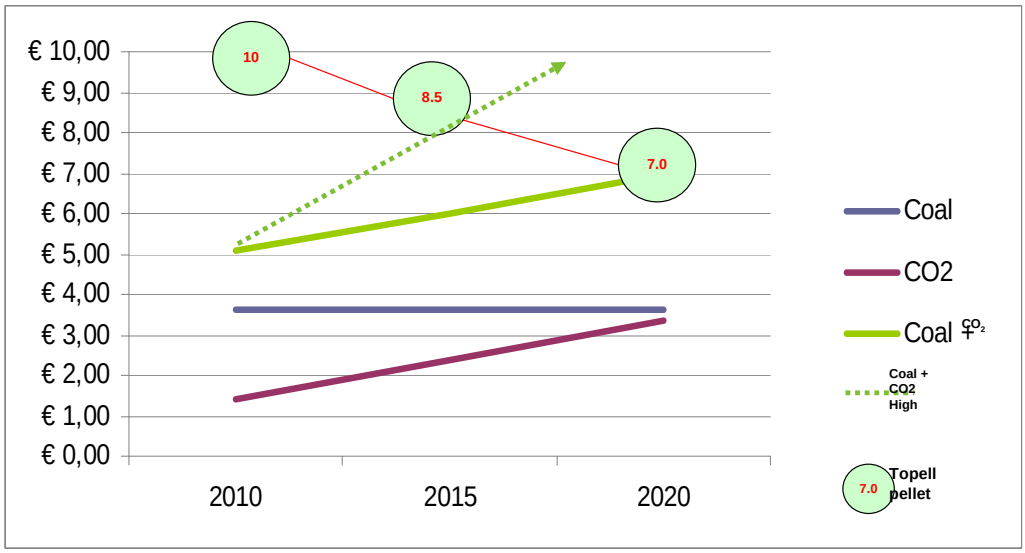


綜上所述，生質燃料不論 Wood Pellets 或 Torrefied pellets 其單位熱值成本遠高於目前本公司之燃煤成本，與天然氣與重油大致相當。本公司目前各類燃料成本與生質燃料之單位熱值比較如下表：

	重油	柴油	天然氣	煤炭	Wood Pellets	Torrefied Pellets
價格	15 元/升	24 元/升	14 元/M3	90 美元/噸	150 美元/噸	250 美元/噸
單位熱值成本 US$/MMBTU	11.5	20.2	11.3	3.8	7.0	10.0

雖然生質燃料具有碳中和二氧化碳零排放的優點，但是在未考慮碳權

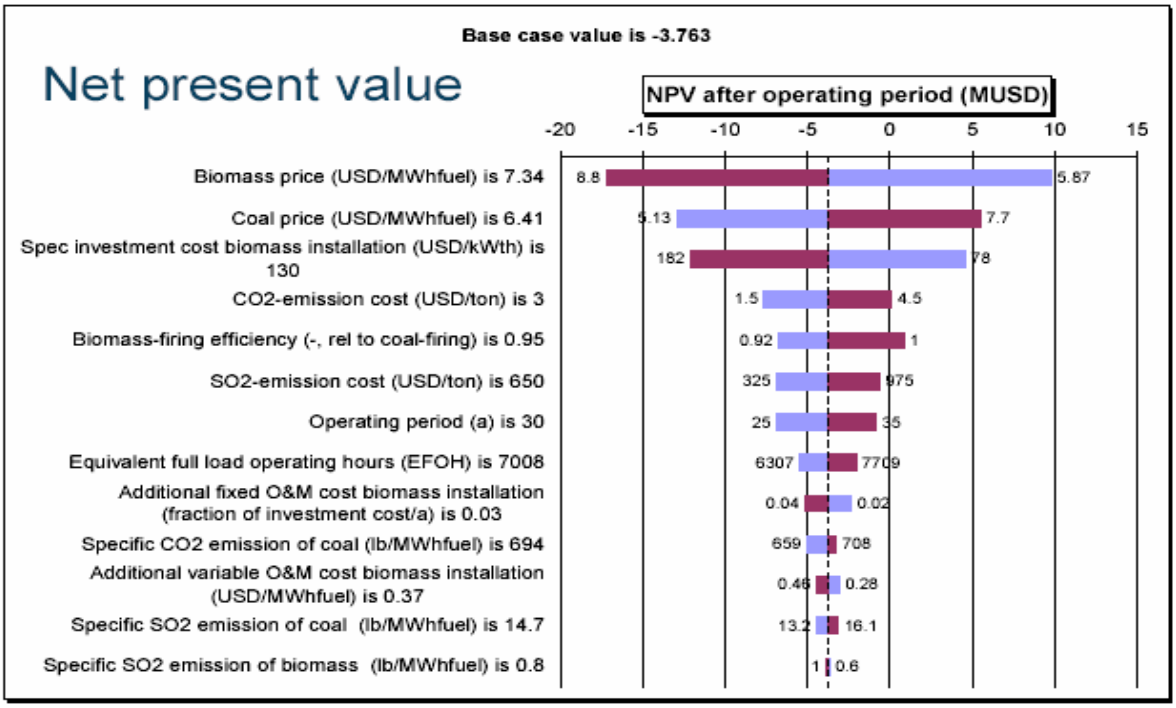
成本之情況下，其經濟性並不具競爭優勢，若考量煤炭加計碳權成本之後之各種情境，生質燃料在未來仍有發展的潛能，以 TOPELL 的 Torrefied pellets 與煤炭為例，煤炭目前成本為 3.6 歐元/GJ，CO_2 成本約 1.5 歐元/GJ，二者合計約 5.1 歐元/GJ，仍低於 Torrefied pellets 的 10 歐元/GJ，但隨著 CO_2 成本上漲，燃煤成本也將逐年提昇，反觀 Torrefied pellets 因技術成熟而逐年下降，預估 2020 年 Torrefied pellets 達 7 歐元/GJ 與燃煤成本相當，若燃煤價格或 CO_2 成本大幅上漲，則 2015 年 Torrefied pellets 與燃煤成本已達相當水準。至於 Wood pellets 之熱值成本約為 6 歐元/GJ，至遲 2015 年就能與燃煤成本競爭。分析說明詳如下圖。



生質燃料混燒之效益分析：

依據 KEMA 能源公司技術資料顯示，目前現有機組改混燒生質燃料之財務分析其淨現值為-376 萬美金，並不具經濟效益。進一步分析各成本項之敏感度分析，其中生質燃料價格影響最高，依序為燃煤成

本、設備修改成本以及 CO_2 成本等，詳細其他各項敏感度分析詳如下圖。



生質能燃料混燒經濟性評估結論：

一、現有機組修改或新增相關設備之投資費用高，以英國 Drax 電廠為例，660MW 機組共 6 部機，改為 10%生質燃料混燒後，總容量為 396MW，合約金額 6300 萬歐元，相當於 240 美元/KW，約為原造價之 20%。

二、目前生質燃料價格仍遠高於現行燃煤之成本，但考慮 CO_2 成本後，隨著生質燃料技術進步，10 年內生質燃料仍具有競爭優勢。

三、生質燃料熱值大多低於本公司現有鍋爐設計值，因此採用生質燃料混燒鍋爐效率大約降低 0.5~1.5%（美國能源部 2004.11.3 資料）。

四、由於採用生質燃料勢必增加相關設備，進而增加電廠營運費用。

五、以台灣目前未完成課徵 CO_2 成本或獎勵使用生質能燃燒補助措施之前，初步評估本公司採用生質能混燒，尚無經濟效益可言。

第三章 歐盟碳權經營簡介

第1節 Climate Exchange PLC簡介

（一） Climate Exchange PLC源起

自從人類大量仰賴石化燃料做為發展經濟的動力來源以來，雖然帶來科技和經濟的快速發展，但卻也造成環境上嚴重的破壞。大量的使用石化燃料造成空氣中的CO_2濃度逐年升高，導致海平面升高、全球氣候暖化和氣候快速變遷等問題，引起了國際社會的高度關注。

1994 年正式生效的聯合國氣候變化綱要公約，為碳交易奠定了法律基礎。而 1997 年所制定的京都議定書更為整個碳權交易市場打下了堅固的基石，並開啟了溫室氣體排放權交易市場的無限商機。


Richard Sandor

倫敦氣候交易所(Climate Exchange PLC)，就是在京都議定書之後，由美國加州大學柏克萊分校教授桑德(Richard Sandor)所創立。

在許多人還從未聽說過全球氣候暖化之前，桑德就醞釀建立二氧化碳交易市場。在 1992 年於里約熱內盧舉行的聯合國地球峰會上，他提交了一篇學術論文，探討如何運用市場機制來降低二氧化碳的排放

量。在九〇年代後期，全球各國開始陸續簽署京都議定書。當時桑德以為美國也會簽署這份議定書，因此他建立了芝加哥氣候交易所，認為美國的二氧化碳排放交易將就此興起。但布希上任後，卻宣佈拒絕簽署該項協定，由於沒有加入議定書，美國的企業就不必削減二氧化碳的排放量，而他創建的交易所似乎也就失去了存在的必要。

然而桑德卻沒有放棄，他把芝加哥氣候交易所改為一套系統，讓企業自發組織起來減少排碳量。2003 年，他與一位在倫敦擔任保險經理的朋友尼爾.埃可特(Neil Eckert)攜手把在美國積累的全部經驗運用到歐洲。當時，歐洲剛剛開始建立自己的交易系統。因此，他們在倫敦建立了一個獨立的二氧化碳交易市場，名為歐洲氣候交易所——(European Climate Exchange)。埃可特後來擔任該所的首席執行長至今。

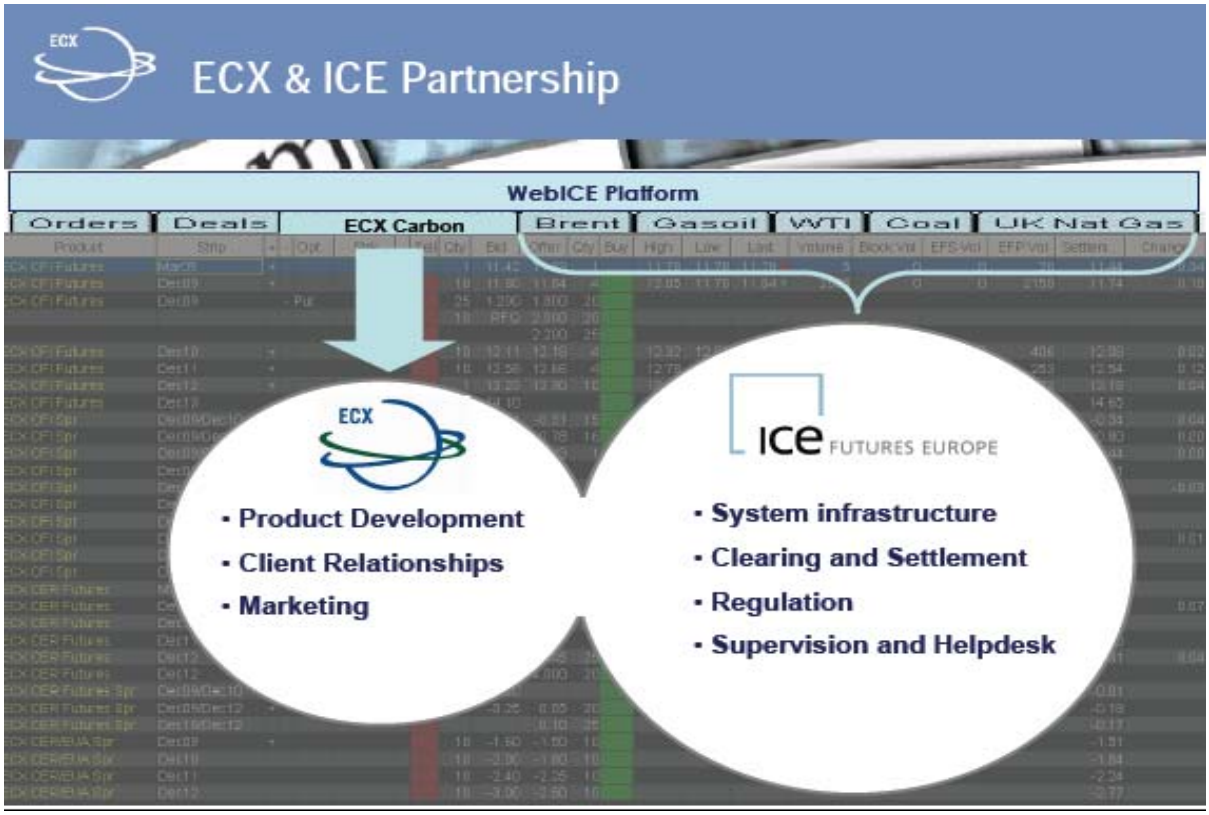
（二） ECX與ICE的合作關係

美國洲際交易所（Intercontinental Exchange，ICE）成立於 2000 年 5 月，總部位於美國喬治亞州亞特蘭大，投資者來自 7 家商品批發商，後來又由 6 家天然氣及電力公司收購了該公司的股權。2001 年，該公司在倫敦收購了國際石油交

易所。經由洲際交易所的電子平台，提供原油及相關提煉品、天然氣、電力、碳排放量等期貨合約交易。此外，匯率和指數期貨及選擇權也都在其業務範圍內。

由於倫敦氣候交易所(Climate Exchange PLC)創立者桑德在洲際交易所擔任董事，透過一項保密的收入共享協議，ICE同意把桑德新建的歐洲氣候交易所(European Climate Exchange, 以下簡稱ECX)納入其交易系統。與ICE的聯姻使ECX把歐洲其他的交易商們甩到了後面。

歐洲氣候交易所自2005年於倫敦設立，最初以EUAs(EU allowance Units, EUAs）為標的，規劃標準化之碳金融工具（Carbon Financial Instruments，簡稱CFIs）商品，包含期貨及選擇權，並負責銷售。CFIs於全球最大的能源期貨電子交易平台ICE Futures Europe 交易，並由歐陸主要之集中交易對手LCH.Clearnet 進行結算，主管機關為英國金融服務管理局（Financial Services Authority, FSA）目前已有超過80 家大型企業簽署會員，承諾交易ECX之商品。由ECX 與ICE Futures Europe 所聯合建構的交易體系，是目前EUAs 交易所中衍生品交易量最大的組織，佔有率超過80%。著實可見倫敦正逐漸發展成為歐盟碳市場中心。



美國未來如果建立了自己的溫室氣體減排系統，那麼倫敦氣候交易所將面臨強大的競爭對手的衝擊。根據分析師估計，美國二氧化碳交易市場的規模是歐洲的三倍左右，這麼多的財富必然會引來競爭。因此倫敦氣候交易所將試圖保持領先，搶佔其他新興市場。

2007 年 12 月，他們與中國石油天然氣集團公司(China National Petroleum Corp)簽署備忘錄，打算在北京建立一個排碳交易平台。在印度也正在試圖建立一個類似於芝加哥的自發交易市場。2008 年 12 月，芝加哥氣候交易所(CCX) 宣布，其合資伙伴天津交易所(Tianjin Climate Exchange, TCX)與香港交易所雙方已在碳排放市場方面的合作機會展開磋商。2009 年 9 月，天津排放權交易所(TCX)正準備推出有可能

成為中國第一個碳市場的計劃。

「我們把未知領域視為機會，而不是障礙。」 倫敦氣候交易所創立人桑德曾這麼說過。

(三) Climate Exchange PLC旗下其他交易所簡介

倫敦氣候交易所(Climate Exchange PLC)旗下其他主要交易所分別為：

1.芝加哥氣候交易所

芝加哥氣候交易所(Chicago Climate Exchange，以下簡稱CCX)成立於2003年，為全球首度由企業自願性發起之溫室氣體排放交易組織，參與者來自美國、加拿大及墨西哥的企業及機構，交易商品含括6種溫室氣體。CCX之交易標的皆為標準化之CFIs。在溫室氣體的查核驗證上，CCX由美國金融產業自律管理機構(Financial Industry Regulatory Authority, FINRA)作為第三者獨立驗證，負責查驗排放基線資料、年排放報告之正確性，及評估補貼計畫之驗證程序，並根據美國環保署針對廠商之排放監測報告、購入能源相關單據等，進行例行性抽查。

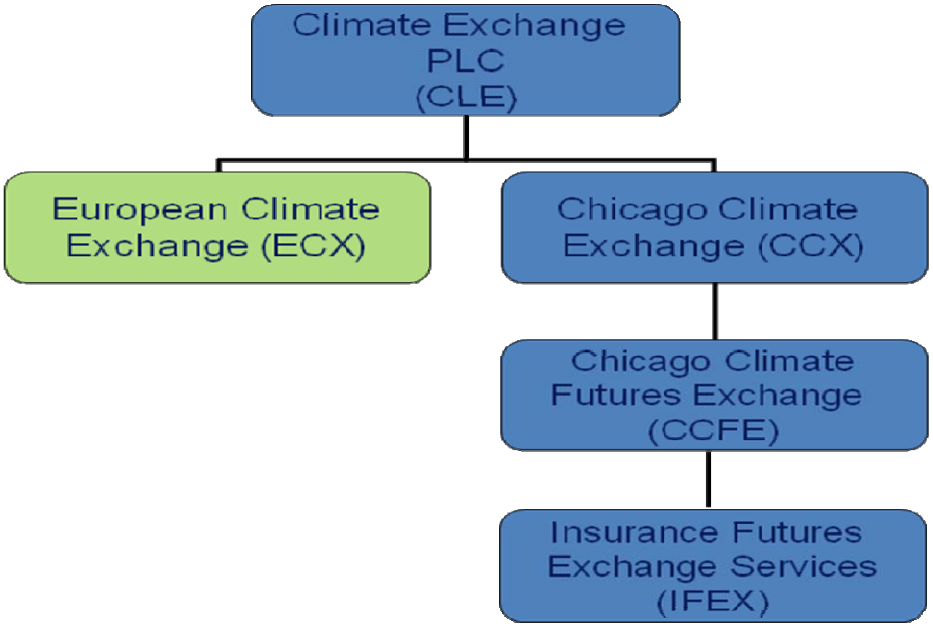
2.芝加哥氣候期貨交易所

芝加哥氣候期貨交易所(Chicago Climate Futures Exchange，以下簡稱CCFX)為芝加哥氣候交易所(CCX)100%控

股之子公司，主要營運項目為排放配額交易及其他環境商品提供標準化的期貨合約。CCFX 提供之商品以期貨及選擇權為主，如：CER(certified emission reductions)期貨及選擇權、CFI、歐盟 CFI 期貨、生態潔淨能源指數期貨、IFEX 事件連結期貨(IFEX Event Linked Futures)、NFI(Nitrogen Financial Instrument)期貨及選擇權、NFI 臭氧季節期貨(Ozone Season Futures)、SFI(Sulfur Financial Instrument)期貨及選擇權等。

