ESCWA / AUE / NEPCO

Capacity Building Workshop

Integration of RES in the Transmission and Distribution Networks in the Arab Region

The role of regulatory authorities in the integration of RES into the networks

Amman, Jordan, 2 Sep 2015

Ernesto Bonafé
Regulatory Expert
Energy Charter Secretariat

Outline

- Liberalisation and regulatory authorities
- RES integration in the Arab region
- RES integration in the EU

Liberalisation

- Authorisation regime
- Unbundling – functional/legal/ownership
- TPA – negotiated/regulated
- Liberalisation – partial/full
- Consumer protection
- Regional integration

NRA

- Designation and Independence
- General objectives
- Competences
- Enforcement
- Accountability
- Regional cooperation

NRA independence

- Legal framework
- Independence of the board
- Sufficient human and financial resources
- Judicial review

NRA competences

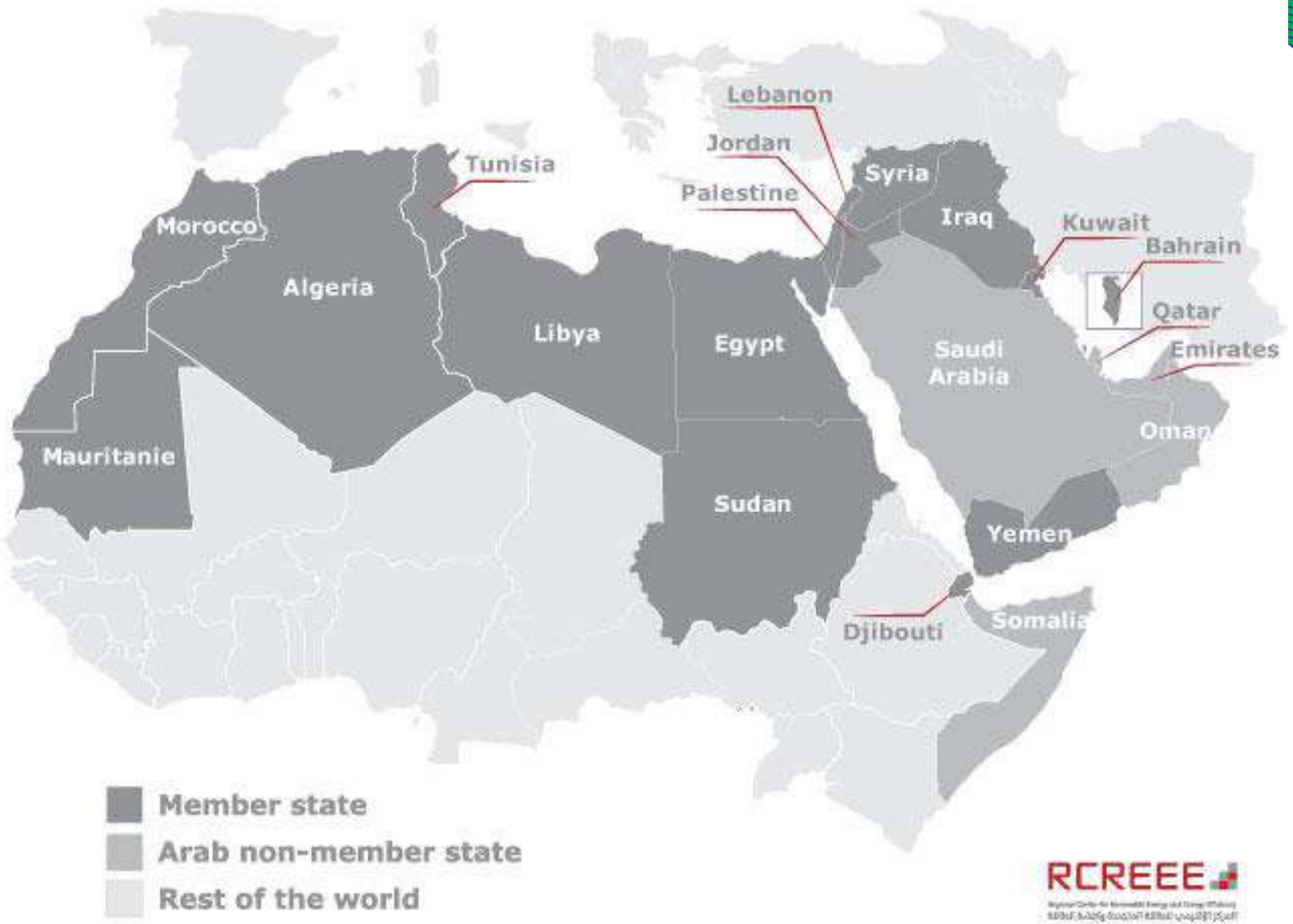
- Tariff setting
- Networks rules and standards
- Market monitoring
- Access to information
- Consumer protection
- Unbundling
- Environmental sustainability

