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**Some characteristics and lessons from the
French renewable electricity
regulation and tariffs system**

A D E M E



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Market Regulation for Electricity from RES

- ❑ **A power market regulation is necessary to attract private investors and to avoid future "stranded costs"**
- ❑ **This regulation should take into account specific characteristics of RETs**
 - ⇒ **Benefit 1** : no fuel costs: no burden in case of new oil crisis
 - ⇒ **Benefit 2** : no CO2 emissions
 - ⇒ **Benefit 3** : no fuel costs, so future decrease in investment cost will give proportional cost/tariff decrease for new projects
 - ⇒ **Burden 1** : long period of time before enjoying profitability (discounted pay-back time: 10 to 15 years or more)
 - ⇒ **Burden2** : "The free energy sources paradox" (see later): for the same profitability, the margin on the cost of a RE based kWh must be twice or three times higher than the margin on a kWh from a fossil fuel based power plant

Two options to regulate market for RES

□ Regulation by quantities

- ⇒ Quotas + competitive calls for tenders (eg: UK, F in 90's, Ir)
- ⇒ Quotas verified from RECs in % of consumption (or sales) + penalties in case of no compliance (UK, Be, Nl, It)

□ Regulation by prices

- ⇒ "Fixed prices" (eg wind power in Dk & G in the 90's)
- ⇒ "Environ. premiums" over the annual avoided cost (Spain)
- ⇒ "**ADVANCED TARIFFS**" (eg wind power in G, F)
 - ➔ Defined for each technology
 - ➔ Defined for each project, e. g. if variable average wind speed (
 - ➔ Fixed tariff within a contract, e. g. defined first from the potential and then from the actual energy yield measured during the first 5 years
 - ➔ Tariffs for new projects are decreasing each year to take into account costs decrease

The European Context

□ Sept 7th 2001 EU Directive:

⇒ RE based electricity should be 22% of EU15 demand in 2010 instead of 14 % in 1997

⇒ Each member state can choose its best RE policy

⇒ If insufficient national results within 4 years, EU can demand member states to adopt the proven best practices and incentives (e. g. minimum feed in tariffs)

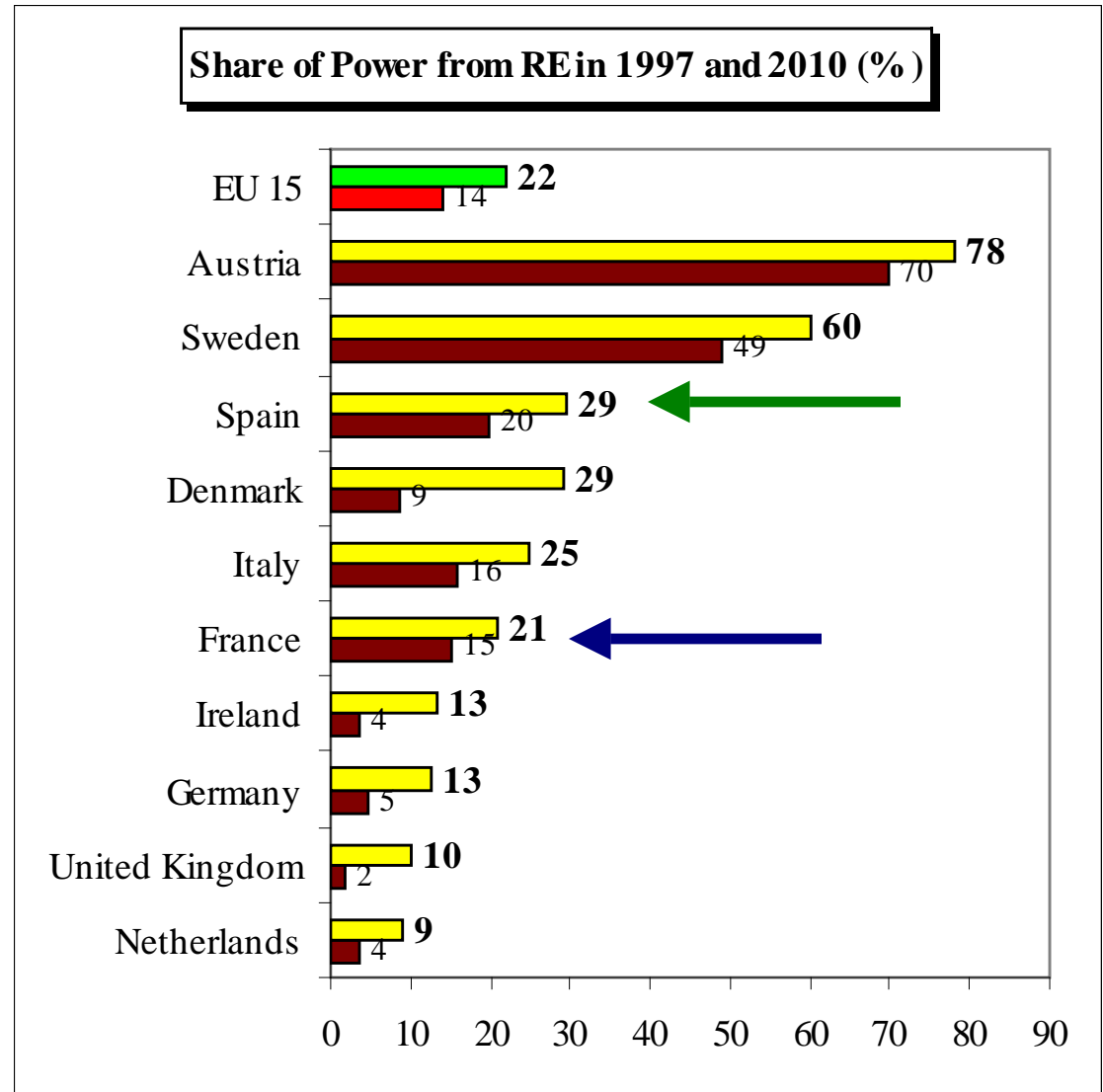
□ 2010 target for wind power :

⇒ 1997: Second contribution (after hydro and biomass) : 40 GW, 80 TWh/year

⇒ EWEA target is now:

→ **75 GW in 2010**

→ including 10 GW offshore



The French Context Within the EU Directive

- ❑ **For France: increase from 15 % to 21 % (including large hydro: 66 TWh)**
 - ⇒ Requires a minimum increase of 40 TWh/year of new RE (excluding large hydro)
 - ⇒ Requires a minimum of 11 GW of wind power in 2010 (versus 0.24 GW in 2003)
 - ⇒ Wind power should contribute to 73 % of new renewable energy increase (81% of new RE power increase)
- ❑ **Those preliminary figures are to be discussed before bottlenecks are assessed (grid access...) and official French commitments are decided and published**

Additional contribution of RETs in France in 2010			Nh ref	P reference	
(2001 ADEME estimate)	TWhe/an	%	h/year at Pref	GW	%
Wind Power	29	73%	2 600	11,2	81%
Biomass	5,9	15%	5 000	1,2	9%
Small Hydro Power	4	10%	4 000	1,0	7%
Geothermal Energy	0,8	2%	7 000	0,1	1%
Photovoltaics	0,3	1%	1 200	0,3	2%
TOTAL new RE contribution	40	100%		13,7	100%
Total with large Hydro	107				
Total 2010 demand incl. DSM	510	21%			

The "Profitability Index" (PI) method

- ❑ **A global economic analysis for preliminary studies**
- ❑ **Constant inflation, results in constant money**
- ❑ **Constant mean yearly Cash-flows :**
 - ⇒ Defines the « references cases »
 - ⇒ By extension following cases are also relevant :
 - ➔ Cash-flows parameters varying by x%/year above or under inflation
 - ➔ Variable cash-flows parameters replaced by their constant equiv. value
- ❑ **Links with other methods :**
 - ⇒ Direct access from PI to IRR, PBP (pay back period), but much more precise (linear variation of PI versus NPV)
 - ⇒ Direct link of PI versus Margin on Cost ==> link with industrial and commercial strategies and policies
 - ⇒ Wise states: almost same economic and fiscal profitability levels

Method (1)

□ **Profitability index** $PI = \text{Net Present Value} / \text{Investment}$

□ **Gives both kWh manufacturing cost and selling price:**

⇒ Tariff $T = ((1 + PI)K_d + K_{om}) I_u / N_h + C_{vu}$ (Euro/kWh)

◆ **CRF** = **Capital recovery factor** (based on actual discount rate = $t = \text{AWCC}$ = Average Weighted Cost of Capital, and n): $CRF = t / (1 - (1+t)^{-n})$

◆ **Kom** = **O&M ratio** = yearly O&M expenses / Investment (wind: $K_{om} = 0.04$)

◆ **Iu** = **investment cost ratio** = I / P (EURO/kW)

◆ **Nh** = $E_y / P = \text{kWh} / \text{kW}$ = number of hours per year at rated power

◆ **Cvu** : variable cost (fuel cost part: $C_{vu} = \text{Fuel Cost} / (\text{Efficiency} \cdot \text{LHV})$)