3. 蒙特婁氣候交易所

蒙特婁氣候交易所(簡稱 MCeX)為因應加拿大政府溫室氣體規範架構(Canadian Regulatory Framework for Industrial GHG Emissions and Domestic Trading System)於 2007 年 7 月成立，由蒙特婁交易所(Montréal Exchange, MX)及芝加哥氣候交易所(CCX)合資運作，以提供加拿大企業多樣化的環境衍生商品為目的。MCeX 使用 SOLA 電子交易平台，結算於加拿大衍生品結算所(Canadian Derivatives Clearing Corporation)；MCeX 之主管機關為魁北克金融市場管理局(Autorité des marchesfinanciers, AMF)，目前僅提供二氧化碳當量(CO_2e)所衍生之期貨。



第2節 ECX交易產品

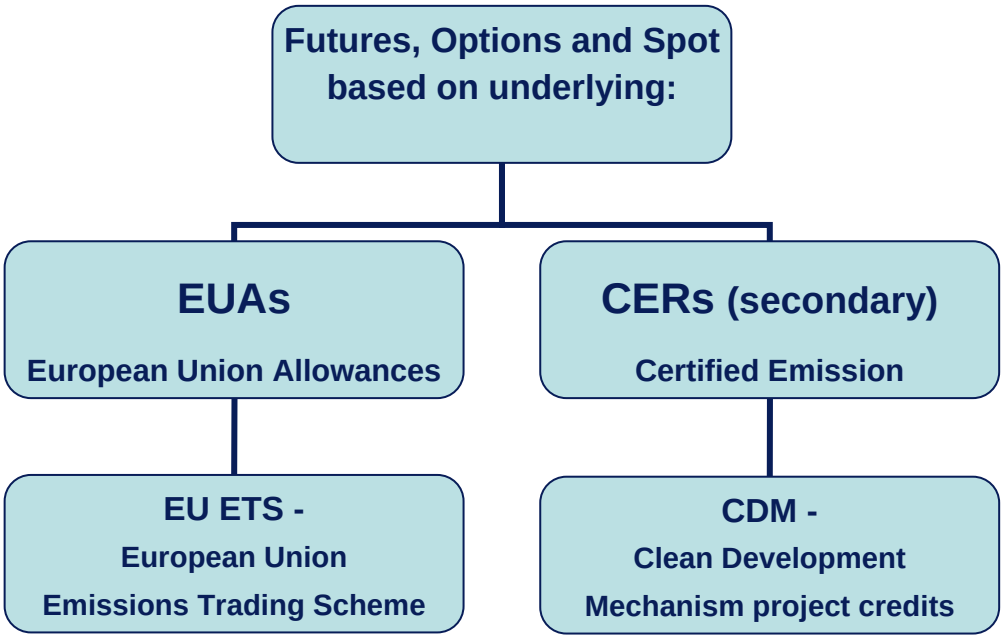
（一） 歐盟排放交易機制(European Union Greenhouse Gas Emission Trading Scheme , EU ETS)

包含德國、英國在內等歐盟 27 個國家，為目前國際間唯一執行強制性溫室氣體總量管制及交易制度的組織，其共同規劃推動之歐盟排放交易機制(European Union Greenhouse Gas Emission Trading Scheme , EU ETS)是目前最大的商業化碳權交易機制，於 2005 年 1 月正式啟動，受管制之設施約已達 12,000 處，排放量約佔歐洲總量的 46%，主要在歐洲氣候交易所（ECX）交易。

歐盟排放交易體系參與 EU ETS 之各國，必須符合歐盟溫室氣體排放交易指令 Directive 2003/87/EC 的相關規定，並以

履行京都減量承諾及減量分擔協議(burden sharing)之決議作為減量目標，執行各國所轄排放源溫室氣體排放量核配之規劃工作。而歐盟 27 國企業必須符合 EU ETS 規定的二氧化碳減排標準，如果減量超過標準，就可賣出稱為「歐盟排碳配額」（EUA）的碳權；如果減排沒有達標，就必須從市場購買碳權。

目前 EU ETS 之交易單位為歐盟排放權配額(EU allowance Units, EUAs)，1 單位的 EUA 等於 1 公噸的 CO_2 當量（tone CO_2 equivalent, tCO_2e）。而為與清潔發展機制(Clean Development Mechanism, CDM)等京都機制連結，京都議定書規範下產生的排放減量單位，將可在 EU ETS 中以等同於 EUAs 的形式交易，但有使用比例限制，以確保各國仍會致力於推動國內減量工作。



（二） 清潔發展機制(clean development mechanism, CDM)

隨著碳交易市場的擴大，歐洲企業亦希望從中國大陸、印度等開發中國家購得較便宜的碳權。這些國家根據京都議定書規定，在減排後獲取的 CER 於 2007 年開始在 ECX 交易。

京都議定書規範 UNFCCC 附件一投資國提供資金或移轉技術予非附件一的地主國，同時取得排放減量認證(certified emission reductions, CERs)，附件一國家可因此而增加 CO_2 的排放量。清潔發展機制是京都議定書下唯一納入非 UNFCCC 附件一國家的彈性減量機制。

該機制由位於德國波恩執委會負責管理執行，如果某專案或企業在執委會註冊並且該單位的減少排放量效果得到認證，就能得到等量的減排認證，1 CER 等於 1 噸二氧化碳或等效的其他溫室氣體的排放指標。

由於已開發國家的能源利用效率高，能源結構優化，新的能源技術被大量採用，這些國家進一步減排的成本極高，減排成本比開發中國家高 5 至 20 倍，所以已開發國家願意以資金援助和技術轉讓的方式，在沒有減排目標的開發中國家實施環保項目。對已開發國家而言，CDM 提供了一種靈活的履約機制；而對於開發中國家，透過 CDM 則可獲得資金援助和先進技術。

第3節 歐洲交易市場現況

歐盟於2004年開始交易碳權，2005年1月開始運作的排放交易制度(eu emission trading scheme, EU ETS)，目前已是全球最大規模的碳權交易市場，2007年EU ETS交易的碳權已達到溫室氣體減量機制之70%。歐盟規定電力、煉油、鋼鐵、水泥和造紙等特定廠商必須符合CO_2的減量標準，若未達到減量標準，則必須買進歐盟排碳配額(eu allowances, EUAs)，1單位EUAs等於1公噸碳權，目前bluenext為EU ETS中最大的碳權現貨市場，歐洲氣候交易所則是最主要的碳權期貨交易所。根據各氣候衍生性產品與交易所的交易資料顯示，碳交易市場的合約類型有期貨(futures)、選擇權(options)及現貨(spot)，其中選擇權為大宗。以下為歐洲各主要氣候交易所：

歐洲氣候交易所(european climate exchange, ECX)	倫敦	EU ETS 下最主要的的 EUAs 期貨市場，商品包括 EUAs 期貨與選擇權、CERs 期貨與選擇權。
北歐電力交易所(nordic power exchange, Nord Pool)	奧斯陸	2005/3 開始交易 EUAs，亦有 CERs 交易，惟成交量不大。
歐洲能源交易所(european energy exchange, EEX)	德國萊比錫	交易 EUAs 現貨與期貨、CERs 期貨。
荷蘭 climex 交易所	阿姆斯特丹	交易 EUAs 與 CERs 現貨。
奧地利能源交易所(energy exchange austria, EXAA)	奧地利	只交易 EUAs 現貨，每週僅交易一次。
巴黎 Bluenext 碳交易市場	巴黎	為 EU ETS 中最大的碳權現貨市場。
義大利電力交易所(IPEX)	羅馬	
倫敦能源經紀協會(LEBA)	倫敦	主要交易天然氣、煤氣以及各類排放量合約，該交易所推出的煤炭指數已成為全球的定價基準。

歐洲排放交易市場中以歐洲氣候交易所為主要交易平台，截至 2009 年 8 月的統計數據,歐洲氣候交易所之交易量所佔比例為 88.5%，每日平均 25,000 筆合約量（相當於 25 百萬噸的 CO_2）其次是 Bluenext 碳交易市場，佔 9.2%。

市場參與者包括投資者（銀行和基金）、套期保值者（電力業者和計畫籌備者）、投機者（投資銀行）及套利者等。清潔發展機制的參與者最為關心的議題是當他們進入任何排放減量交易或是協議時，該項交易或協議是否公平？

所有京都議定書附件 2 國家將可得到指定分配數量(assigned amount units, AAUs)，排放量超出既定限額的國家或公司可在雙方交易的基礎下進行國際排放交易。為了買賣 AAUs，必須進行國際認證和溫室氣體盤查以符合資格。若干政

府機構早已參與購買來自 CDM/JI 下所產生之 CERs 及 ERUs，但遲至京都議定書減量時程開始時(2008)才開始交易 AAUs，AAUs 的來源主要是東歐國家、俄羅斯及烏克蘭等轉型經濟體，這些國家的實質排放量實際上低於它們的許可排放量，一旦 AAUs 的需求和供給導致市場的成立，便會影響 CERs 的長期需求。不過因為 EU ETS 尚未承認 AAUs 可抵銷碳排放，私人機構對 AAUs 的需求將有所限制。交易 AAUs 可能會衍生一些相關問題，AAUs 的供給來源可能大部分是來自減少工業生產，而非採取溫室氣體排放減量措施。

經歐盟執行委員會(European Commission, EC)通過之國家分配計畫(National Allocation Plan, NAPs)，為 EU ETS 建立全盤架構。雖然 CERs 和 ERUs 都可在 EU ETS 下進行交易，但 EU ETS 管制下的國家分配計畫，其第二階段減量時程(2008-2012)給予 CERs 和 ERUs 的交易一些限制，不過這些限制隨著在不同的國家執行而有不同：能夠交易 CERs 和 ERUs 比例最高的是德國，規定 20%；交易比例最低的是斯洛伐克，規定 7%。

第四章 結語與建議

一、生質燃料混燒已在歐洲、美加、日本進行多年，已累積甚多經驗，可供本公司參考。

二、目前國外既有發電用粉煤鍋爐之混燒比例仍低（5~10%以下），若欲提高混燒比例，除政府政策引導（獎勵、強制、灰再利用法令配合修改）外，需再提高生質燃料品質（成份、特性、熱值、研磨性）及混燒技術再精進（即對混燒為何會影響鍋爐上、下游設備之機制要更了解、預測工具及線上監控儀器之引進以減少結渣、積灰、腐蝕等問題）方能達成。

三、本公司發電用粉煤鍋爐設計條件及生質燃料來源、成份、特性等，與國外情況不會完全相同，而鍋爐燃燒行為非常複雜，變數非常多，故國外經驗僅供參考，建議本公司政策決定混燒之前，須委請工程顧問公司與專業廠家進行更嚴謹的評估，再進行設備之新增或修改，以利混燒成功順利。

四、碳權經營相當複雜且影響本公司之永續經營，因此公司在毫無經驗下宜及早因應準備。

參考文獻：

1、 ECN /Biomass co-firing in high percentages-opportunities in conventional and advanced coal-fired plants/2008

2、 TOPELL/Topell on torrefaction/2009

3、 Doosan Babcock Energy/Practical experience of biomass co-firing in large coal-fired utility boilers/2009

4、 KEMA /Technical status of biomass co-firing/2009

5、 KEMA/co-firing high percentages-new chances for old power stations/2008

6、 ECX/The Carbon Market/ECX Emissions Contracts/2009

附錄：相關簡報資料：

1. TOPELL

2. ECX

3. Doosan Babcock Energy

Topell-TPC-CSC

The Hague, October 28, 2009

TOPELL

AGENDA

1. Introduction to torrefaction:
    1. Characteristics
    2. Competition
    3. Markets
    4. Pricing
2. Combination with CHP

Torrefaction is favourable to the environment

Topell meets the most stringent environmental criteria and creates social value

- 94% reduction in CO_2 emission; LCA (life cycle analysis) Topell process by RUG(Rijks Universiteit Groningen) and DHV(Engineering Consultant)
- No competition with food production; Topell uses inedible residues of fibrous biomass from local sources
- Improves biodiversity through landscape and forest maintenance
- Preserves environmental quality
- Zero water pollution
- Creates new green economies and employment both at regional and at global level
- Biomass originates from certified sustainable sources
- Responsible approach towards landscaping
- Residual biomass is main feedstock source
- We meet cradle to cradle waste free principle

TOPELL

COMBINING TORREFACTION AND PELLETING

LEADS TO SUPERIOR ENERGY DENSITY (GJ/M^3)

Handling characteristics improve substantially

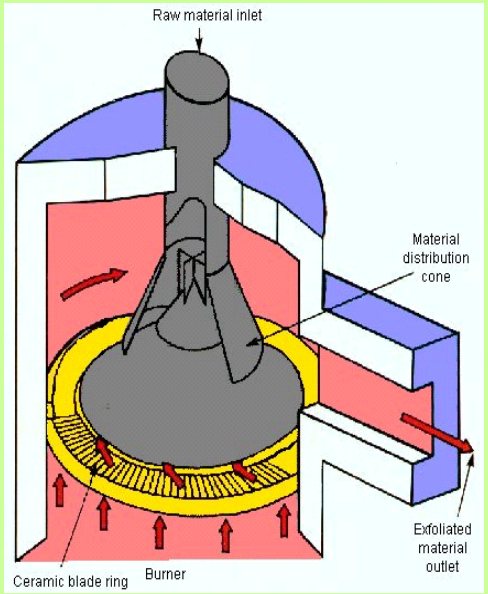
Torrefaction	+	Pelleting	=	Torrefied pellets
• Increased calorific value (~22 MJ/kg) when compared to wood (~+30%) • Hydrophobic nature • Easy grindability • No biological activity • Homogeneous output from heterogeneous input		• Increased bulk density (~ 850 kg/m^3) when compared to regular wood pellet (~+30%)		• Increased energy density (~19 GJ/m3) when compared to wood pellets (~+70%) • Hydrophobic nature • Easy grindability • No biological activity • Homogeneous output from heterogeneous input

TOPELL

TORREFACTION with the TORBED

Horizontal motion and subjecting the base layer of the bed to high impact gas velocities and thus higher heat and mass transfer rates.

Torbed-reactor



How it functions

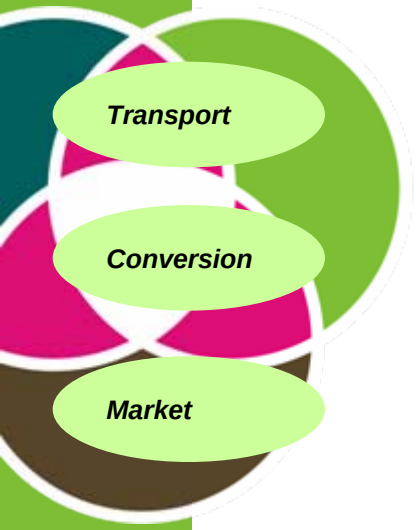
TOPELL

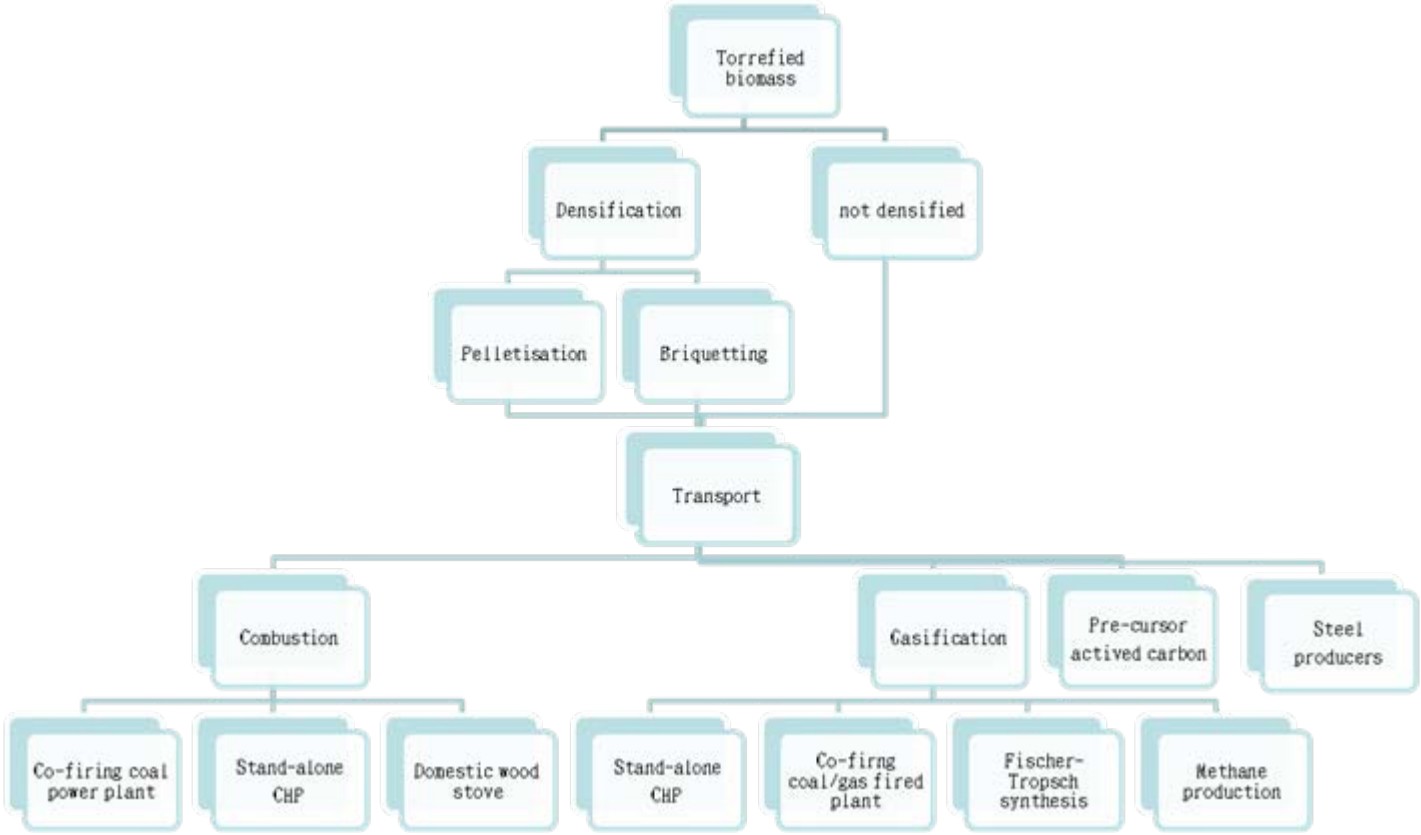
Topell claims to be global leader in torrefaction technology

opportunity to take strategic position

- **Torrefaction process time of 60-120 seconds** versus 15 minutes to 2 hours++ for all other reactor technologies
- **AAA companies like Shell are using Torbed reactor** versus predominantly new or developmental reactor types from competitors
- **RWE has invested in Topell process** versus no significant corporate investments for other technologies
- **Proven trackrecord for upscaling of Torbed** versus wellknown difficulties with upscaling of other technologies like fluidized beds(ECN) and kilns(Stramproy)
- **Lower cash cost per mt produced** (no moving parts, short residense time etc.) versus fluidized beds and rotary kilns

Torrefied biomass is crucial biomass pre-treatment step for numerous energy applications





TOPELL

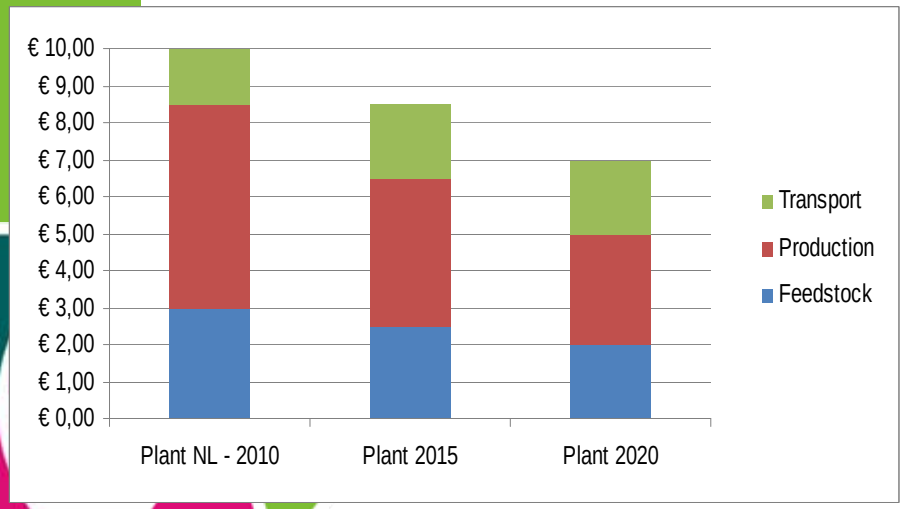
F

Start of construction September 2009, plant start up in June 2010

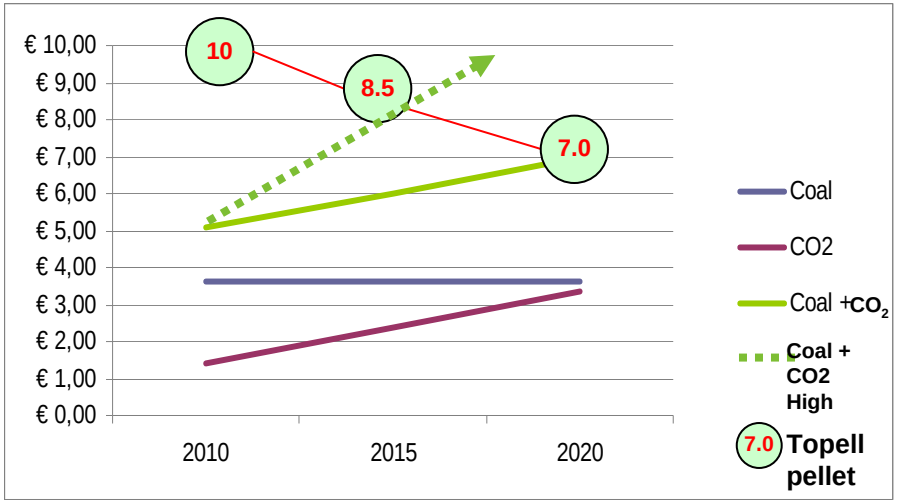
TOPELL

Torrefied pellets can compete with coal + CO_2 in near future

Breakdown Price CIF Rotterdam Topell pellet (€/GJ) (1)



Price CIF Rotterdam of Coal vs. Topell pellet (€/GJ) (1)

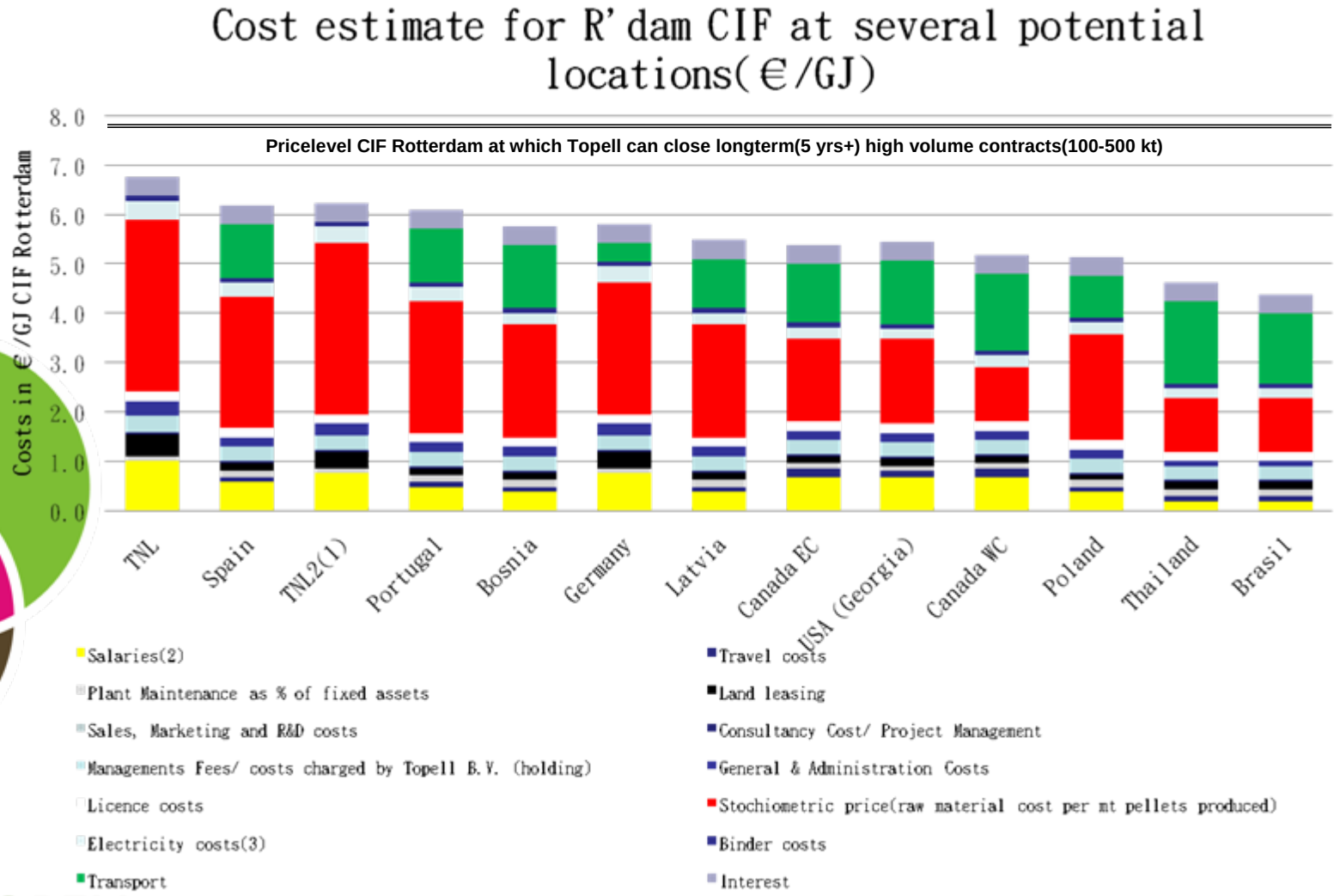


(1) Topell analysis
(2) Coal CIF Rotterdam put at € 80. CO2-emission rights put at € 15/25/35 per ton for 2010/2015/2020.

TOPELL

PRICEWISE NORTH-AMERICA/CANADA PROVIDES FOR EXCELLENT SOURCING

Poland and Latvia competitive in Europe



TOPELL

Polow Biomass Gasifier Remijn: heat application

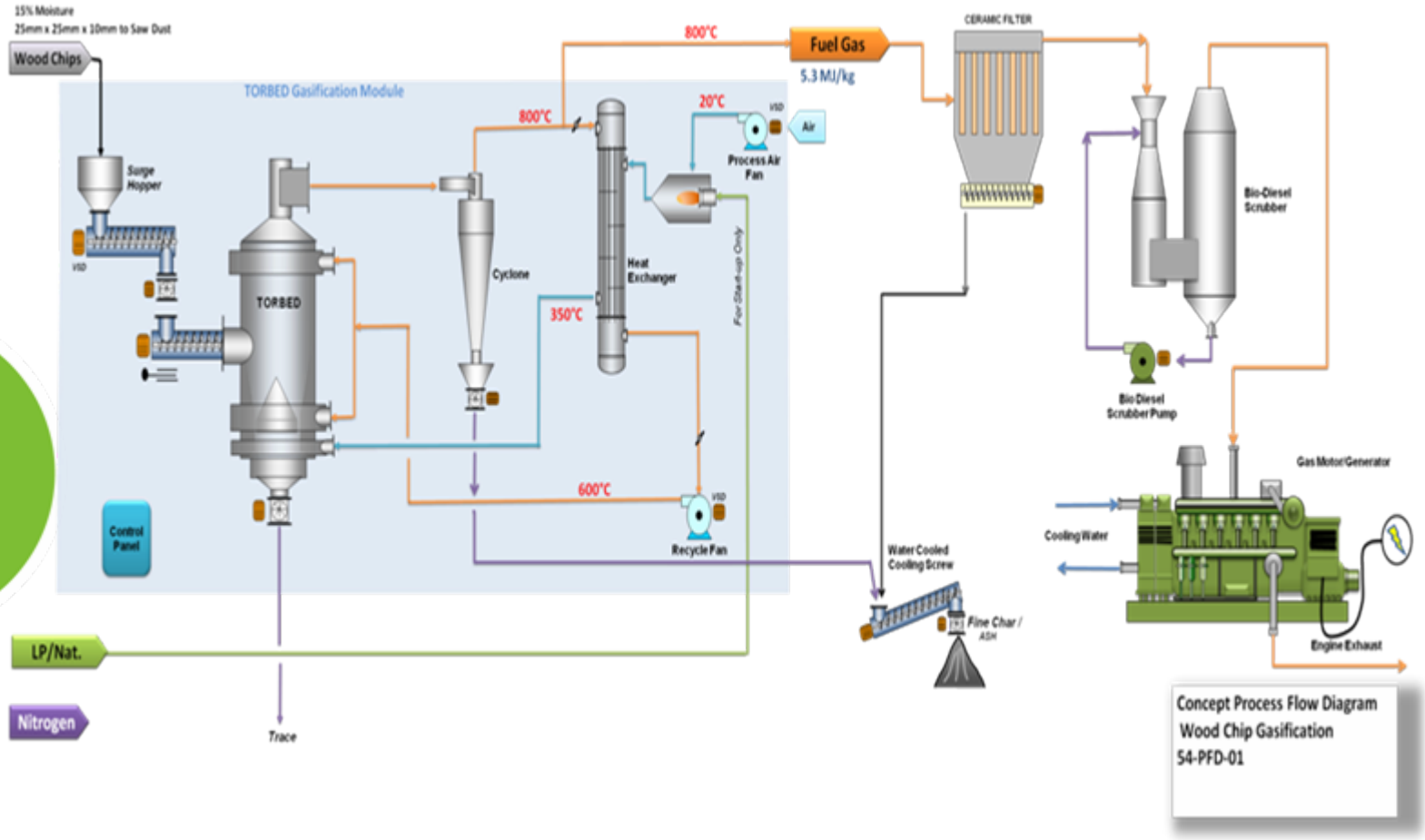
Biomass: demolition wood chips

Application: natural gas replacement

Capacity: 3,5 MWth

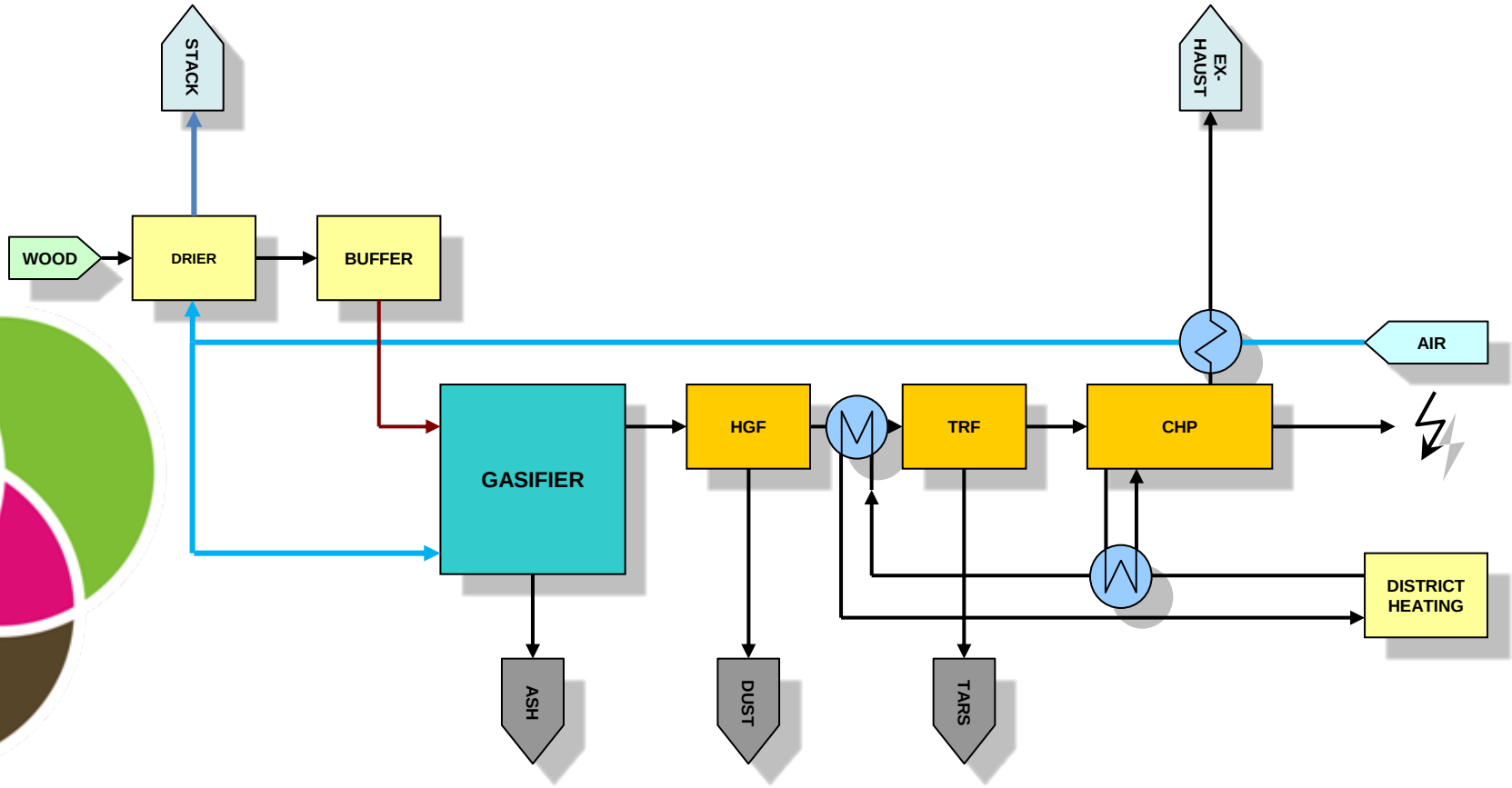
TOPELL

Typical lay-out for electricity generation using Polow/Torbed® gasifier system



TOPELL

Schematic overview for discussion



TOPELL

TOPELL OFFERS
a ‘competitive’ return and roll out opportunities to more plants

Topell brings:	Partner preferably brings:
• Technology • Sales contract • Limited project equity • (Possibly) Project finance	• Feedstock contract (commercial terms) • Location and permits (commercial terms) • Project equity • Project development/early stage project management
Topell gets:	**Partner gets:**
• Ownership > 50% in JV • Pellets to be marketed as Topell pellets	• Long-term off take of biomass at commercial rates, from JV. • ‘Competitive' return on equity capital in JV. Return higher than return on equity in regular wood pellet plant.