⇒ If $PI=0$, Tariff = ODC (Overall Discounted Cost), Margin = 0

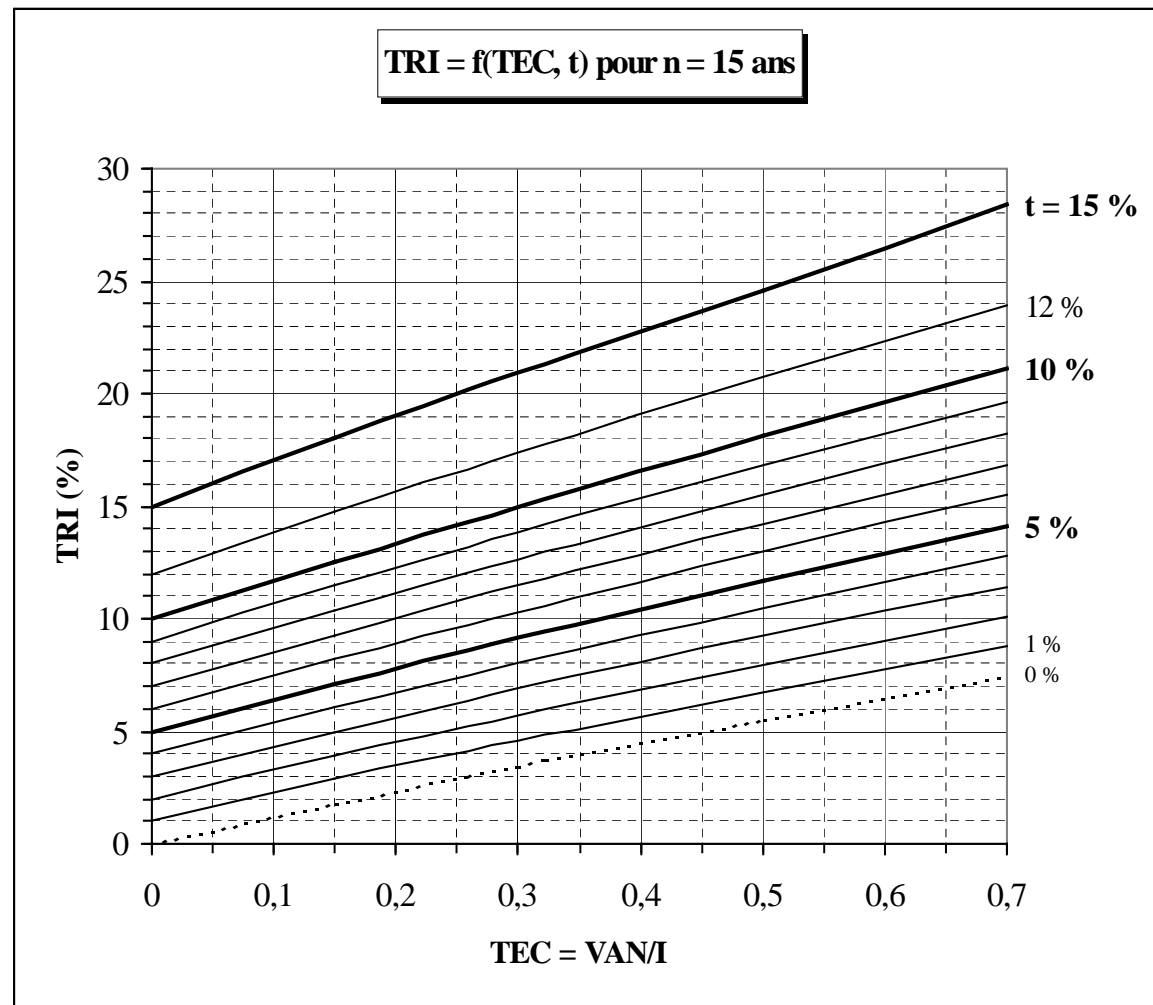
□ **Direct link** $PI \Leftrightarrow IRR$ or $DPBT$ (disc. PB time)

$$CRF (IRR, n) = (1+PI).CRF (t, n)$$

$$CRF (t, DPBT) = (1+PI).CRF (t, n)$$

Links PI / IRR for n = 15 years

- Ex: $t = 6\%$: 100 % PI variation from 0.15 à 0.3 : IRR vary only from 8 to 10.3 %



Method (2) Universal linear model $PI = f(\text{Tariff } T)$

$$\Rightarrow PI = aT - b = (N_h / CRF \cdot I_u)(T - C_{vu}) - (1 + K_{om} / K_d)$$

→ where $I_u = I / P$, $N_h = E_a / P$, $K_{om} = D_{om} / I$, $CRF = t / (1 - (1+t)^{-n})$

→ C_{vu} = part of cost due to the fuel (Zero for wind/solar/hydro systems)

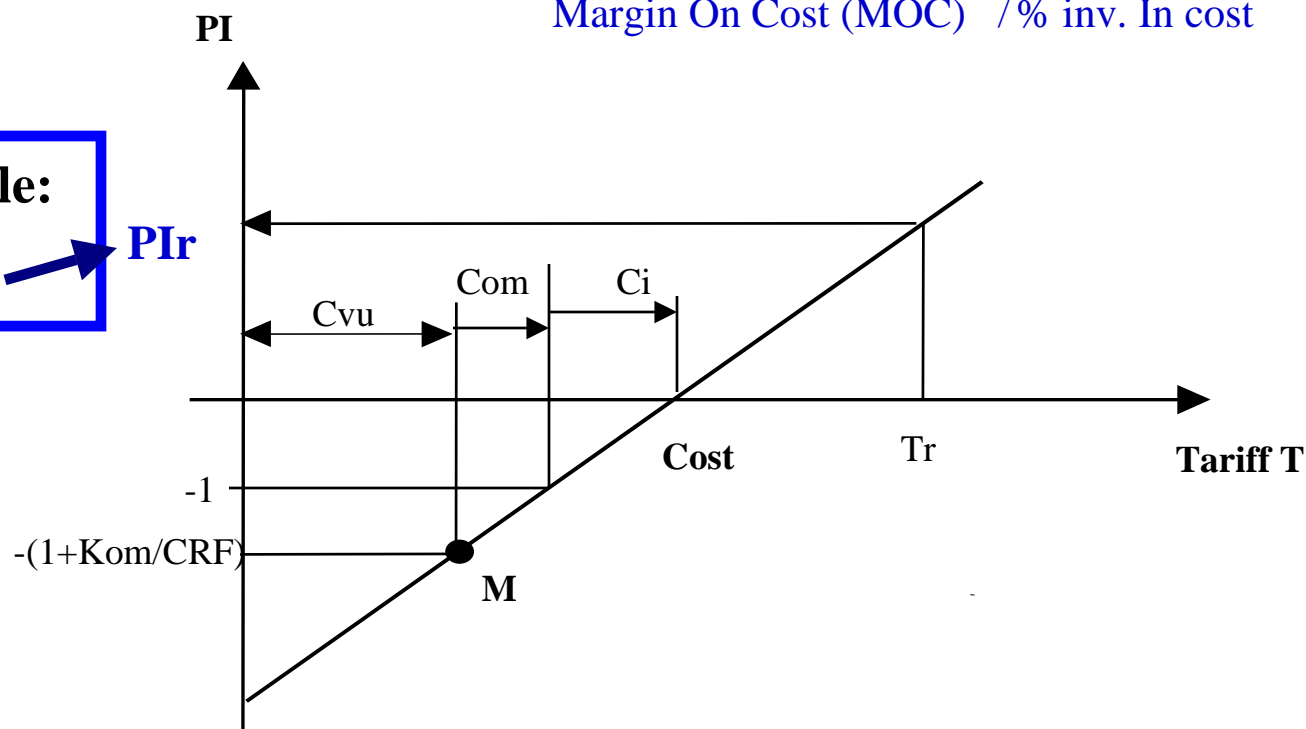
→ C_{om} = part of the cost due to O&M costs = $K_{om} \cdot I_u / N_h$

→ C_i = part of the cost due to the investment cost = $CRF \cdot I_u / N_h$

⇒ From Thales of Milet: $PI = \{(T - \text{Cost}) / \text{Cost}\} / (c_i / \text{Cost})$

Margin On Cost (MOC) / % inv. In cost

Golden rule:
 $PI > 0.3$



Method (3)

□ Margin on cost, MOC

$$\Rightarrow \text{MOC} = (\text{Price} - \text{Cost}) / \text{Cost}$$

□ MOC of Fossil versus Renewable Energy Sources

\Rightarrow Introducing K_{fuel}

$\rightarrow K_{\text{fuel}} = \text{cost per kWh without fuel cost} / \text{cost per kWh}$

$\rightarrow K_{\text{fuel}} = 1,0$ for Wind; $0,5$ for Coal; $0,33$ for CCGT

$$\Rightarrow \text{MOC} = \text{PI} * K_{\text{fuel}} * (K_d / (K_d + K_{om}))$$

At equal kWh cost, if $\text{PI}_{\text{Renewables}} = \text{PI}_{\text{Fossil}}$, then:

$$\text{MOC}_R / \text{MOC}_F > 1 / K_{\text{FUEL}_F}$$

A Renewable energy investment commands a higher margin to reach the same profitability than a Fossil energy investment !!