EXPECTED RoE SUBSTANTIALLY HIGHER WHEN COMPARED TO SIMILAR INVESTMENT IN WOOD PELLETS

US Plant example

	Torrefied pellets	Conventional wood pellets
Cost of factory	€ 12,000,000	€ 6,000,000
Equity investment	€ 4,000,000	€ 2,000,000
Sales price per ton	€ 175	€ 107
Direct costs per ton	€ 46	€ 47
Indirect costs per ton	€ 53	€ 47
EBITDA per ton	€ 76	€ 14
Net Profit per ton	€ 36	€ 5
IRR to shareholders	49.4%	11.3%

Topell will try to organize a 'fully contracted' supply chain (with both feedstock and off-take contracts) as to optimize financial structure

Assumptions:

- ***Torrefaction plant and conventional wood pellet plant have comparable maximum output of 62,000 tons p.a. Actual output is 55,800 tons p.a. (90% of max capacity).***
- ***Debt/Equity is 33%/67%. Equity for torrefaction plant is € 4 mn. Equity for wood pellet plant is € 2 mn***
- ***Sales prices is Ex-Works.***
- ***Biomass prices are those available in US: $35 per ton at 43% wetness for conventional pellet plant (adjusted with factor 1.74 for cost per output ton), versus $23 per ton at 35% wetness for torrefaction plant (adjustment factor 2.03).***
- ***Indirect costs per ton, which includes staff, maintenance, are similar between 2 plants. However, the difference is explained by technology royalties for Topell plant and higher plant maintenance costs (due to higher CAPEX).***

TOPELL

The Carbon Market

How to Trade ECX Emissions Contracts

ECX

EUROPEAN CLIMATE EXCHANGE

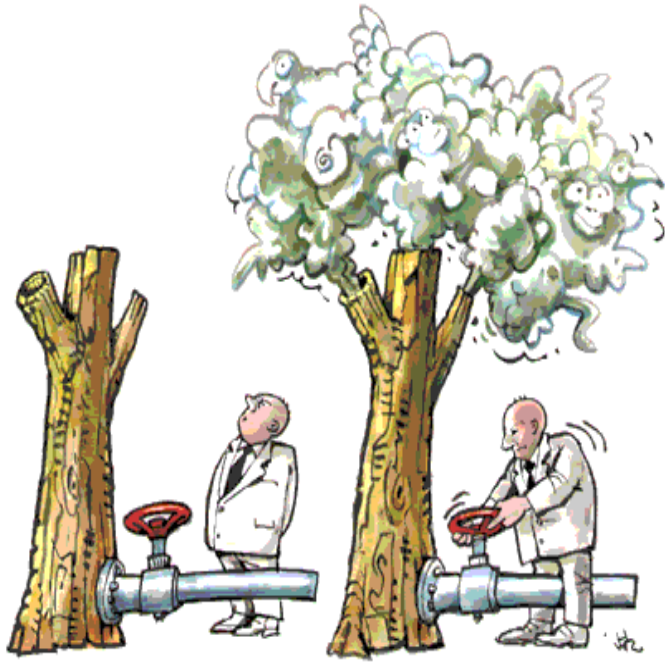
July 2009

Contents

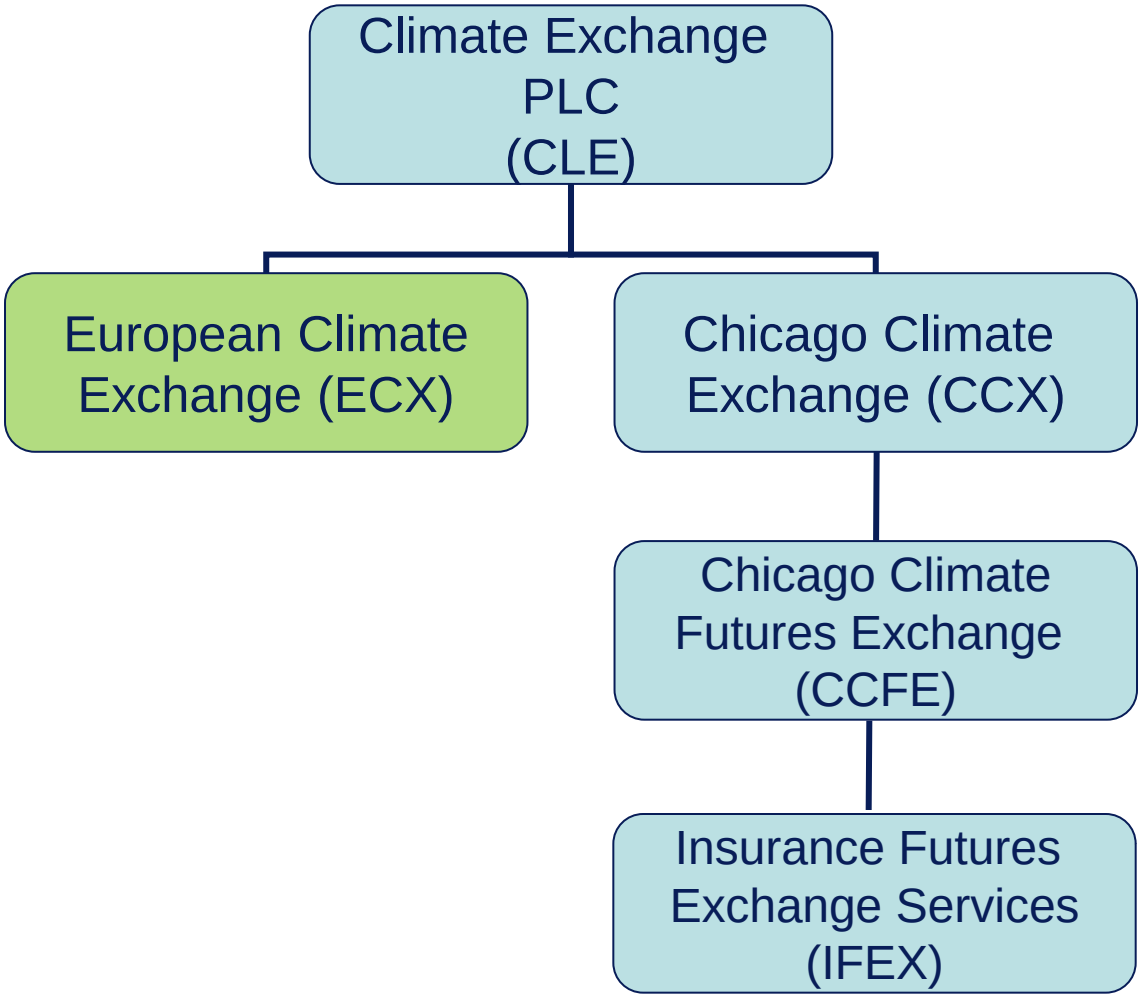
- About The Market
- About ECX
- Price, Volume and Open Interest Developments
- How to Trade
- Members List
- Front end trading application: WebICE
- Fees and Margin Rates
- Appendix: Contract Specifications, OTC Clearing, ECX Indices etc

Why are we trading CO2 in Europe?

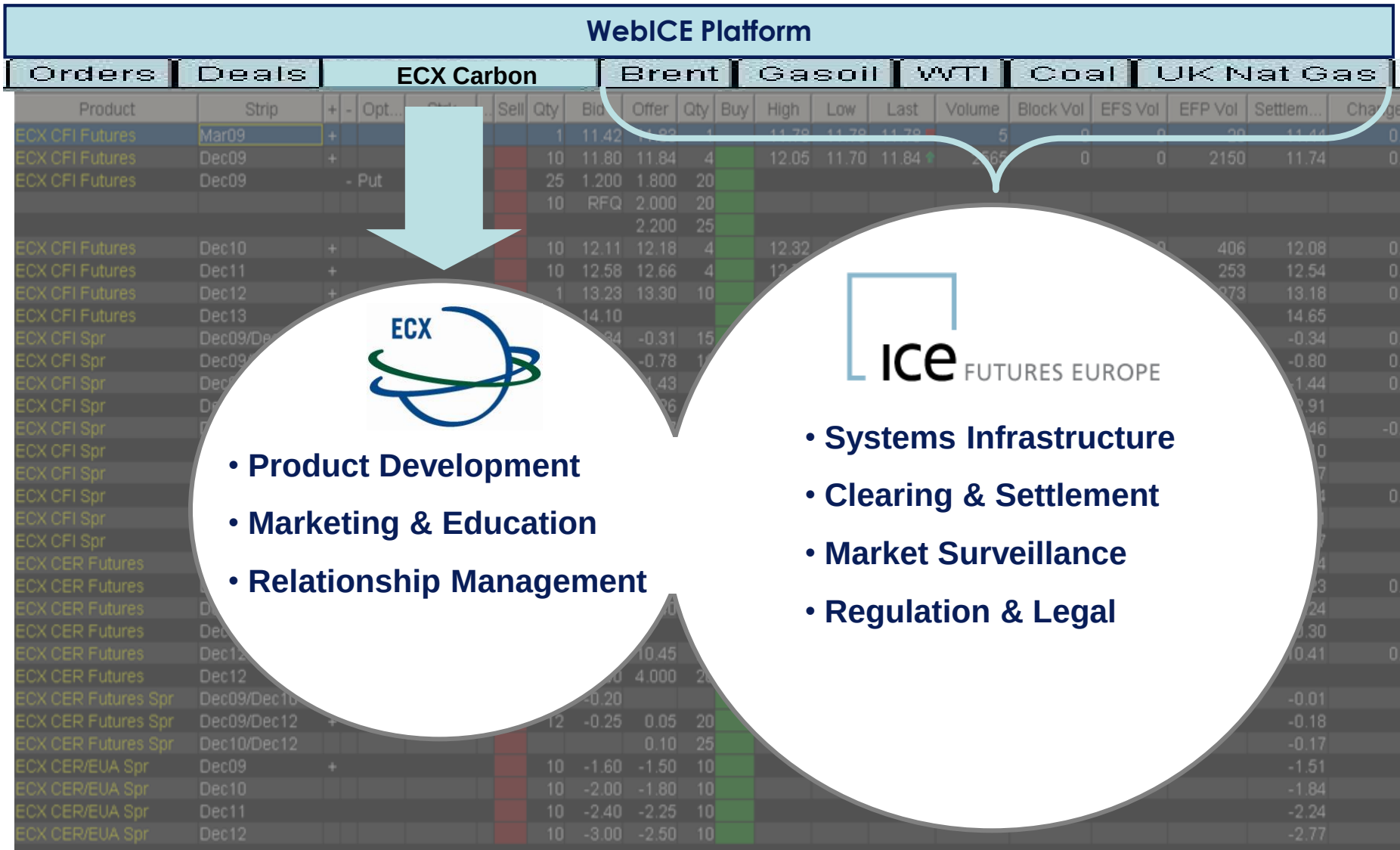
- Every year, 30 billion tonnes of carbon dioxide (CO2) is pumped into the atmosphere globally (Europe: 5 billion tonnes)
- 'Cap-and-trade' - originally from the US
- Kyoto Protocol (-5% from 1990 level by 2012) tools:
  - Emissions Trading
  - CDM (Clean Development Mechanism) → CERs
  - JI (Joint Implementation) → ERUs
- EU Emissions Trading Scheme (EU ETS)
  - Begun 2005, runs in phases
  - Covers 5 sectors (52% of EU's total CO2 emissions)
  - 12,000 energy-intensive installations across EU27
  - 1 EU Allowance (EUA) equals 1 tonne of CO2
  - Annual verification of emissions output in April
- Beyond Kyoto (post 2012)?



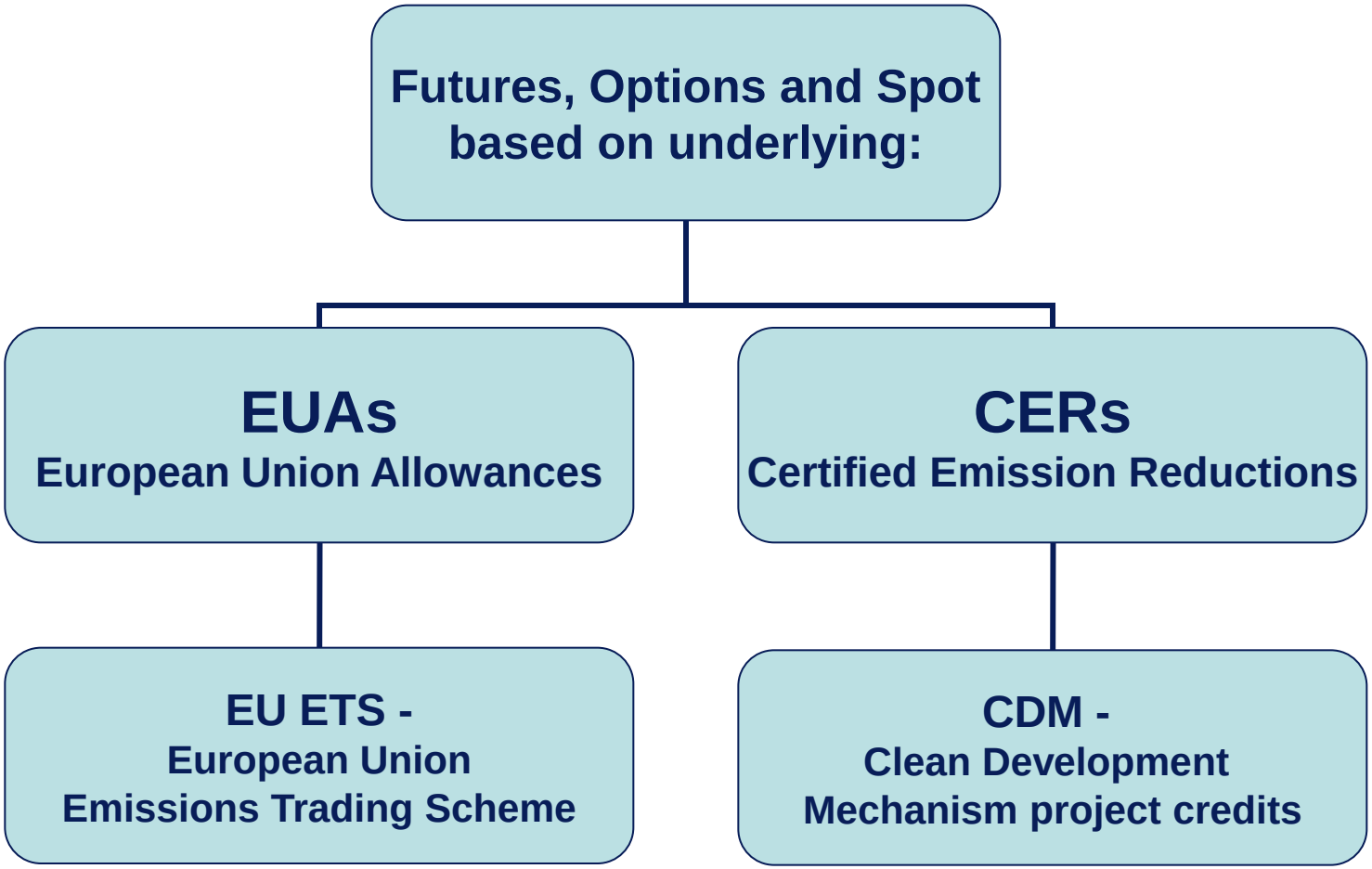
About ECX: Corporate structure



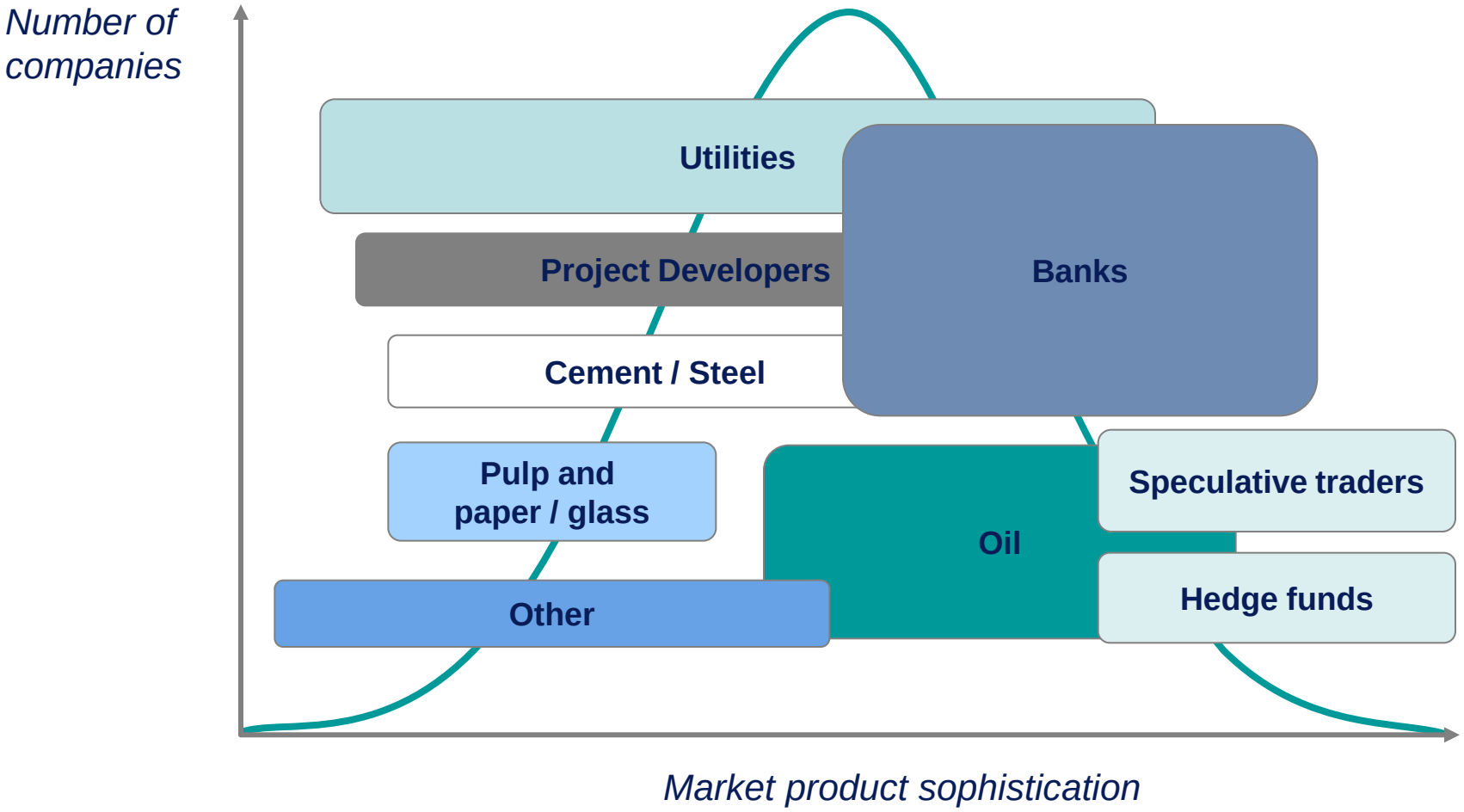
ECX & ICE Partnership



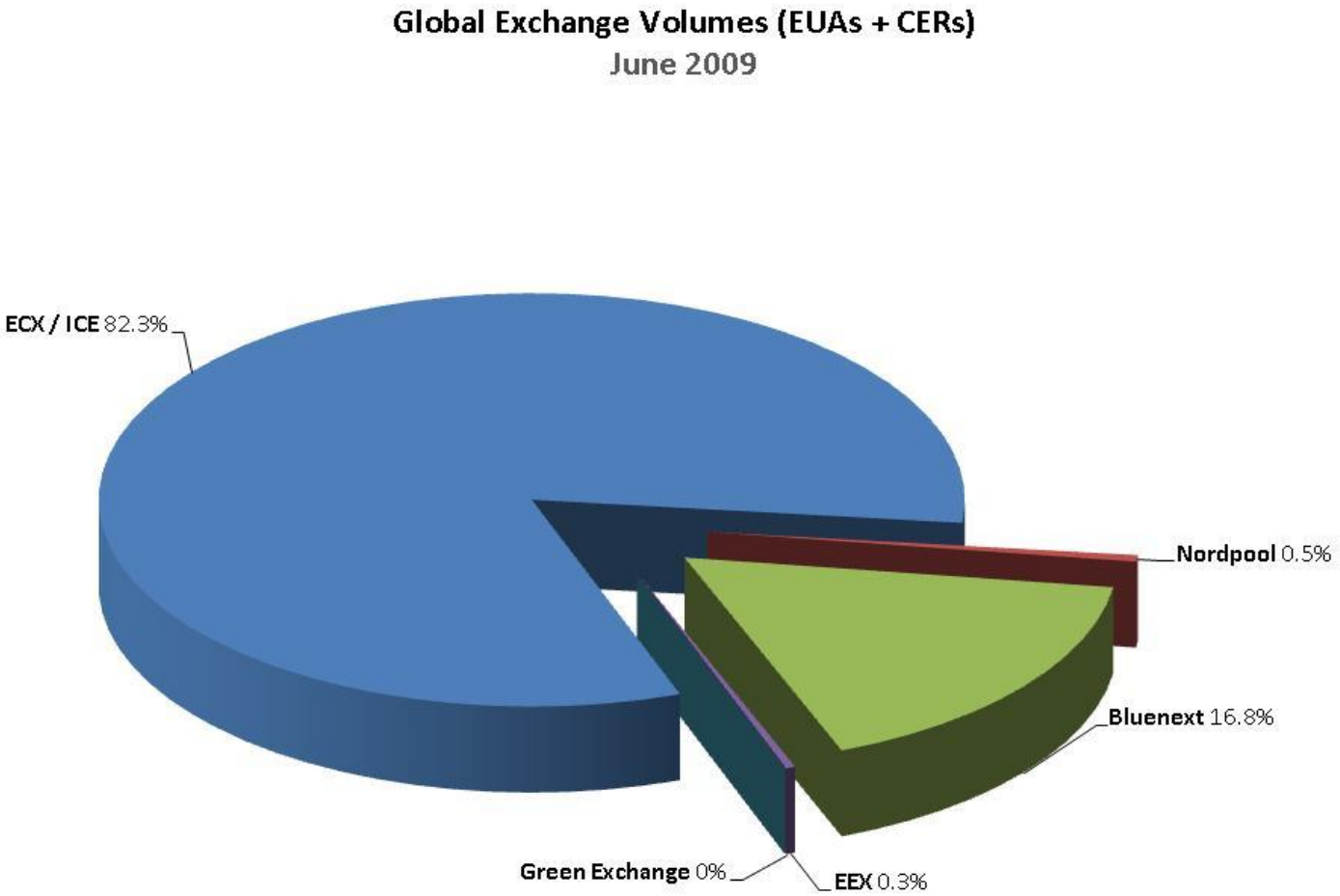
ECX Products



Who is the Carbon Market?

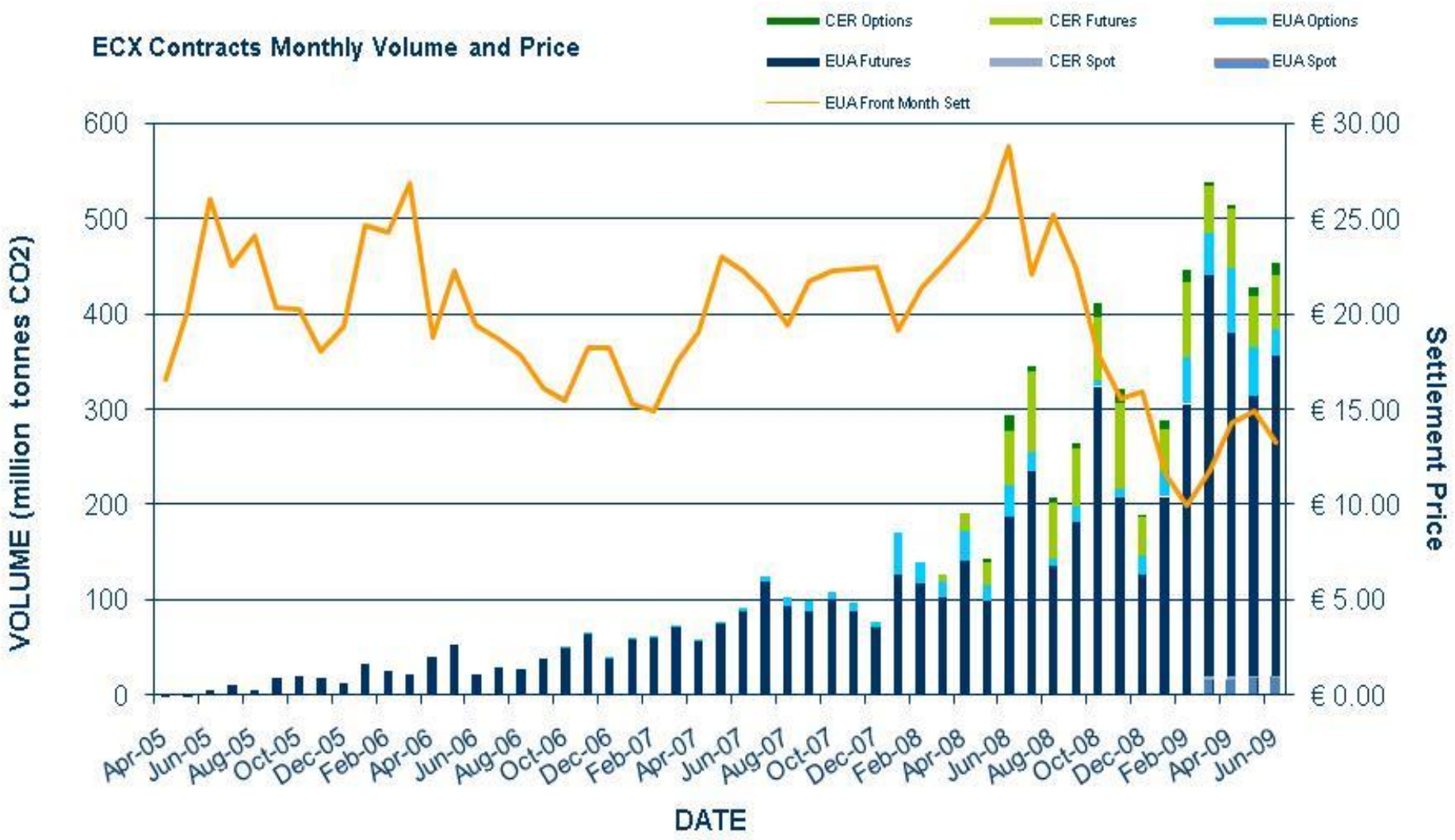


Market Shares

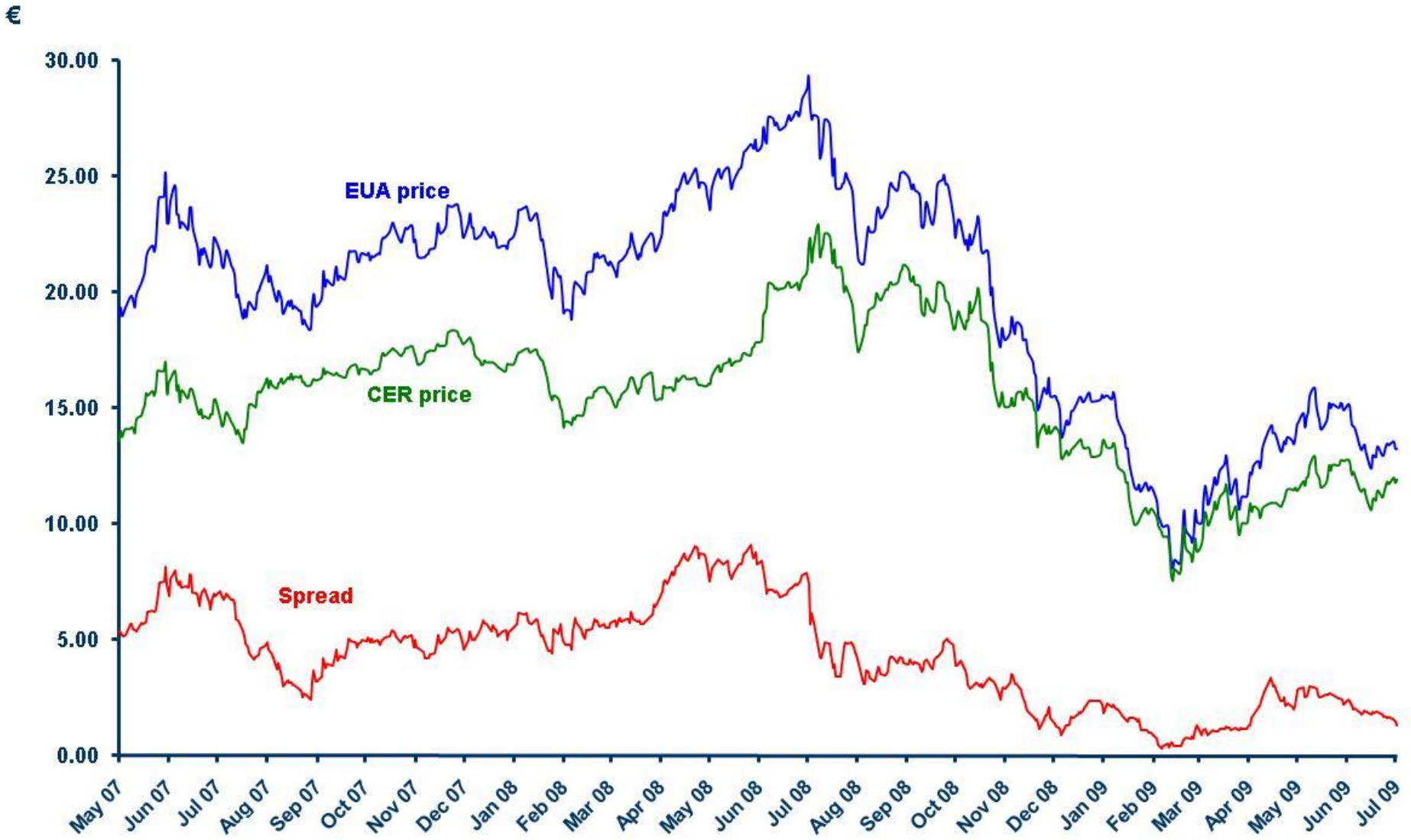


Price and volume – ECX Contracts

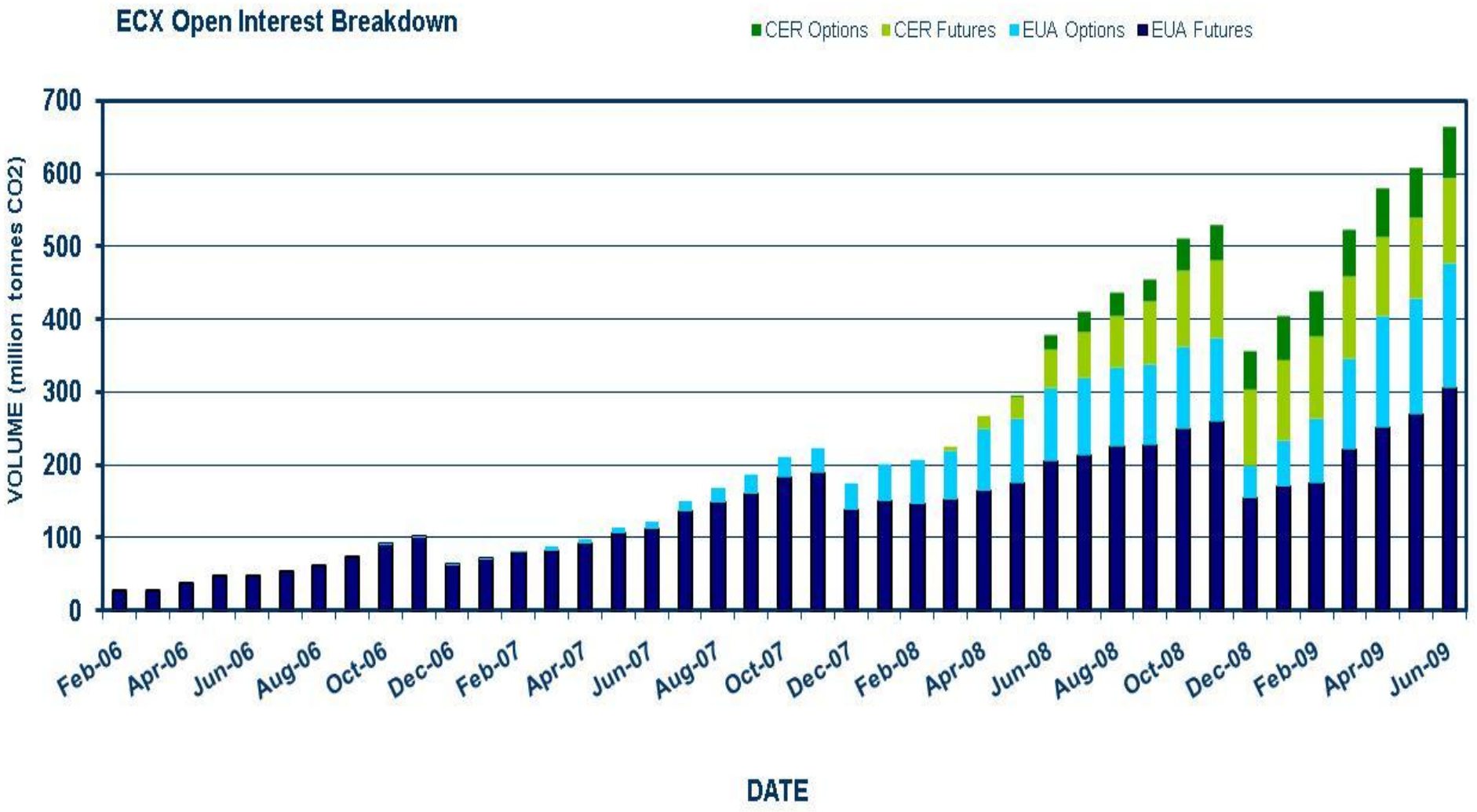
- 2005: 94 million tonnes of CO2 traded – market value €2.1 billion
- 2006: 452 million tonnes of CO2 traded – market value €9 billion
- 2007: 1 billion tonnes of CO2 traded – market value €17.5 billion
- 2008: 2.8 billion tonnes of CO2 traded – market value €55.9 billion



EUA-CER Price Spread



Open Interest ECX Contracts



How to Trade ECX Products

- There are two ways to access the market :
  - Become a **Member** of ECX on ICE Futures; or
  - **Order-Route** as a customer of a Clearing Member on ICE Futures Europe
- Access route decision will be driven by:
  - Nature of company
  - Type of trading activity
  - Volume of trading activity
  - Regulatory status

ICE Futures Members enabled to trade ECX Contracts

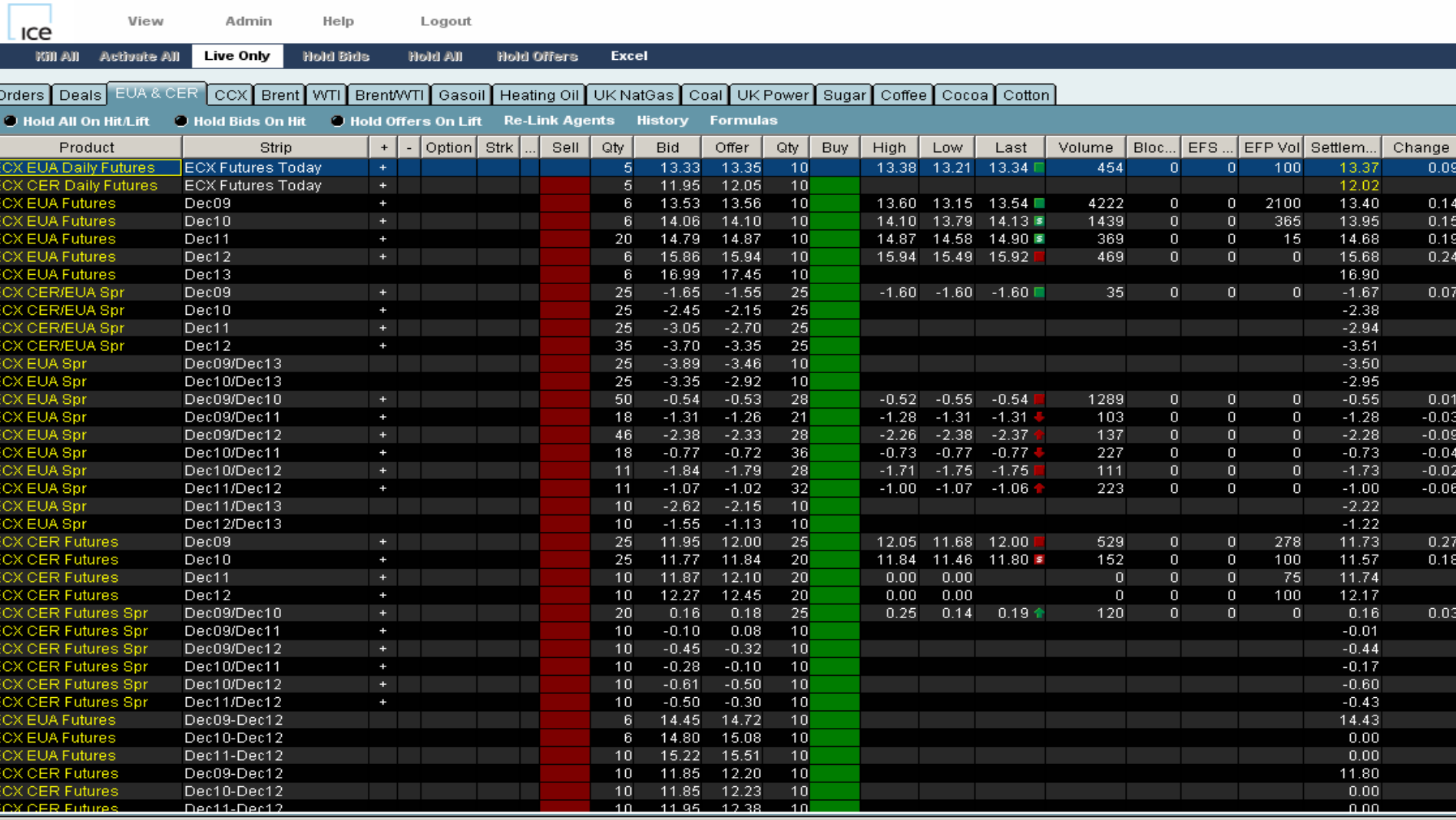
Accord Energy	Gazprom Marketing & Trading	Rand Financial Services
ADM Investor Services	Geneva Ireland Trading	RBC Capital Markets Corporation
All Energy Trading	Getco	RBS Sempra Energy Europe
All Options Curaçao	GFI Securities	REN Trading
Atel Trading	GH Financials	Royal Bank of Canada Europe
Bache Commodities	Goldman Sachs International	Sagacarbon
Banco Santander	HSBC Bank	Saxon Financials
Barclays Capital	ICAP Securities	Schneider Trading
BG International	IMC Trading	Schnell & Co.
BHF Bank	Infinium Capital Management	Scottish Power Energy
BNP Paribas Commodity Futures	Jane Street Global Trading	SEB Futures
BP Gas Marketing	Jaypee International	Shell Energy Trading
British Energy Trading and Sales	JP Morgan Securities	Shell Int. Trading & Shipping
Carbon Capital Markets	Jump Trading	Smartest Energy
CEZ	KFW	Spectron Energy Services
Citadel Derivatives Trading	Klimalnvest	Statkraft Energi
Citadel Equity Fund	Lehman Brothers International	Sucden UK
Citigroup Global Markets	Limestone Trading	Susquehanna
Climate Change Capital	Liquid Capital Securities	TFS Derivatives
Credit Suisse Securities	Madison Tyler Trading	The Royal Bank of Scotland
Deutsche Bank	Marex Financial	ThyssenKrupp
Dresdner Bank	Marubeni Corporation	Tibra Trading Europe
E&T Energie	Merrill Lynch Commodities	Total Global Steel
EDF Trading	Merrill Lynch International	Tradelink
EDP – Energias de Portugal	MF Global	Triland USA
EGL Spain	Mizuho Securities USA	TRX Futures Limited
EGL Trading AG	Morgan Stanley	Tullett Prebon Securities
Electra Deutschland	Natixis Commodity Markets	UBS Clearing & Execution
Electrabel	Newedge (formerly Calyon)	UBS
Endesa Generacion	Newedge (formerly FIMAT)	Vattenfall
First New York Securities	Nomura International plc	Universal Data
Fortis Bank Global Clearing	Optiver VOF	Verbund
Galp Power	R.J. O'Brien & Associates	Wachovia Bank