Method (4)

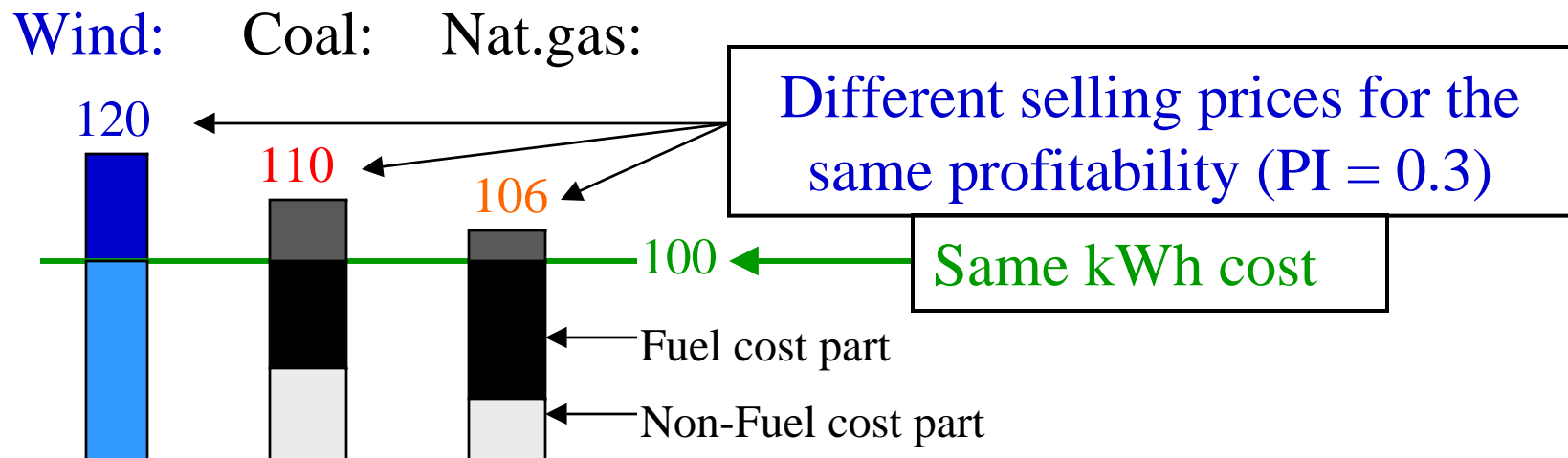
- ❑ **The « zero fuel cost RETs paradox » (wind, hydro, solar, geothermal based power plants) :**

⇒ $(MOC_{wind} / MOC_{fossil}) = (\text{cost} / \text{non fuel cost part})_{fossil}$

⇒ MOC wind = 2 times MOC coal = 3 times MOC nat. gas !

⇒ Minimum 10 % MOC from coal plants ==> **PI = 0,3**

- ❑ **Implies minimum PI value of 0.3 for wind projects (project IRR = 10% for $t = 6\%$ and $n = 15$ years)**



The model $PI = f(\text{electricity kWh tariff } Te) \text{ for CHP}$

□ Data:

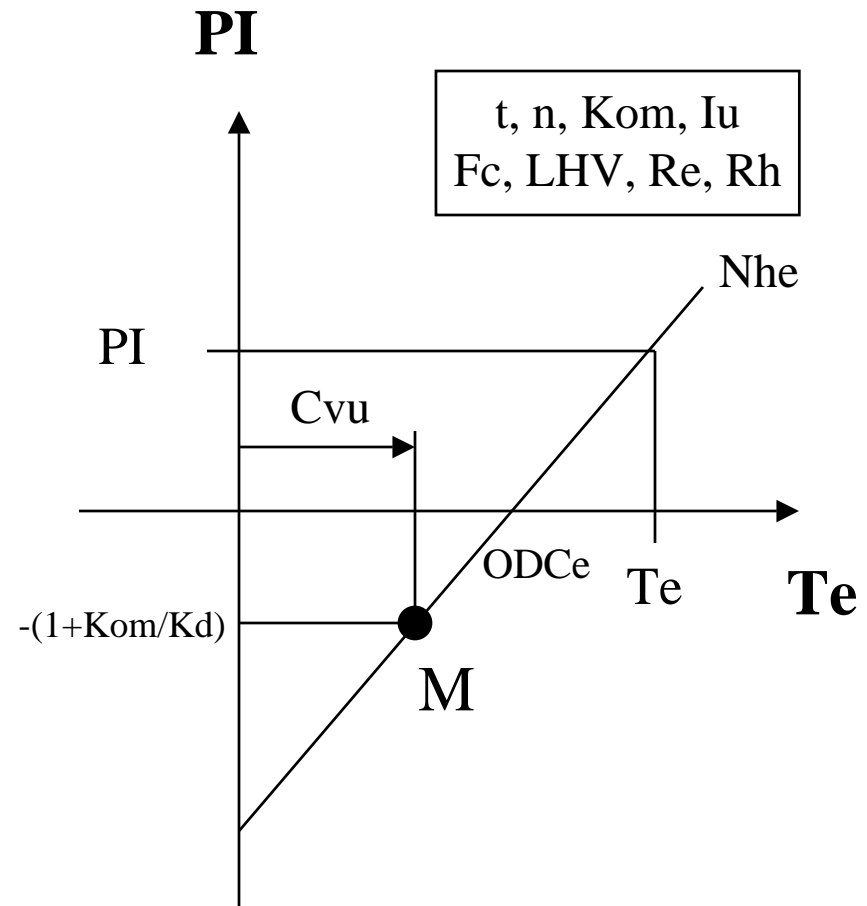
- ⇒ Discounting: $n, t = AWCC$
- ⇒ $I_u = I/P_e$ (EUR/kWe)
- ⇒ $N_{he} = E_{La}/P_e$ (hours/year)
- ⇒ $K_{om} = D_{om}/I$
- ⇒ $R_e = E_{La}/THI$; E_{La} : annual electr. sold
- ⇒ THI = total yearly heat input from fuel
- ⇒ $R_h = Heats/THI$; $Heats$: annual heat sold
- ⇒ F_c (EUR/kg, EUR/m³)
- ⇒ LHV (kWht/kg, kWht/m³)
- ⇒ TV_h (F/kWht)

□ $PI = a(TVe - C_{vu}) - b$

⇒ $C_{vu} = (F_c/R_e \cdot LHV) - (R_c/R_e)TV_h$

□ $Tve = c I_u + C_{vu}$

⇒ $c = (1 + TEC)K_a(1 - Si) + K_{em}(1 - Se)/N_{he}$



Example 1: comparing coal & CHP from biomass

❑ Differences:

⇒ costs: 1.7
c€/kWh

⇒ Tariffs 2,6 c€
(+50%)

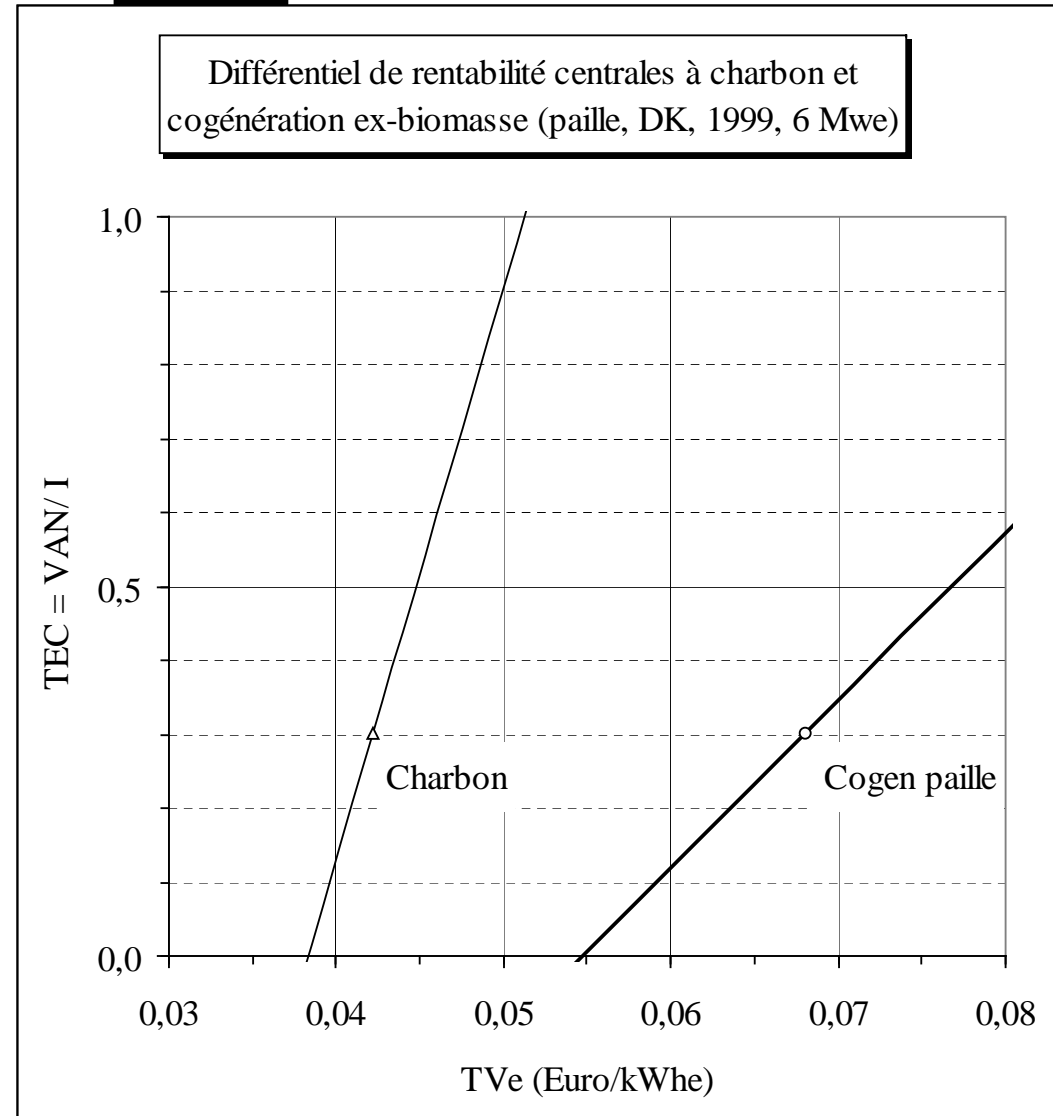
❑ Efficient Tariffs 6,8 c€ versus 4,2 (+62%)