ICE Clear Europe Clearing Members

ADM Investor Services, Inc.
Bache Financial Limited
Santander
Barclays
BHF Bank
BNP Paribas
citigroup
Credit Suisse
Deutsche Bank
Dresdner Bank
Fortis
Goldman Sachs
HSBC
JPMorgan
MF Global
MAREX Financial
Merrill Lynch
Mizuho
Morgan Stanley
Natixis
The Pulse of Finance
Newedge
AND FINANCIAL SERVICES, INC.
RBC Royal Bank
SEB
UBS

Clearing Members of ICE Futures Europe able to offer clearing and trading services for ECX Contracts to third parties.

ICE ECX Screen Shot



Product	Strip	+	-	Option	Strk	...	Sell	Qty	Bid	Offer	Qty	Buy	High	Low	Last	Volume	Bloc...	EFS ...	EFP Vol	Settlem...	Change
ECX EUA Daily Futures	ECX Futures Today	+						5	13.33	13.35	10		13.38	13.21	13.34	454	0	0	100	13.37	0.09
ECX CER Daily Futures	ECX Futures Today	+						5	11.95	12.05	10									12.02	
ECX EUA Futures	Dec09	+						6	13.53	13.56	10		13.60	13.15	13.54	4222	0	0	2100	13.40	0.14
ECX EUA Futures	Dec10	+						6	14.06	14.10	10		14.10	13.79	14.13	1439	0	0	365	13.95	0.15
ECX EUA Futures	Dec11	+						20	14.79	14.87	10		14.87	14.58	14.90	369	0	0	15	14.68	0.19
ECX EUA Futures	Dec12	+						6	15.86	15.94	10		15.94	15.49	15.92	469	0	0	0	15.68	0.24
ECX EUA Futures	Dec13							6	16.99	17.45	10									16.90	
ECX CER/EUA Spr	Dec09	+						25	-1.65	-1.55	25		-1.60	-1.60	-1.60	35	0	0	0	-1.67	0.07
ECX CER/EUA Spr	Dec10	+						25	-2.45	-2.15	25									-2.38	
ECX CER/EUA Spr	Dec11	+						25	-3.05	-2.70	25									-2.94	
ECX CER/EUA Spr	Dec12	+						35	-3.70	-3.35	25									-3.51	
ECX EUA Spr	Dec09/Dec13							25	-3.89	-3.46	10									-3.50	
ECX EUA Spr	Dec10/Dec13							25	-3.35	-2.92	10									-2.95	
ECX EUA Spr	Dec09/Dec10	+						50	-0.54	-0.53	28		-0.52	-0.55	-0.54	1289	0	0	0	-0.55	0.01
ECX EUA Spr	Dec09/Dec11	+						18	-1.31	-1.26	21		-1.28	-1.31	-1.31	103	0	0	0	-1.28	-0.03
ECX EUA Spr	Dec09/Dec12	+						46	-2.38	-2.33	28		-2.26	-2.38	-2.37	137	0	0	0	-2.28	-0.09
ECX EUA Spr	Dec10/Dec11	+						18	-0.77	-0.72	36		-0.73	-0.77	-0.77	227	0	0	0	-0.73	-0.04
ECX EUA Spr	Dec10/Dec12	+						11	-1.84	-1.79	28		-1.71	-1.75	-1.75	111	0	0	0	-1.73	-0.02
ECX EUA Spr	Dec11/Dec12	+						11	-1.07	-1.02	32		-1.00	-1.07	-1.06	223	0	0	0	-1.00	-0.06
ECX EUA Spr	Dec11/Dec13							10	-2.62	-2.15	10									-2.22	
ECX EUA Spr	Dec12/Dec13							10	-1.55	-1.13	10									-1.22	
ECX CER Futures	Dec09	+						25	11.95	12.00	25		12.05	11.68	12.00	529	0	0	278	11.73	0.27
ECX CER Futures	Dec10	+						25	11.77	11.84	20		11.84	11.46	11.80	152	0	0	100	11.57	0.18
ECX CER Futures	Dec11	+						10	11.87	12.10	20		0.00	0.00		0	0	0	75	11.74	
ECX CER Futures	Dec12	+						10	12.27	12.45	20		0.00	0.00		0	0	0	100	12.17	
ECX CER Futures Spr	Dec09/Dec10	+						20	0.16	0.18	25		0.25	0.14	0.19	120	0	0	0	0.16	0.03
ECX CER Futures Spr	Dec09/Dec11	+						10	-0.10	0.08	10									-0.01	
ECX CER Futures Spr	Dec09/Dec12	+						10	-0.45	-0.32	10									-0.44	
ECX CER Futures Spr	Dec10/Dec11	+						10	-0.28	-0.10	10									-0.17	
ECX CER Futures Spr	Dec10/Dec12	+						10	-0.61	-0.50	10									-0.60	
ECX CER Futures Spr	Dec11/Dec12	+						10	-0.50	-0.30	10									-0.43	
ECX EUA Futures	Dec09-Dec12							6	14.45	14.72	10									14.43	
ECX EUA Futures	Dec10-Dec12							6	14.80	15.08	10									0.00	
ECX EUA Futures	Dec11-Dec12							10	15.22	15.51	10									0.00	
ECX CER Futures	Dec09-Dec12							10	11.85	12.20	10									11.80	
ECX CER Futures	Dec10-Dec12							10	11.85	12.23	10									0.00	
ECX CER Futures	Dec11-Dec12							10	11.95	12.38	10									0.00	

ECX EUA Daily Futures - ECX EUA Daily - ECX Futures Today, 10 @ 13.34 (16:49:30 BST)
ECX CER Futures - ECX CER - Dec09, 25 (16:46:30 BST) **<<EFP/EFS>>**
ECX EUA Futures - ECX - Dec09, 2 @ 13.54 (16:47:36 BST)
ECX EUA Futures - ECX - Dec09, 2 @ 13.54 (16:46:17 BST)
ECX EUA Futures - ECX - Dec09, 25 (16:44:04 BST) **<<EFP/EFS>>**
ECX EUA Futures - ECX - Dec09, 5 @ 13.53 (16:43:39 BST)
ECX EUA Daily Futures - ECX EUA Daily - ECX Futures Today, 14 @ 13.34 (16:43:24 BST)

Futures Fee Structure:
ECX EUA & CER Futures Contracts

	Amount
Exchange fee	
Members' proprietary business (inc. Blocks, EFPs and EFSs)	€2.00 per lot per side (€0.002 per tonne)
Order-routers and other non-proprietary business (inc. Blocks, EFPs and EFSs)	€2.50 per lot per side (€0.0025 per tonne)
ICE Clear Europe Clearing fee	
All business (inc. Blocks, EFPs and EFSs)	€1.50 per lot per side (€.0015 per tonne)

Spot Fee Structure:
EUA and CER Daily Futures ('Spot') Contracts

	Amount
Exchange fee	
Members' proprietary business (inc. Blocks, EFPs and EFSs)	€4.00 per lot per side (€0.004 per tonne)
Order-routers and other non-proprietary business (inc. Blocks, EFPs and EFSs)	€5.00 per lot per side (€0.005 per tonne)
ICE Clear Europe Clearing fee	
All business (inc. Blocks, EFPs and EFSs)	€3.00 per lot per side (€.003 per tonne)

Membership Fee Structure:

	Annual Subscriptions		Application fees (one-off)		Total year 1 fees for trading ECX products
Participant	ICE Membership	Emissions Trading Privilege	ICE Membership	Emissions Trading Privilege	
General	£6,000	€ 2,500	£2,500	€ 2,500	£8,500 + € 5,000
Trade	£2,500	€ 2,500	£2,500	€ 2,500	£5,000 + € 5,000

Margin Rates
EUA and CER Contracts – July 2009

Margin comes in two forms: Initial and Variation Margin

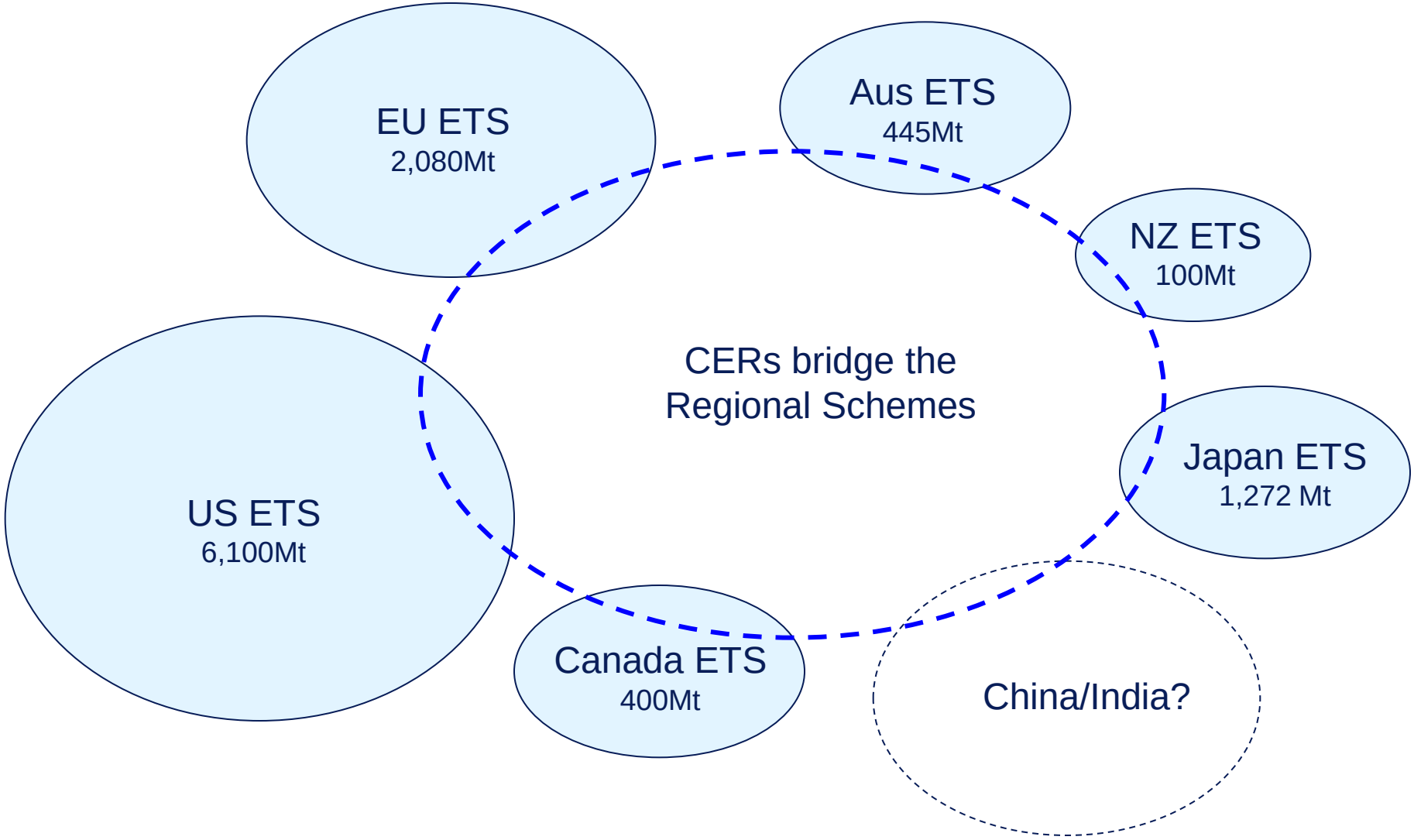
Initial margin is a returnable good faith deposit required whenever a futures or options position is opened. The money is returned when the position is closed out or expires (goes to delivery)

Initial margin	ECX EUA Futures Contract (per lot)	ECX CER Futures Contract (per lot)	ECX EUA and CER Daily Futures Contract ('Spot') Seller Security (expressed as a percentage of EDSP)
Outright 2008 – 2014	Ranges from €1,602 to €1,800 (€1.602 to €1.80 per tonne)	€1,400 (€1.40 per tonne)	EUA: 14% CER: 16%
Inter-month spread	€525 (€0.525 per tonne)	€300 (€0.300 per tonne)	N/A

Variation Margin represents the profit/ loss in a position each day. ICE Clear Europe calculates the profits/ losses sustained on each position at the end of day.

Initial margin for Options is not charged on a "per lot" basis but is calculated according to the overall risk (delta) of the open position. Further details available in 'ICE ECX Contracts: User Guide' and a margin calculator 'ICE SPAN' can be downloaded from: ***https://www.theice.com/clear_europe_span.jhtml***

Where Next?


EU ETS
2,080Mt
Aus ETS
445Mt
NZ ETS
100Mt
CERs bridge the
Regional Schemes
US ETS
6,100Mt
Japan ETS
1,272 Mt
Canada ETS
400Mt
China/India?

Future Outlook

"The total global carbon market value could reach €2 trillion ($3.1 trillion) by 2020."

- POINT CARBON, May 2008

Appendix

How to Become an Order-routing Client

- No need to apply for ICE Futures membership
- Client signs Terms of Business with Clearer
- Clearer provides either WebICE or ISV (Independent Software Vendor) solution for trading
- Client has direct electronic execution ability onto the ICE platform for the trading for ECX CFIs
- Trades are registered with ICE Clear Europe in name of clearer and client remains anonymous
- Access via a broker will be arranged between broker and Clearing Member and brokerage fees will be charged

How to Become an ECX CFI Member of ICE Futures

Complete:

a) Application Form;
b) Electronic User Agreement (EUA)
c) If Clearing Member: Have or be in the process of securing membership of ICE Clear Europe; or

   If Non-Clearing Member: Clearing Agreement;
d) Assign at least one Responsible Individual (RI) to trade;
e) Application processed and formally presented to the ICE Futures' Authorisation, Rules and Conduct Committee for approval;
f) Pay application fee and annual subscription.

Contract Specifications
ICE ECX EUA Futures Contract

Contracts listed	Contracts are listed on a quarterly expiry cycle such that 16 contract months are listed from Dec 2009 to Dec 2012 on a March, June, September and December cycle. Additionally, Dec 2013 and Dec 2014 are listed.
Minimum Trading Size	1 lot / contract (= 1000 tonnes CO2 EU allowances)
Tick Size	€0.01
Settlement & Delivery	Contracts are physically settled by transfer of allowances from seller's account to buyer's account via clearing member account and ICE Clear Europe. Delivery takes place three days after last trading day.
Settlement prices	Trade weighted average during the daily closing period (16:50:00 – 16:59:59 hours UK Local Time) with Quoted Settlement Prices if low liquidity.
Clearing & Contract Security	ICE Clear Europe acts as central counterparty to all trades and guarantees financial performance of ICE Futures contracts registered in the name of its Members.
Trading system	Trading will occur on ICE Futures' electronic trading platform (known as the ICE Platform) which is accessible via WebICE or through a conformed Independent Software Vendor.
Standard Trading hours	07:00 to 17:00 UK Local Time (02:00 to 12.00 EST)

Contract Specifications
ICE ECX CER Futures Contract

Contracts listed	Contracts are listed on a quarterly expiry cycle such that 16 contract months are listed from Dec 2009 to Dec 2012 on a March, June, September and December cycle.
Unit of Trading	One lot of 1000 certified emission reduction units (CER) (i.e. units issued pursuant to Article 12 of the Kyoto Protocol and the decisions adopted pursuant to the UNFCCC to the Kyoto Protocol with the exception of allowances generated by hydroelectric projects with a generating capacity exceeding 20MW, LULUCF activities and nuclear facilities). Each CER being an entitlement to emit one tonne of carbon dioxide equivalent gas.
Minimum Trading Size	1 lot / contract (= 1000 tonnes Certified Emission Reduction units)
Tick Size	€0.01 per tonne (i.e. €10.00 per lot)
Settlement & Delivery	Contracts are physically settled by transfer of CERs from seller's account to buyer's account via clearing member account and ICE Clear Europe. Delivery takes place three days after last trading day. The Exchange will, from time to time, issue a list of Registries from which ICE Clear will accept and will deliver CERs. Initially, this will be restricted to the UK Registry.
Settlement prices	Trade weighted average during the daily settlement period (16:50:00 – 16:59:59 hours UK Local Time) with Quoted Settlement Prices if low liquidity.
Clearing & Contract Security	ICE Clear Europe acts as central counterparty to all trades and guarantees financial performance of ICE Futures contracts registered in the name of its Members.
Standard Trading hours	07:00 to 17:00 UK Local Time (02:00 to 12.00 EST)

Contract Specifications
ICE ECX EUA Options Contract

Contracts Listed	Up to 8 contract months are listed on a quarterly expiry (March, June, September and December), with 4 new contract months listed on expiry of the December contract. Additional December contracts are listed out to Dec 12.
Minimum Trading Size	1 lot / contract (= 1000 tonnes CO2 EU allowances)
Tick Size	€0.01 (tick size capability up to 3 decimal places)
Settlement & Delivery	ECX EUA Options Contracts turn into ECX EUA Futures Contracts at expiry (which are physically settled contracts) 3 business days before the expiry of the relevant ECX EUA Futures Contract.
Settlement Prices	Trade weighted average during the daily settlement period (16:50:00 – 16:59:59 hours UK Local Time) with Quoted Settlement Prices if low liquidity.
Clearing & Contract Security	ICE Clear Europe acts as central counterparty to all trades and guarantees financial performance of ICE Futures contracts registered in the name of its Members.
Standard Trading Hours	07:00 to 17:00 UK Local Time (02:00 to 12.00 EST)
Option Style & Premium	European-style. Premiums are paid at the time of the transaction.
Quotation	A range of strike prices are automatically listed for each contract month covering the price range from €1.00 – €55.00. The Exchange may add one or more strike prices nearest to the last price listed as necessary. Strike price intervals are €0.50.
Trading System	Trading will occur on ICE Futures electronic trading platform (known as the ICE Platform) which is accessible via WebICE or through a conformed Independent Software Vendor.