❑ Tariffs Chp

⇒ G: 8.7 to 10.2 c€

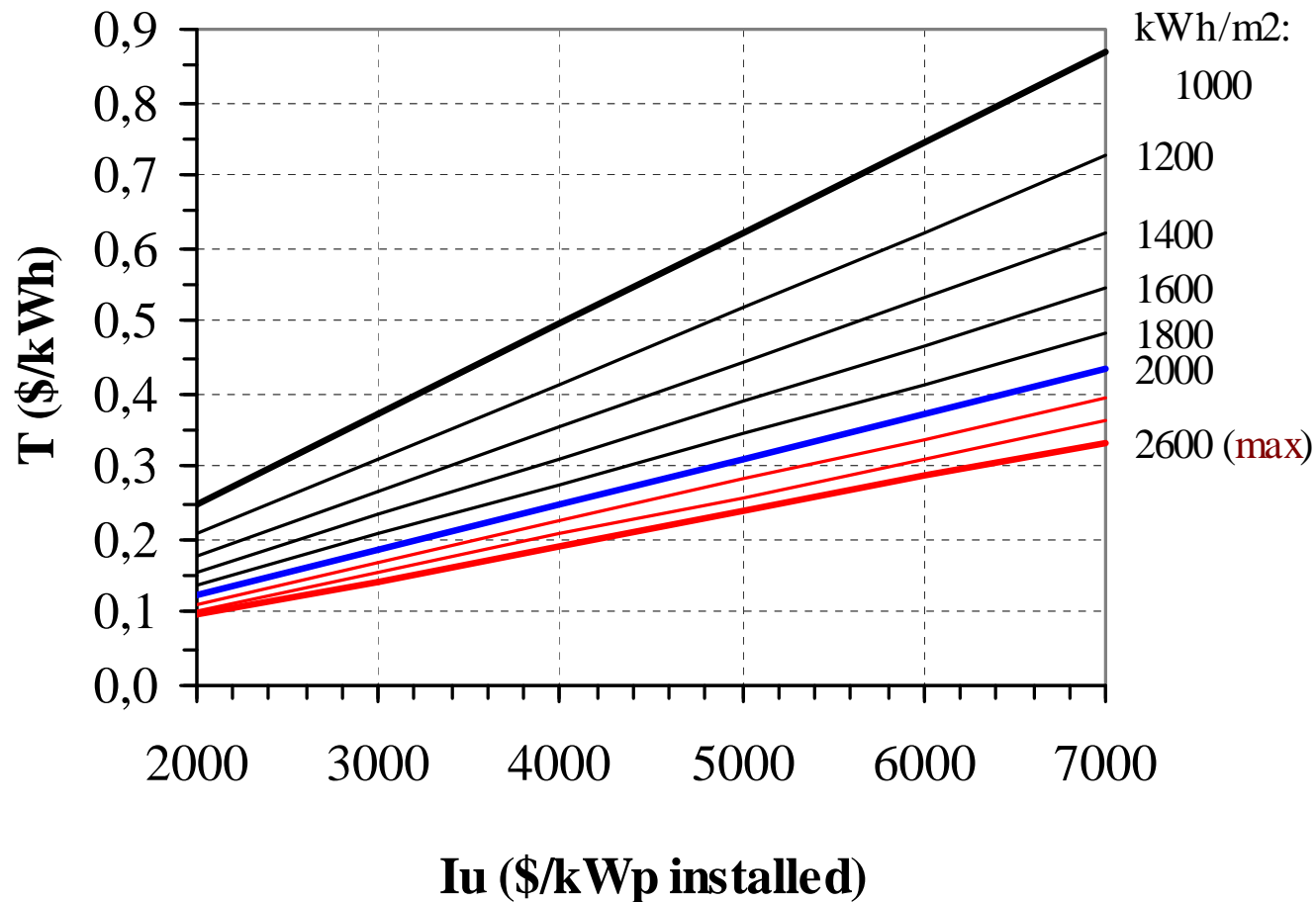
⇒ DK: bonus 1.3 to
4.6 cE/kWh

⇒ Sp: 3 cE/kWh



Example 2: efficient tariffs for commercial PV

Efficient tariffs of the kWh from on grid PV ; PI = 0,3
t=5 %, n=20 years, Kom=2 %, Kp=0,75, IRR=8,3 %, PBT=13,4 y.



Example 3: “Advanced tariffs” for Wind Power

❑ **Taking into account return of experience and context:**

⇒ Competitive calls for tenders (e. g. “EOLE 2005”)

→ Not enough efficient for new French Wind Energy goals: from 5 up to 11 GW installed in 2010 (within the EU RE electricity Directive)

→ Feb. 2000 French electric law: the only solution for projects > 12 MW

⇒ Green certificates: not proven, not sufficient for 5 to 11 GW

⇒ “Fixed Tariffs”: past and ongoing successes (Dk, G, Sp...)

❑ **Basis: fair profitability for private investors:**

⇒ Minimum profitability for strong market growth, including on low quality sites largely available (from $N_h = 2\,000$ h/y)

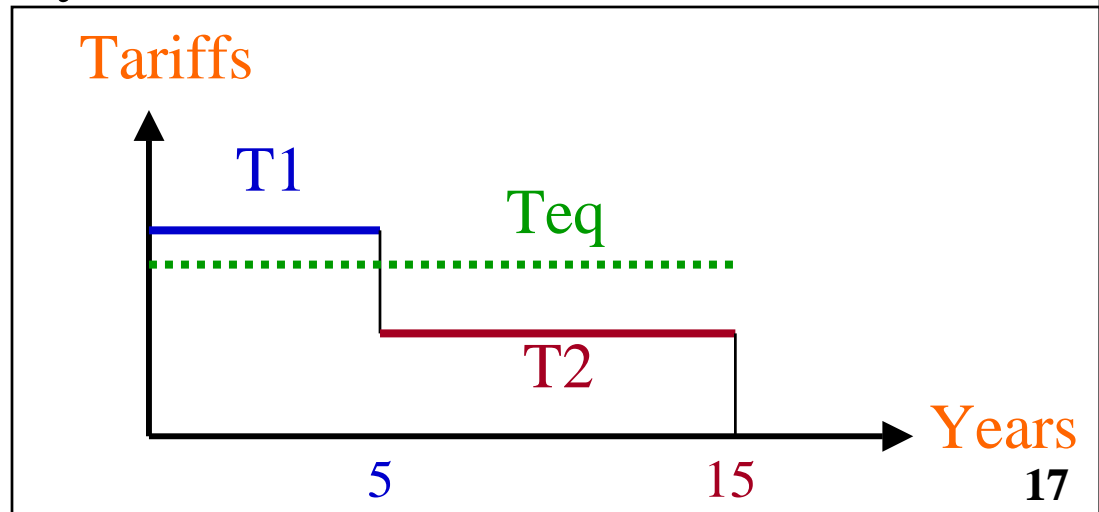
⇒ No undue profits on high quality sites: tariffs adapted to potential energy yields

⇒ Simple system, easy to define, to control and to adapt

⇒ Not state aid: charging the cost on all electricity consumers

Principles for Tariffs Definition and Calculation

- ❑ **Two successive tariffs levels (F: only for P < 12 MW):**
 - ⇒ T1 fixed for all projects from years 1 to 5 (= German idea !)
 - ⇒ T2 variable for projects from years 6 to 15 (diff. From Ger.)
 - ⇒ T1 and T2 define a constant “equivalent tariff”, T_{eq}
 - ⇒ Ref. N_{hmin} : $PI = P_{Imin} \Rightarrow T_{eqmax} = T2_{max} \Rightarrow T1 = T2_{max}$
 - ⇒ Ref. N_{hmax} : $PI = P_{I_{max}} > P_{Imin} \Rightarrow T2_{min}$
- ❑ **For a specific project (P < 12 MW):**
 - ⇒ N_h from average values years 1 to 5
 - ⇒ T2: linear calculation
 - ⇒ T_{eq} from (T1, T2, t)
 - ⇒ PI from T_{eq} , N_h , I_u
- ❑ **Reference values:**
 - ⇒ $I_u = 1067$ EURO/kW
 - ⇒ $K_{om} = 4\%$, $t = 6.5\%$

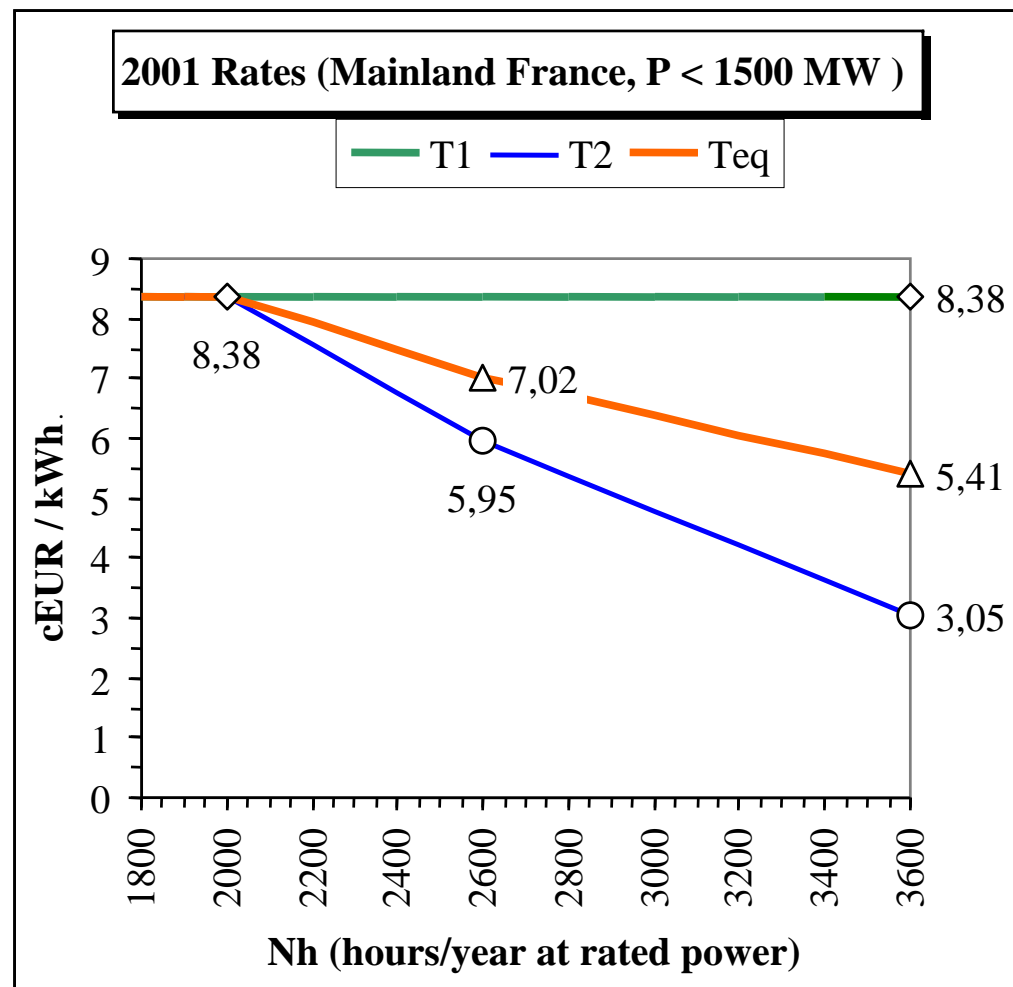


Other Principles and Final “Details”

- ❑ **Large diff. N_{hmin} - N_{hmax} \implies N_{hint} and two R2 lines**
- ❑ **protection of tariffs within a specific contract:**
 - \Rightarrow No perfect \implies decrease of profitability with inflation rate
- ❑ **Reference N_h value: average on 3 years (5 -worst-best)**
- ❑ **T2 values for years 6-10 & 11-15:**
 - \Rightarrow Less 25% for kWh beyond ($N_{href} \times 5$)
- ❑ **Provisional reference I_u decrease for next years:**
 - \Rightarrow -3.3 % per year from 2002 (current EUROS)
 - \Rightarrow Formula for correction from inflation from 2003+
- ❑ **Two sets for N_h reference values:**
 - \Rightarrow “Favourable” till sums of signed contracts is under 1.5 GW
 - \Rightarrow “Less favourable” after 1.5 GW of signed contracts

Results: June 8th 2001 Arrêté, 2001 Tariffs

Reference values for 2001 tariffs					
Mainland France, projects < 12 MW					
Nh:	P (MW)	P (MW)	cEURO / kWh		
			T1	T2	Teq
Nhmin:	2000	1900	8,38	8,38	8,38
Nhint:	2600	2400	8,38	5,95	7,02
Nhmax:	3600	3300	8,38	3,05	5,41
Corsica & Overseas Depart. projects <12 MW					
Nh:	P (MW)	P (MW)	cEURO / kWh		
			T1	T2	Teq
Nhmin:	2050		9,15	9,15	9,15
Nhint:	2400		9,15	7,47	8,21
Nhmax:	3300		9,15	4,57	6,59

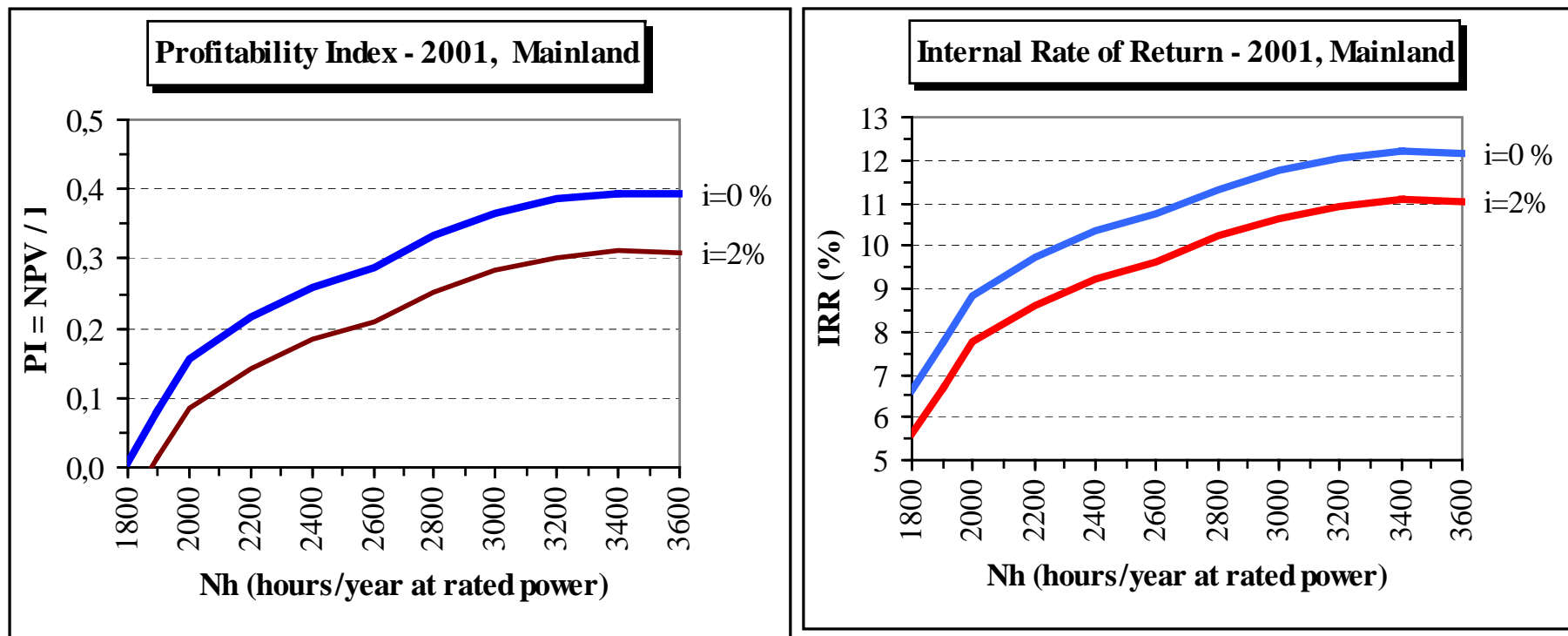


□ Hypothesis for Teq:

⇒ Real discount rate $t = 6.5\%$

⇒ $n = 15$ years

Results: 2001 projects profitability (Mainland)



□ Reference case (P < 12 MW per project):

⇒ $I_u = 1067$ EUR/kW. Value at year 16: 15% of initial invest.

⇒ Yearly O&M expenses: $K_{om} = 4\%$ of initial investment

⇒ Mean inflation rate 2001 - 2015: $i = 0\%$ or $i = 2\%$ / year

Adaptation, Control, Monitoring

□ Possibility to easily adapt reference values:

⇒ From wind atlas and GW goals:

→ Nh min, Nh max: minimum and maximum quality of sites

⇒ From economic and fiscal context:

→ PI min and PI max (increased profitability with energy yield)

⇒ e. g. in France: Corsica and overseas departments

□ Control: is “fraud” on Nh on years 1-5 profitable ??

⇒ Increase of profitability with Nh: incentive to good yields

⇒ Discounting: advantages to first years cash-flows (CFs)

⇒ Maximum debt years 1 to 5-7: need to maximise first CFs

□ Monitoring:

⇒ Actual Iu, Kom, Nh (versus Ws), economic profitability

Potential Consequences

□ Potential consequences:

- ⇒ 7 to 10 GW in 2010 (compared to 3 GW goal in jan. 2000)
- ⇒ Easier to achieve than with only competitive calls for tenders and/or green certificates (not excluded for $P > 12$ MW)
- ⇒ Attention to be given to projects planning, grid connection, public acceptance, “popular involvement” in wind projects

□ $P > 12$ MW: future calls for tenders from CRE (12/2003)

□ Over-cost estimation for a 9 GW goal:

- ⇒ Charged over all electricity consumers (contribution to a specific fund for all electricity public services charges)
- ⇒ For 9 GW in 1/1/2010 (total 2001-2025: 325 TWh)
 - ➔ Total < 5 bEUR (discount rate: 5%, avoided cost 4,1 cEURO/kWh)
 - ➔ Maximum in 2017: < 1cF/kWh (<0.15 cEURO/kWh)

Adapting the French Wind Power Tariff System

❑ **Some Improvements are possible:**

⇒ Replace the energy yield ratio Nh (kWh/kW.year) by Eas (kWh/m².year)

→ See the rationale in the Chabot-Kellet-Saulnier paper at Global Wind Power Conference, Paris, April 2002

→ Gives less "temptations" to "manipulate" the P/S ratio of the wind turbines

⇒ Avoid the sharp step from "favourable conditions before 1,5 GW of contracts" to "less favourable ones after 1,5 GW"