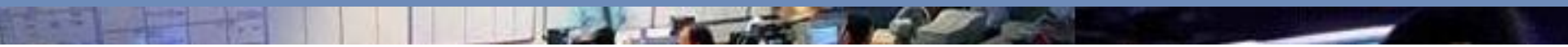
Contract Specifications
ICE ECX CER Options Contract

Contracts Listed	Up to 8 contract months are listed on a quarterly expiry (March, June, September and December), with 4 new contract months listed on expiry of the December contract. Additional December contracts are listed out to Dec 12.
Minimum Trading Size	1 lot / contract (= 1000 tonnes CO2 EU allowances)
Tick Size	€0.01 (tick size capability up to 3 decimal places)
Settlement & Delivery	ECX CER Options Contracts turn into ECX CER Futures Contracts at expiry (which are physically settled contracts) 3 business days before the expiry of the relevant ECX CER Futures Contract.
Settlement Prices	Trade weighted average during the daily settlement period (16:50:00 – 16:59:59 hours UK Local Time) with Quoted Settlement Prices if low liquidity.
Clearing & Contract Security	ICE Clear Europe acts as central counterparty to all trades and guarantees financial performance of ICE Futures contracts registered in the name of its Members.
Standard Trading Hours	07:00 to 17:00 UK Local Time (02:00 to 12.00 EST)
Option Style & Premium	European-style. Premiums are paid at the time of the transaction.
Quotation	A range of strike prices are automatically listed for each contract month covering the price range from €1.00 – €55.00. The Exchange may add one or more strike prices nearest to the last price listed as necessary. Strike price intervals are €0.50.
Trading System	Trading will occur on ICE Futures' electronic trading platform (known as the ICE Platform) which is accessible via WebICE or through a conformed Independent Software Vendor.

Contract Specifications
ICE ECX CER Daily Futures Contracts

Contracts listed	The contract is a daily contract. Only one Daily Contract is listed at any one time
Unit of Trading	**EUAs:** One lot of 1,000 EU Allowances. Each EU Allowance being an entitlement to emit one tonne of carbon dioxide equivalent gas. **CERs:** One lot of 1,000 Certified Emission Reduction units (i.e. units issued pursuant to Article 12 of the Kyoto Protocol and the decisions adopted pursuant to the UNFCCC to the Kyoto Protocol with the exception of allowances generated by hydroelectric projects with a generating capacity exceeding 20MW, LULUCF activities and nuclear facilities). Each CER being an entitlement to emit one tonne of carbon dioxide equivalent gas.
Minimum Trading Size	1 lot / contract (= 1,000 tonnes European Allowances)
Tick Size	€0.01 per tonne (i.e. €10.00 per lot)
Delivery	Delivery is between Clearing Members and ICE Clear Europe during a Delivery Period. The Delivery Period is the period beginning at 18:30 hours on the Contract Date and ending at 19:00 hours on the second Business Day following the relevant Contract Date. There is provision for 'Late' and 'Failed' delivery within the Contract Rules.
Settlement prices	Trade weighted average during the daily closing period (16:50:00 – 16:59:59 hours UK local time) with Quoted Settlement Prices if low liquidity.
Clearing & Contract Security	ICE Clear Europe acts as central counterparty to all trades and guarantees financial performance of ICE Futures contracts registered in the name of its Members.
Trading hours	07:00 to 17:00 UK Local Time (02:00 to 12.00 EST)
Margin	Seller pays margin ("Seller's Security") by 09:00 on T+1
Payment	Buyer pays full contract value by 09:00 on T+1

The Block/EFP/EFS Mechanisms



- Block trades are large (minimum 50 lots) pre-negotiated futures transactions executed off-screen, avoiding price distortion. Block trades need to be reported to the Exchange within 5 minutes of execution. Their price and volume is reported to the market.

- The Exchange-for-Physical (EFP) and Exchange-for-Swap (EFS) mechanisms can be used by participants in the emissions markets who wish to avoid bilateral risk exposure, by registering positions with the Exchange for clearing by ICE Clear Europe. Price is not published.

- In order to use the Block/EFP/EFS mechanisms, both counterparties of the trade are required to have a clearing agreement in place with a Clearing Member of ICE Futures Europe.

ECX Indices

- **ECX EUA Emissions Morning Marker**
  A trade-weighted average of all ECX EUA futures trades within 15 minute period from 9.00 –9.15 UK Local Time. Published shortly after 9.15 UK Local Time for the Sep 09,Dec09, Dec10, Dec11 and Dec12 contract months.

- **ECX EUA Emissions Index**
  A trade-weighted average of all ECX EUA futures trades over the course of the trading day (07:00-17:00). Published shortly after 18.00 UK Local Time for the Sep09, Dec09, Dec10, Dec11 and Dec12 contract months.

- **ECX CER Emissions Index**
  A trade-weighted average of all ECX CER futures trades over the course of the trading day (07:00-17:00). Published shortly after 18.00 UK Local Time for the Sep09, Dec09, Dec 10, Dec11 and Dec12 contract months.

- *ECX indices are used by the market as benchmarks but are not tradable. Available on www.ecx.eu (under Market Data)*

Other Information
Authorised Data Vendors and VAT

Codes for viewing live ECX CFI prices

Vendor	EUA Futures	EUA Options	CER Futures	CER Options	EUA Daily Futures	CER Daily Futures
Bloomberg	EMIT (see tab 92 for EUA Futures)	OMON	CARA comdty CT<GO>	CARZ9C	ICEDEUA	ICEDCER
CQG	UX	UX	QCER	Options QCER	ECX	CES
E-Signal/ FutureSource	LUX	ECFI{month}-ICE	<17t>CERmy	CER{month}-ICE	ECS 9H-ICE	CES 9H-ICE
ICE Live	LUX	LUX	LUX	LUX	LUX	LUX
IDC	<17>t,UX		<17t>CERmy			
Reuters	0#CFI:	CFI+	0#CERE:	0#CERE+	0#CFI2D:	ICEDCER

Value Added Tax (VAT):

The UK's HM Revenue and Customs have confirmed that the trading of the ICE ECX EUA and CER Futures on the Exchange between the Member and ICE Futures Europe has been granted interim approval to be zero-rated for VAT purposes under the terms of the Terminal Markets Order.

Delivery Mechanism

Seller's Account | Seller's Clearing Member's Account | ICE Clear Europe Account | Buyer's Clearing Member's Account | Buyer's Account

- EUAs are held in dematerialized form in National Registries connected to the CITL (EU Registry). The accounts refer to the National Registry account where the entity wishes to make / take delivery.

Doosan Babcock Energy

Practical experience of biomass co-firing in large coal-fired utility boilers.

Taiwan Power
October 2009

Content of presentation

- General issues
- The general approach to biomass co-firing and current status in Britain
- Biomass types and biomass pre-treatment/handling issues
- Biomass co-firing options
- The milling of biomass pellets in coal mills
- The co-milling of biomass with coal in coal mills
- The direct injection of pre-milled biomass
- Combustion through dedicated burners
- Combustion through modified biomass burners
- Direct injection to the pulverised coal pipework
- Technical issues associated with biomass co-firing at elevated levels
- Ash-related issues
- Conclusions

Doosan Babcock Energy

General comments and current status in Britain

General comments on the role of biomass co-firing

- **Current predictions indicate that the utilisation of steam coal for power production worldwide will increase substantially over the next few decades.**
- **The market demand will be for high efficiency, clean, coal-fired power generation plants, with biomass co-firing capabilities and the capability to capture and store carbon dioxide.**
- **Co-firing is a very attractive option for the utilisation of biomass and for the delivery of renewable energy, in terms of the capital investment requirement, the security of supply, the power generation efficiency and the generation cost.**
- **This is recognised by IEA Bioenergy and in the EC Biomass Action Plan, and by EC member state and other governments who have introduced specific policy instruments to encourage co-firing activities.**

Biomass co-firing –general issues

- To date, biomass co-firing activities worldwide have almost exclusively been associated with retrofit projects to existing coal power plants.
- There have been concerns about the availability of biomass, the long term security of subsidy incomes and about impacts on power plant performance and integrity.
- The emphasis has been on the minimisation of the risk of significant impacts on the coal plant operations, performance and integrity.
- The biomass co-firing activities are additional to the installed coal-firing systems.

- A number of the new build coal power plant projects currently being developed in Europe and elsewhere have a requirement for a co-firing capability, generally at the 10-20% level, on a heat input basis.

The current status of biomass co-firing in Britain

- In April 2002, the British government introduced the Renewables Obligation, which provides financial incentives to the generators of electricity from renewable sources, including by biomass co-firing.
- This produced a relatively dramatic increase in biomass co-firing involving all of the large coal-fired power plants in Britain.
- The co-firing has been mainly by pre-mixing the biomass with the coal and co-milling and, more recently, by direct injection of pre-milled biomass.
- To date, the cumulative power generation from co-firing biomass is in excess of 9 million MWh, with a total ROC value in excess of £400 million.
- The level of co-firing activity at individual stations has varied significantly.

General approach to biomass co-firing in Britain

- The general approach at a number of the stations has been as follows:
  - Establish co-firing by pre-mixing the biomass with the coal and co-milling at minimum capital cost, and with short project lead times.
  - Obtain the Section 11 Variation for commercial co-firing activities.
  - Integrate the biomass co-firing into the normal station operations.
  - Upgrade the biomass reception, storage, handling and mixing facilities, to increase throughput and reduce mechanical handling constraints, dust generation, etc.
  - Start consideration of the direct firing of the biomass to permit higher co-firing ratios.
  - Installation of direct biomass co-firing facilities.

Current status of biomass co-firing at the large central coal-fired stations in Britain (April 2002-April 2009)

Station	Capacity (MW_e)	Generator	Cumulative GWh
Aberthaw	1,455	RWE npower	431
Cockenzie	1,200	Scottish Power	217
Cottam	2,000	EdF	571
Didcot	2,100	RWE npower	417
Drax	**4,000**	**Drax Power**	**2,263**
Eggborough	1,960	British Energy	742
Ferrybridge	**2,035**	**SSE**	**2,132**
Fiddlers Ferry	**1,995**	**SSE**	**1,409**
Ironbridge	970	E.on UK	178
Kingsnorth	2,034	E.on UK	769
Longannet	2,400	Scottish Power	680
Ratcliffe	2,010	E.on UK	38
Rugeley	1,000	Int. Power	337
Tilbury	1,085	RWE npower	100
West Burton	1,980	EdF	392
		Total MWh	**10,676**

Doosan Babcock Energy

Biomass types and pre-treatment/handling issues

General biomass types

Agricultural products	Forestry products	Domestic and municipal wastes	Energy crops
Harvesting residues	**Harvesting residues**	**Domestic/industrial**	**Wood**
Straws Corn stalks	Forestry residues	MSW/RDF/SRF Scrap tyres Wood wastes Sewage sludges	Willow Poplar Cottonwood
Processing residues	**Primary process residues**	**Urban green wastes**	**Grasses etc.**
Rice husks Sugarcane bagasse Olive/palm oil/sunflower husks and residues Fruit residues	Bark Sawdusts Offcuts	Leaves Grass and hedge cuttings	Switch grass Reed canary grass Miscanthus
Animal wastes	**Secondary process wastes**		
Poultry litter Tallow Meat/bone meal	Sawdusts Offcuts		

Biomass materials utilised in large quantities in Northern Europe

- The solid wastes from agricultural industries, and principally palm oil and olive oil production,
- Pellets made from dried sawdusts and other materials,
- Dried sludges,
- Wood materials in various forms, i.e. sawdusts, forestry residues, wood processing residues, short rotation coppice wood, etc.
- Cereal straws and other dry agricultural residues in baled form.

- The majority of the biomass material co-fired has been imported from other parts of Europe and from outside Europe.

Biomass pre-treatment

As with all fuels, biomass material may require significant pre-treatment prior to firing. This may include:

- **Chipping or shredding,**
- **Dewatering and/or drying,**
- **The removal of tramp material, normally by air classification or magnetic separation,**
- **Milling,**
- **Pelletisation or other densification,**
- **Torrefaction or pyrolysis, with pelletisation.**

The infrastructure for the supply and pre-treatment of biomass materials in very large quantities for co-firing is still under development in most countries.

Materials handling issues – general

- Biomass materials are generally delivered as pellets, granular materials or dusts, or as baled materials.
- In Britain to date, the costs of the specialised storage, handling and feeding equipment required for baled materials have been prohibitive for co-firing projects.
- Most biomass materials are easy to ignite and have self-heating tendencies.
- Most biomass materials generally require covered storage, although the open storage of sawdusts and wet wood chips is practised.
- The biggest single problem has been associated with the tendency of many biomass materials to generate dust, with the associated health and safety/fugitive emissions issues.

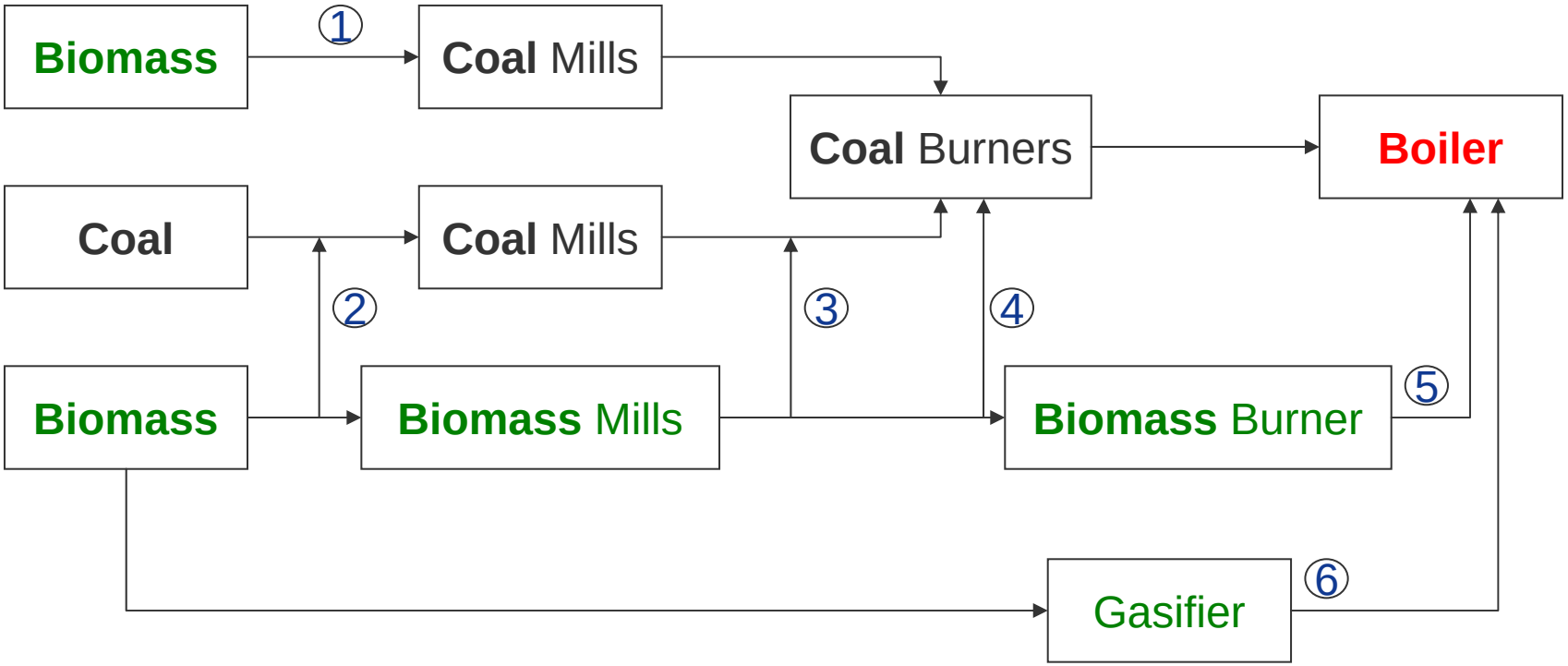
Doosan Babcock Energy

Biomass co-firing options

Current biomass co-firing options for retrofit projects

- The milling of biomass pellets in coal mills,
- The co-firing of solid biomass, in granular, pelletised or dust forms, by pre-mixing with the coal and processing the mixed fuel through the installed coal handling, milling and firing systems,
- The direct co-firing of milled solid biomass by pneumatic injection into the furnace through dedicated biomass burners or through the existing coal burners,
- The indirect co-firing of solid biomass by gasification and co-firing of the product gas,
- The parallel co-firing of solid biomass in a dedicated biomass boiler, with utilisation of the steam in the power generation system of a large coal power plant, and
- The co-firing of liquid biomass materials as a replacement for fuel oil, for light-up/mill support and for load carrying.