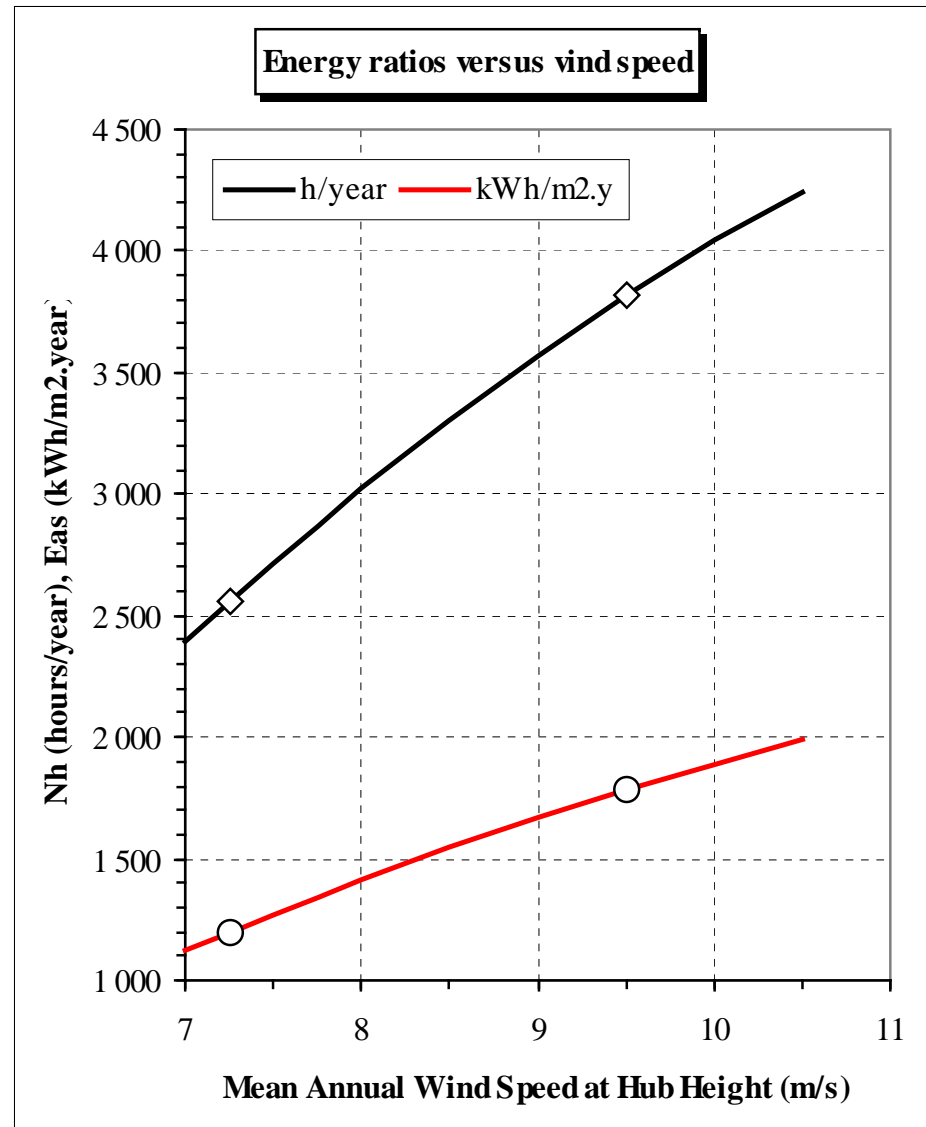
⇒ Get a better protection of the tariff within a contract from the effect of inflation (eg 80% of the tariff protected instead of only 60 % in France or 0 % in Germany)

❑ **Case studies in the case of an "European Windy Country": Ireland**

The ADEME / SEI "Kinsale 2002 Tariffs" test

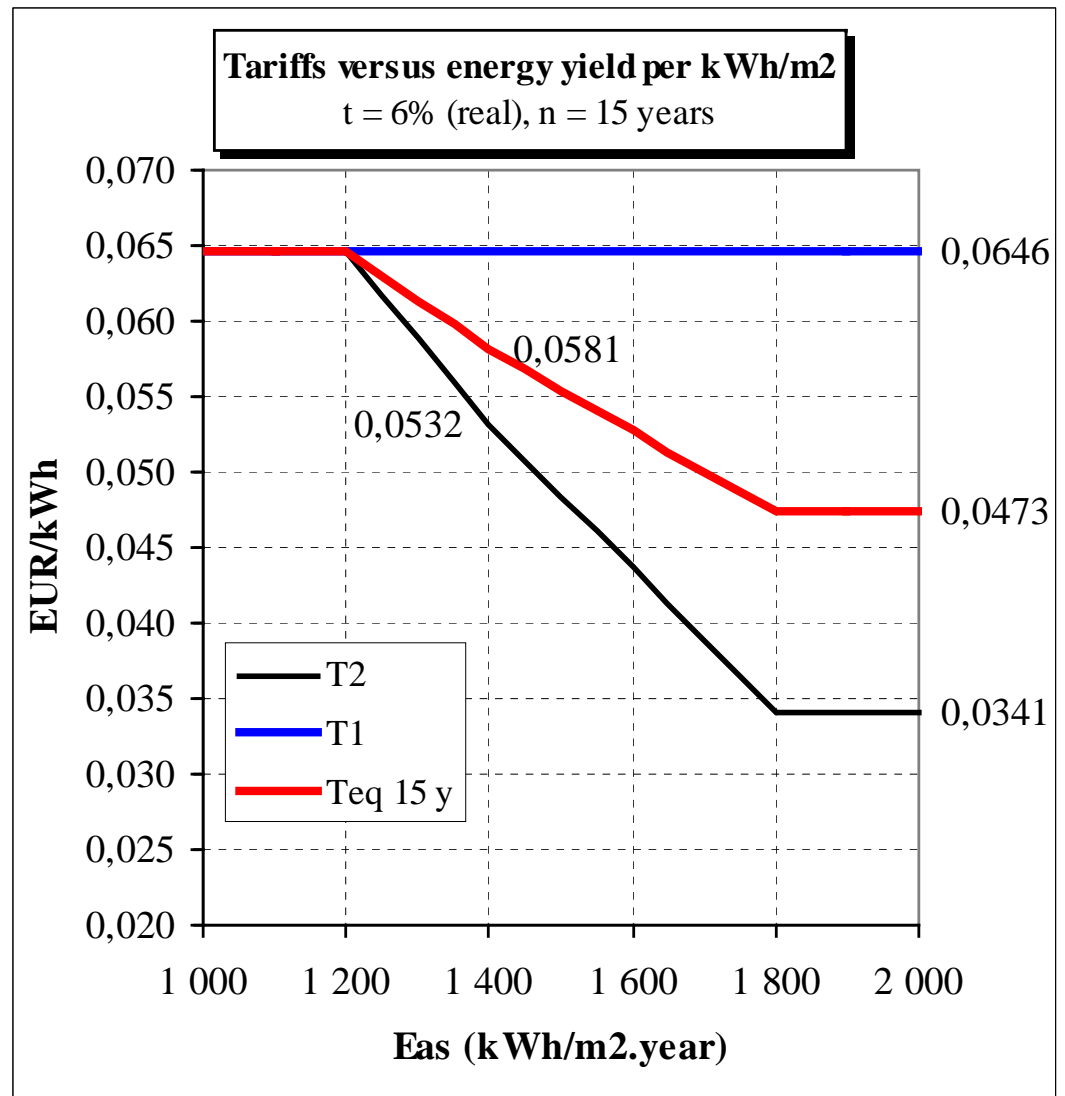
- ❑ **Not "The solution", only an illustration of the method**
- ❑ **Based on the *Eas* energy yield (kWh/m².year)**
 - ⇒ *Eas min* = 1200 kWh/m².y (around 7.3 m/s at hub height, equivalent to $Nh = 2600$ h/y for a 460 W/m² wind turbine, or equivalent to an average annual capacity factor $ACF = 30$ %)
 - ⇒ *Eas max* = 1800 kWh/m².y (around 9.5 m/s at hub height, equivalent to $Nh = 3600$ h/y or $ACF = 41$ %)
 - ⇒ An intermediate *Eas* = 1400 kWh/m².year ($Nh = 3000$ h/y)
- ❑ **Calculation based on:**
 - ⇒ Real averaged weighted cost of capital = discount rate $t = 6$ %
 - ⇒ Purchase contracts on $n1 = 15$ years or $n2 = 20$ years
 - ⇒ Investment cost ratio: *Ius* = 468 EUR/m² of swept area (*Iup* = 1000 EUR/kW for a WT with $Ps = 468$ W/m²)
 - ⇒ O&M expenses ratio: *Kom* = 4 % of investment, per year

Example of energy yields versus wind speed



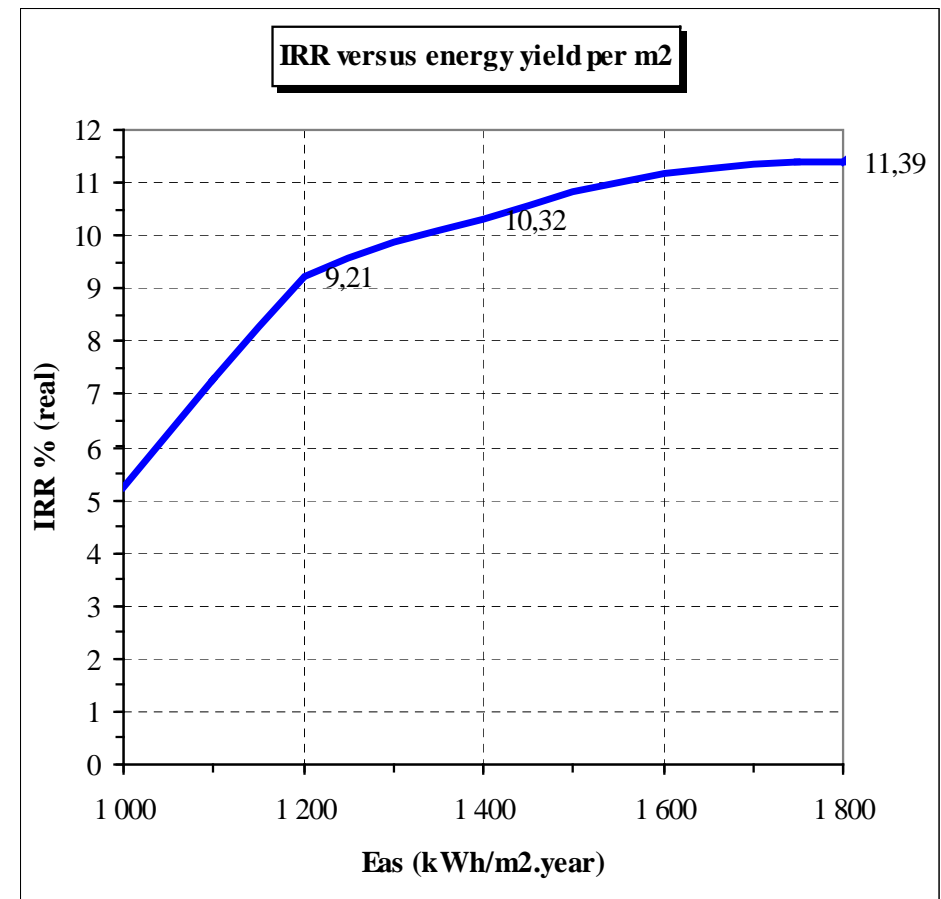
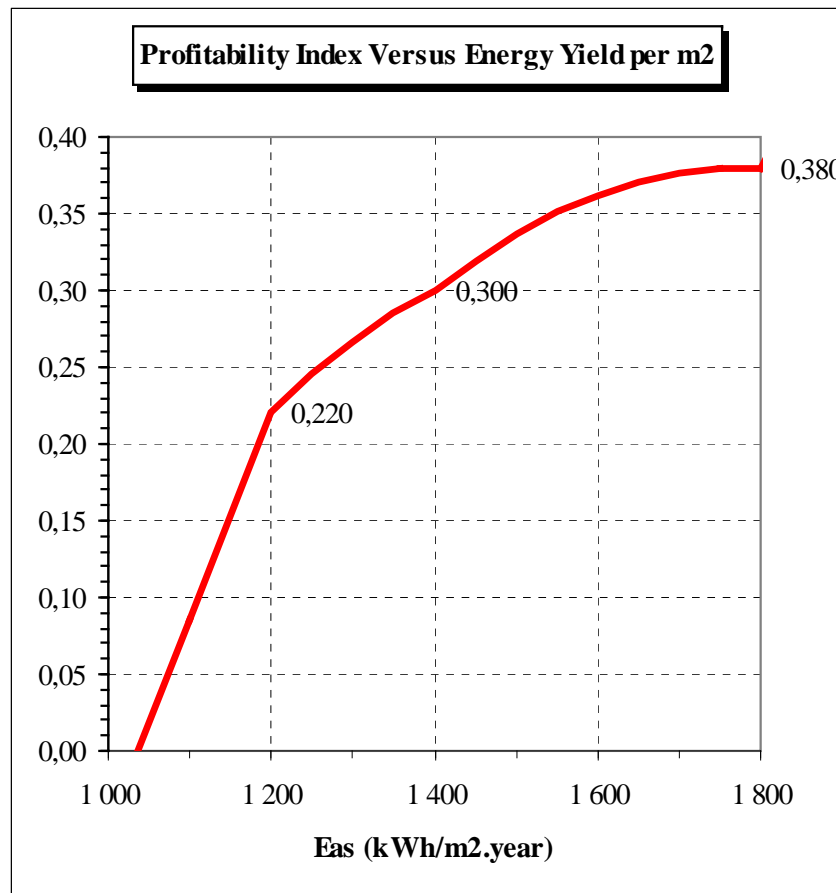
Results for purchase contracts on 15 years

- ❑ **T1 from year 1 to 5**
- ❑ **T2 from year 6 to 15**
- ❑ **Teq calculated from**
 - ⇒ T1,
 - ⇒ T2
 - ⇒ t (AWCC, different for each investor, here t = 6%)
- ❑ **For Eas < or = 1200:**
T1=T2=Teq

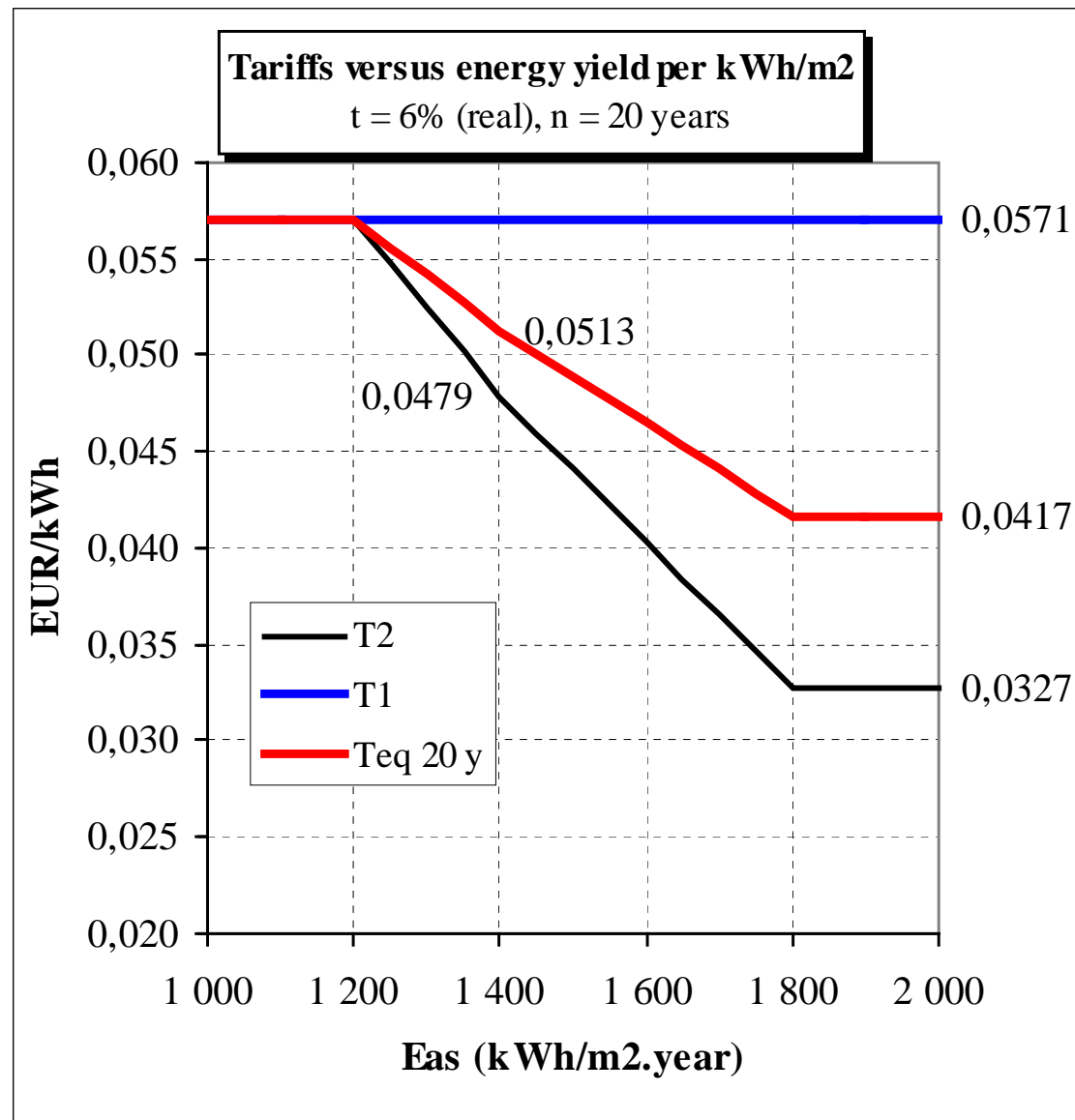


Profitability results for 15 years contracts

- ❑ Profitability increases with Eas (to lower over-costs)
- ❑ PI from 0.22 to 0.38 ; IRR from 9.2% to 11.4 %