The principal direct and indirect biomass co-firing options



1. The milling of biomass (pellets) through modified coal mills,
2. The pre-mixing of the biomass with the coal, and the milling and firing of the mixed fuel through the existing coal firing system,
3. The direct injection of pre-milled biomass into the pulverised coal pipework,
4. The direct injection of pre-milled biomass into modified coal burners or directly into the furnace,
5. The direct injection of the pre-milled biomass through dedicated biomass burners, and
6. The gasification of the biomass, with combustion of the product gas in the boiler.

Biomass co-firing by pre-mixing with coal and co-milling

- Co-firing by co-milling has been the preferred approach for stations embarking on co-firing for the first time.
- The capital investment can be kept to modest levels, and the expenditure is principally on the biomass reception, storage and handling facilities.
- The project can be implemented in reasonable time.
- This approach is particularly attractive when there are concerns about the security of supply of the biomass materials, and about the long term security of the subsidy payments for co-firing.

Biomass co-firing by pre-mixing and co-milling

In general, this approach permits co-firing at levels up to 5-10% on a heat input basis.

The key constraints are:

- The availability of suitable biomass supplies,
- The limitations of the on-site biomass reception, storage and handling facilities and
- The limitations associated with the ability of the coal mills to co-mill biomass materials.

There are also safety issues associated with the bunkering and milling of the mixed coal-biomass material.

The co-milling of biomass with coal in coal mills

- In Britain, a range of biomass materials are being co-milled with coal in ball and tube mills, and in vertical spindle ball and ring, and roller mills.
- These mills depend on the coal particles being subject to brittle fracture, and this does not apply to most biomass materials.
- There is a tendency for the biomass particles to accumulate in the mill, during normal operation, and to take longer to clear from the mill during shutdown.
- With vertical spindle mills there is a tendency for the mill differential pressure and the mill power take to increase when co-milling biomass.
- The mill product topsize tends to increase, due to the lower particle density of the biomass, i.e. larger biomass particles can exit the classifier.
- When co-milling wet biomass materials there will be an impact on the mill heat balance, and this may be a limiting factor.

Safety issues when co-milling biomass in large vertical spindle coal mills

- The key issue in mill safety is avoiding hot primary air coming into direct contact with dry fuel.
- This is particularly important during certain mill operations such as:
  - planned and emergency shutdowns,
  - restarts after emergency shutdowns,
  - loss of coal or intermittent coal feed incidents, etc.
- Biomass has high volatile matter content and combustible volatiles are released in significant quantities at temperatures above about 180ºC, i.e. at much lower temperatures than for bituminous coals.
- It is usually advisable to reassess and modify the mill operating procedures to allow the co-milling of biomass safely.

Biomass storage shed

Biomass pre-mixing system

Biomass co-milling - conclusions

- This approach has been employed successfully at a number of power plants across Europe for the co-firing of a range of solid biomass materials.
- The incidence of significant mill safety issues when co-milling biomass has been fairly modest.
- In general, this approach has permitted the co-firing of up to 10% biomass on a heat input basis, although 5-6% or less is more common.
- The most common problems have been associated with the reception, storage and handling of the biomass, with the most important problems being associated with the generation of biomass dust.

Milling pelletised biomass in coal mills

- The milling of wood pellets in coal mills, and the firing of the mill product through the existing pipework and burners, is done at a small number of power stations in Europe, including Hasselby in Sweden.

- The coal mills are very robust, and have high availability/low maintenance requirements.

- At best, the coal mill breaks the pellets back to the original dust size distribution.

- The mill has to be modified to operate with cold primary air. There are generally no requirements for modifications to the grinding elements.

- The maximum heat input from the mill group is significantly derated, commonly to around 50-70% of that with coal.

Doosan Babcock Energy

Direct injection of pre-milled biomass

Direct injection co-firing systems for biomass basic options

- The biomass can be pre-milled either off-site or on-site.
- All direct injection co-firing systems involve the pneumatic conveying of the pre-milled biomass from the fuel reception and handling facility to the boiler house.
- There are three basic direct injection co-firing options:
  - Direct injection into the furnace with no combustion air,
  - New, dedicated biomass burners, and
  - Injection of the biomass into the pulverised coal pipework or through modified burners.

Direct injection through dedicated burners

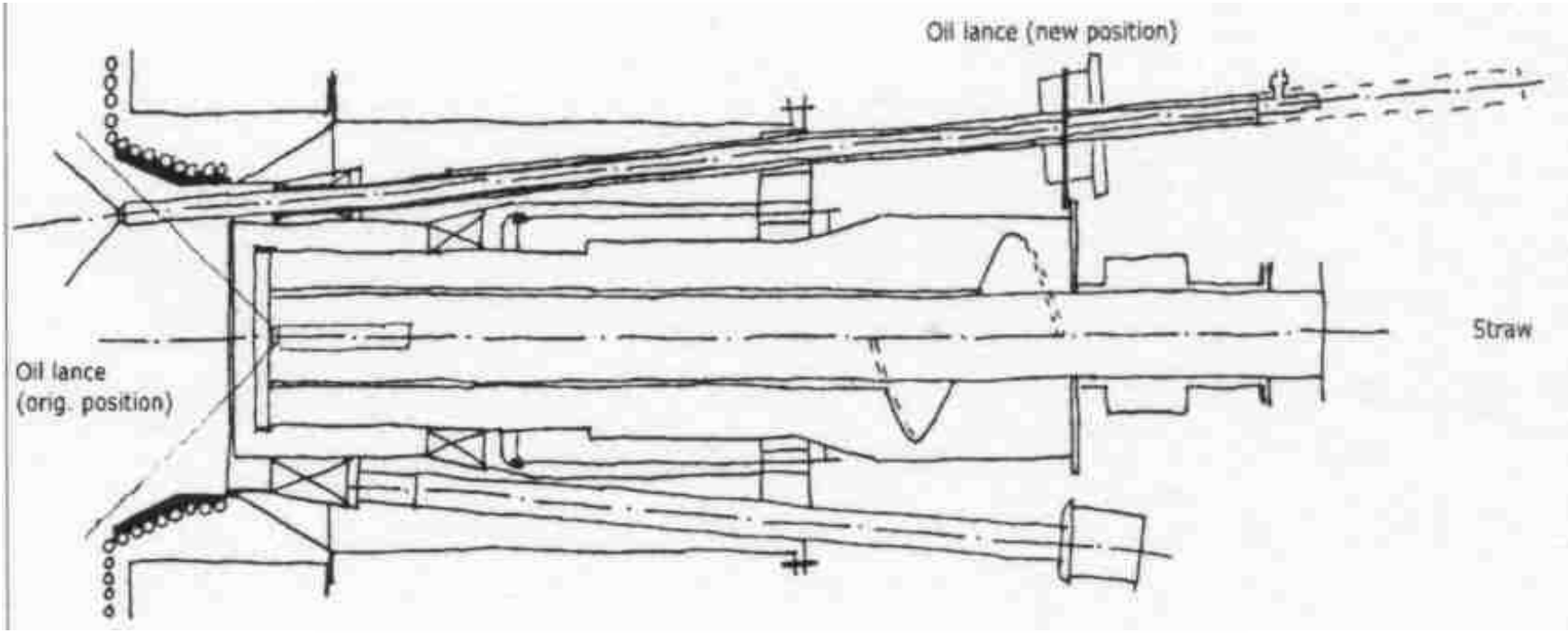
- If the existing coal-firing capability is to be maintained, additional burners are required for biomass firing.
- Appropriate locations for the biomass burners are not easy to find, particularly as a retrofit, and additional furnace penetrations and burner support structures are required.
- Fuel and air supply systems for the biomass burners have to be installed, and flame monitoring equipment for the biomass flames are required.
- The impact of exposure of the 'out of service' biomass burners to the coal-fired furnace gases needs assessed.
- The impacts of biomass burners on the coal-firing system have to be assessed.
- The biomass burners are normally based on conventional pulverised coal burners or cyclone burners (Ferrybridge).

Overall, the installation of dedicated biomass burners is regarded as being an expensive and relatively high risk approach to biomass co-firing.

Direct injection into modified burners

- This has been achieved successfully for both wall-fired and corner-fired furnaces.
- The quantities of biomass that can be co-fired into a single burner are quite modest,
- Modification of the existing coal burners involves additional cost and risk compared to injection into the pulverised coal pipework.
- This approach may be necessary in some cases, depending on the nature of the biomass, particularly if there is a risk of blockage of the fuel supply pipework at splitters, e.g. with chopped straw at Studstrup in Denmark.

Studstrup coal-straw burner
Modified MB Mark III LNB



Direct injection into the pulverised coal firing system

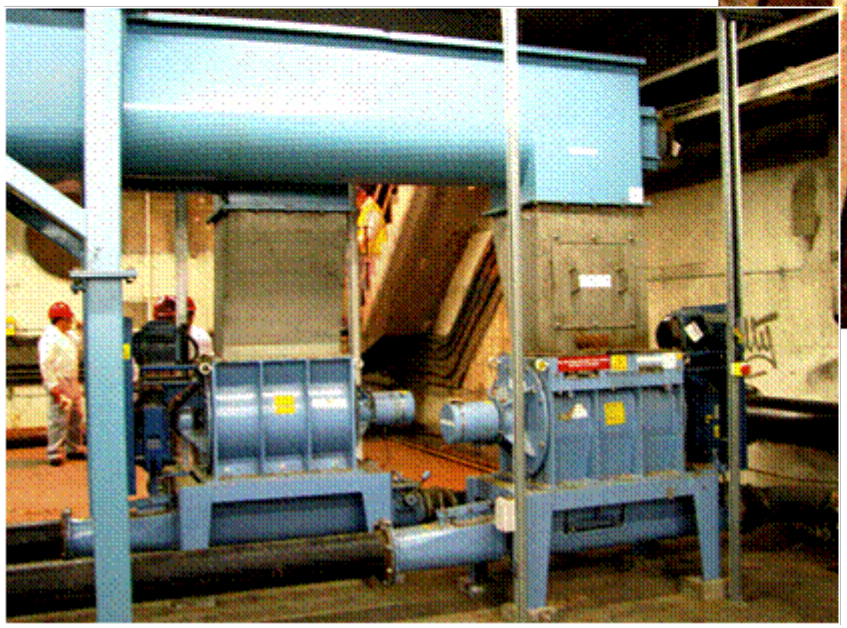
- Direct injection into the existing coal firing system is relatively simple and cheap to install.
- The mill air and fuel flow rates can be reduced in line with the biomass conveying air flow rate, and the heat input to the mill group from the biomass.
- Both the mill and the burners can be maintained within their normal operating envelopes for both the heat input and primary air flow rate.
- The maximum heat input from the mill group is not affected, and can be increased in some cases.
- There are new interfaces between the mill and biomass conveying system controls, covering permits to operate, biomass system shutdowns, start-ups and trips, etc.

- There is a recent demonstration of a direct firing system at Drax Power Station in Britain. The system has been in successful operation since summer 2005, firing a wide variety of pre-milled biomass materials. This system is currently being extended significantly.

Drax Direct Co-firing
The biomass metering and feeding system

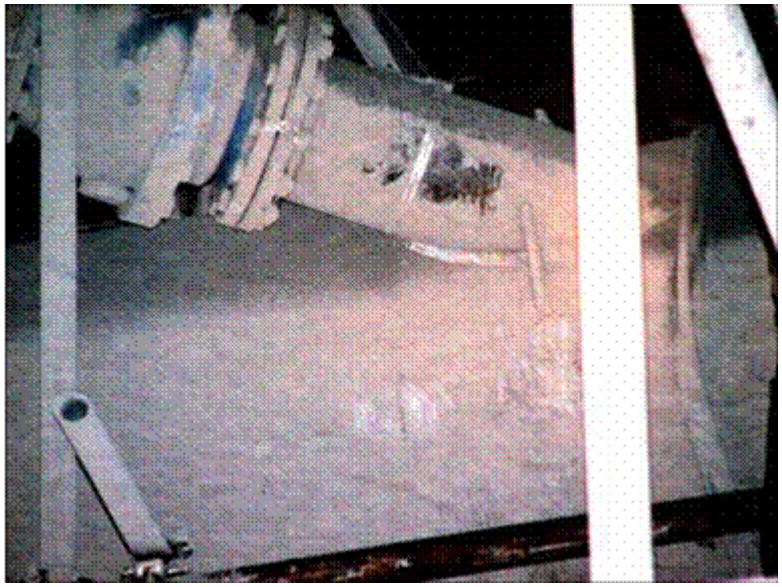
The prototype direct co-firing system has been in successful operation since summer 2005, firing a range of pre-milled biomass materials.

Drax are now replicating this approach to two mills on all six boilers.



Drax Direct Co-firing
The biomass pipes and the injection point

- **The injection point is in the mill outlet pipes, just downstream of the product dampers. The injection point is a simple shallow angle T-in, fitted with an actuated shut-off valve for the biomass,**
- **Both the mill and the burners are maintained within their normal operating envelopes for both the heat input and primary air flow rate. The maximum heat input from the mill group is not affected.**



Doosan Babcock Energy

Biomass ash-related issues

Technical issues with biomass co-firing at elevated levels

- The procurement of very large quantities of biomass,
- Fuel quality/flexibility issues, and off-site biomass storage and pre-processing arrangements and costs.
- Fuel deliveries/reception, on-site handling, storage and pre-processing of very large quantities of biomass.

- Direct injection of pre-milled biomass at high biomass co-firing ratios, and the impact on combustion/NO_x control,
- The increased risks of excessive ash deposition, and fireside boiler tube corrosion.
- The production of mixed biomass/coal ashes and the risks to the normal ash utilisation/disposal routes.

Biomass ash effects

- Most biomass materials have low ash contents (<5%), compared to most power station coals.
- The biomass ashes are very different chemically from coal ashes, i.e. they are not an alumino-silicate system, but a mixture of simple inorganic compounds, of Si, K, Ca, P and S.
- There are concerns about increased rates of deposition on boiler surfaces and the surfaces of SCR catalysts.
- There are concerns about increased rates of high temperature corrosion of boiler components, with high chlorine biomass materials.
- Biomass co-firing tends to increase the level of submicron aerosols and fume in the flue gases, and may impact ESP collection efficiency.
- There may be utilisation/disposal issues with mixed coal/biomass ashes.

Biomass ash compositions

Biomass	Forestry residue	SRC willow	Cereal straw	Oil seed rape straw	Olive residue	Palm kernel	Distillers grains	Poultry litter
Ash (%)	2	2	5	5	7	4	4	13
Analysis (mg kg^{-1})								
Al	-	-	50	50	1,500	750	-	600
Ca	**5,000**	**5,000**	**4,000**	**15,000**	**6,000**	**3,000**	**1,000**	**20,000**
Fe	-	100	100	100	900	2,500	-	900
K	**2,000**	**3,000**	**10,000**	**10,000**	**23,000**	**3,000**	**8,000**	**5,000**
Mg	800	500	700	700	2,000	3,000	2,000	5,000
Na	200	-	500	500	100	200	1,500	3,000
P	**500**	**800**	**1,000**	**1,000**	**1,500**	**7,000**	**12,000**	**14,000**
Si	3,000	-	10,000	1,000	5,000	3,000	400	9,000

The key biomass mineral transformations in flames

- The fusion or partial fusion of quartz and silica particles and, at high temperatures, interactions to form alkali and alkaline earth metal silicates,
- The fusion or partial fusion of alumino-silicates,
- The decomposition of carbonates, oxalates, chlorides, etc. and other inorganic salts,
- The volatilisation of alkali metals and some heavy metals,
- Particle fragmentation by thermal shock and the rapid release of gaseous species from particles, and
- The coalescence of intra-particle mineral particles.

The most important ash-related issues in combustors and boilers

- The formation of fused or partly-fused agglomerates and slag deposits at high temperatures within furnaces,
- The formation of bonded ash deposits and accumulations of ash materials at lower temperatures on surfaces in the convective sections of boilers,
- The accelerated metal wastage of furnace and boiler components due to gas-side corrosion under ash deposits, and due ash particle impact erosion or ash abrasion of boiler components and other equipment,
- The formation and emission of sub-micron aerosols and fumes,
- Biomass ash impacts on the performance of flue gas cleaning equipment, and
- The handling and the utilisation/disposal of ash residues from biomass combustion plants, and of the mixed ash residues from the co-firing of biomass in coal-fired boilers.

The control of ash deposition

- The **careful design of the furnace and boiler convective section**, which recognises properly the characteristics and behaviour of the fuel ash, is of prime importance. The incorporation of specific furnace and boiler design features to minimise ash deposition, and to aid the removal of ash and the avoidance of ash accumulation.

- The correct design, operation and maintenance of the **combustion equipment and of the on-line cleaning systems** are important issues.

- **Intensive cleaning** of the furnace and boiler surfaces during outages can be very effective in increasing the operating times between outages.

- There are **specialised on-line deposition monitoring and sootblowing control systems** that are commercially available and that can assist significantly with the optimisation of the sootblower operations and the control of ash deposition.

Overview of ash-related issues

- The chemistry and mineralogy of biomass ashes and of the mixed ashes from co-firing biomass with coal are reasonably well understood.
- There are risks of decreased ash fusion temperatures and increased slag formation, depending principally on the co-firing ratio, and the ash content and ash chemistry of the biomass.
- There are risks of increased fouling of convective pass surfaces and of SCR catalysts.
- The Slagging and Fouling indexes and other assessment methods devised for coal ashes can be applied successfully to biomass-coal ash mixtures, with appropriate modification.
- In general, the plant experience at co-firing ratios less than 10% on a heat input basis, indicates that the impacts on ash deposition have been modest.
- At higher co-firing ratios the risks of increased deposition and other ash-related impacts are higher, and this will lead to restrictions in the range of biomass materials that can be co-fired.

Conclusions

- Large scale biomass co-firing is one of the most efficient and cost effective approaches to generating electricity from renewable sources.
- Biomass co-milling is being practised successfully, as a retrofit to existing plants, by a number of coal plant operators in Britain and continental Europe.
- Direct injection co-firing projects are currently being implemented as a means of increasing the co-firing levels.
- Injection of the biomass into the pulverised coal pipework is the preferred direct firing solution for both retrofit and new build projects.
- To date, the impacts on boiler plant operations have been modest but this will increase with increasing co-firing ratios and with higher ash biomass materials.
- A number of the new build coal power plant projects have a biomass co-firing requirement.

Thank you for your attention

W R Livingston

Doosan Babcock

blivingston@doosanbabcock.com