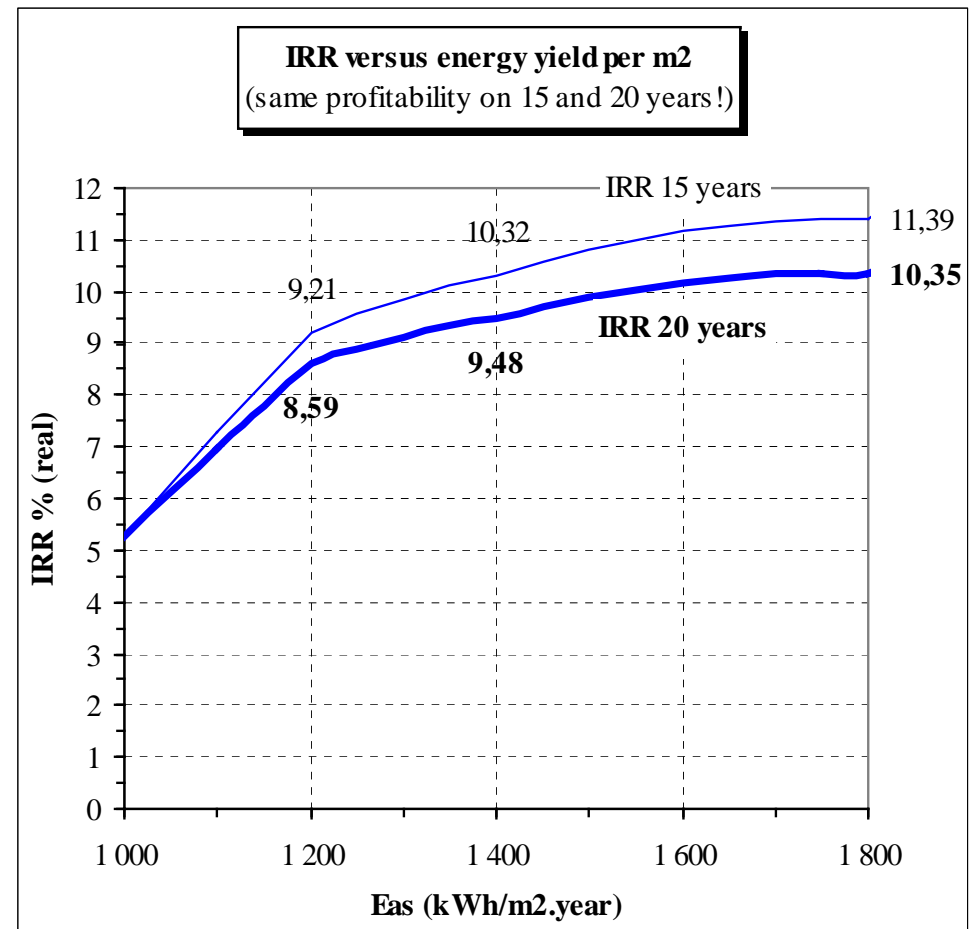
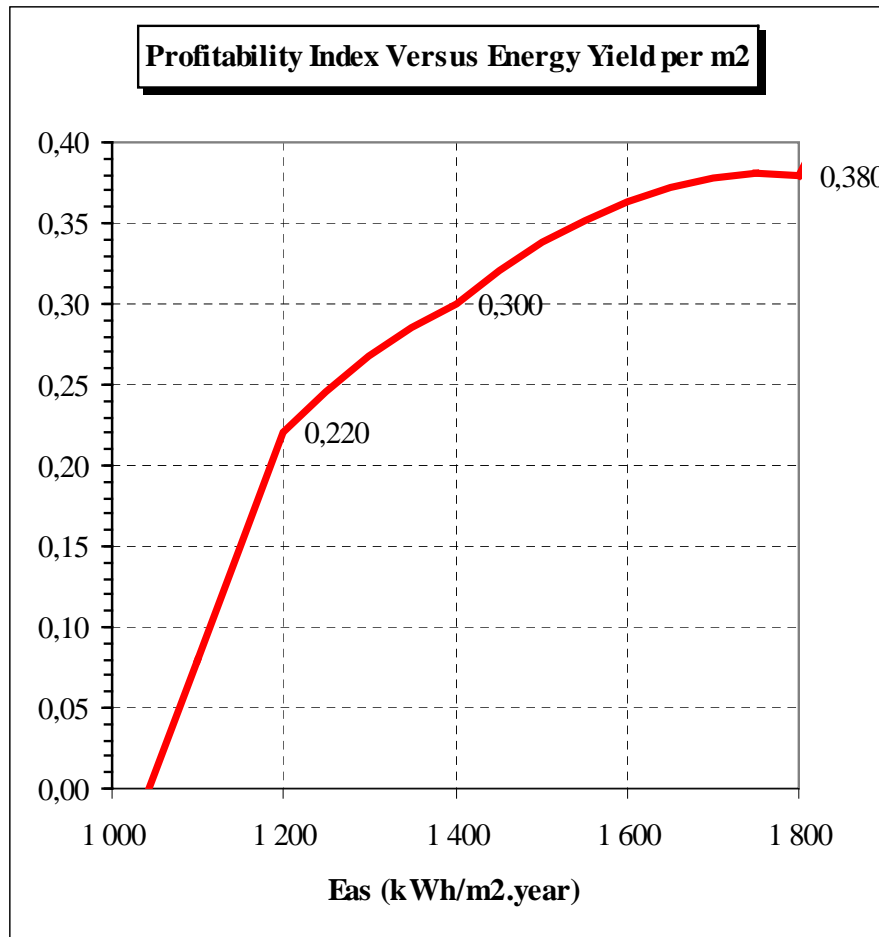


Results for purchase contracts on 20 years

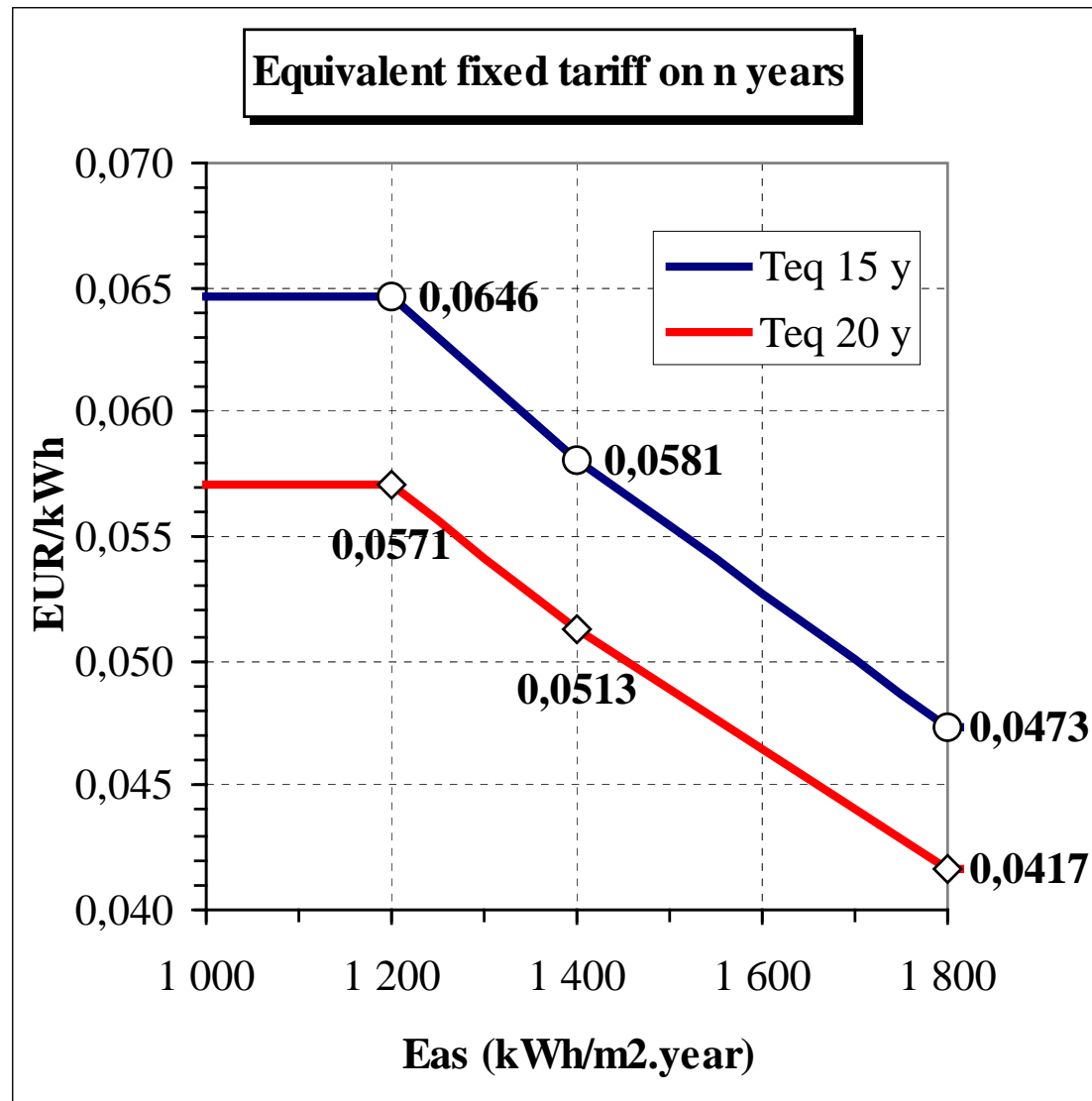


Profitability results for 20 years contracts

- Same hypothesis for PI values ==> same profitability



Comparison of tariffs on 15 or on 20 years



Synthesis of numerical values

- ❑ Values are for $I_u = 1000 \text{ EUR/kW}$, $t = 6 \%$, $Kom 4\%$
- ❑ To be tested with precise Irish data (t , I_u , Kom values) !

Reference energy yield				Tariffs for contracts on 15 years (cEUR/kWh)				
V	Eas	Nh	Fc	T1	T2	Teq	PI	IRR
m/s	kWh/m ² .y	h/year	%	cEUR	cEUR	cEUR		%
app 7,3	1200	2600	30%	6,46	6,46	6,46	0,22	9,2
app 8	1400	3000	34%	6,46	5,32	5,81	0,3	10,3
app 9,5	1800	3600	41%	6,46	3,41	4,73	0,38	11,4

Reference energy yield		Tariffs for contracts on 20 years (cEUR/kWh)					
	Eas	T1	T2	Teq	PI	IRR	
	kWh/m ² .y	cEUR	cEUR	cEUR		%	
		1200	5,71	5,71	5,71	0,22	8,6
		1400	5,71	4,79	5,13	0,3	9,5
		1800	5,71	3,27	4,17	0,38	10,4

Conclusions

❑ **Defining a fair and efficient tariff system was possible**

- ⇒ Taking into account other “success stories” (Dk, G, Sp)
- ⇒ Within a deregulated electricity market ("advanced tariffs")

❑ **The Profitability Index Method gives:**

- ⇒ A rational basis for minimum values of profitability
- ⇒ Simple formulas to define, monitor, adapt the tariff system

❑ **Positive market answer in France after 2001 wind tariffs**

- ⇒ 14 GW of files (P < 12 MW), 7 to 10 to be built before 2010
- ⇒ Over-cost should not be over the ones from 7 to 10 GW by other ways

❑ **Light case study for the Irish wind context shows that:**

- ⇒ Adaptation of advanced tariffs systems is easy
- ⇒ Due to good winds, tariffs should be lower than in Germany & France

❑ **Ademe is open to collaborate with other EU RE agencies**

- ⇒ Exchange of information and experience
- ⇒ Also in view of the EC report on best regulation for RE dissemination