RES benefits

- Reducing dependence on imports
- Long term energy security
- Meeting growing energy demand
- Market competition
- Climate change
- Rural electrification
- Industrial development

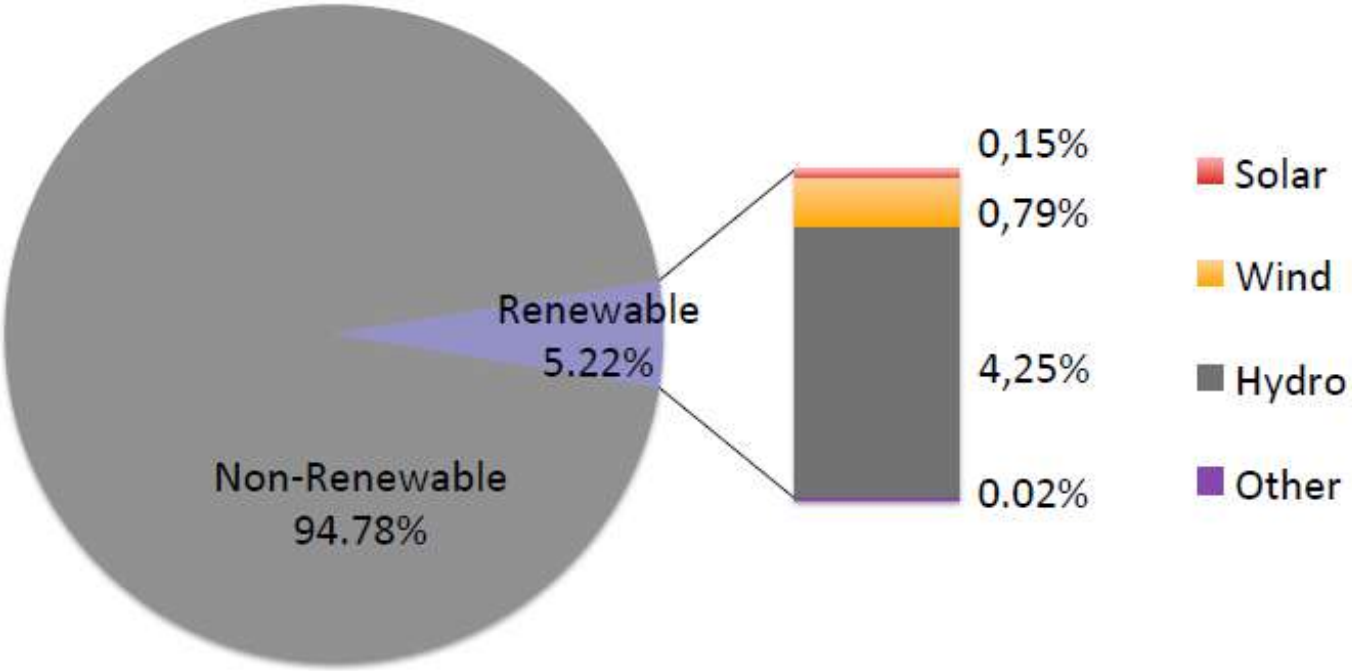
RES promotion

- Legislative framework
- Regulator
- National targets
- Promotion mechanisms
- Market access
- Tracking electricity


Lebanon
Jordan
Palestine
Syria
Tunisia
Iraq
Kuwait
Bahrain
Morocco
Algeria
Libya
Egypt
Qatar
Saudi Arabia
Emirates
Oman
Mauritanie
Sudan
Yemen
Djibouti
Somalia
Member state
Arab non-member state
Rest of the world

RCREEE

Renewable Energy Installed Capacity, 2014



Targets – *North Africa*

Algeria: 6% generation (2015); 15% (2020); 40% (2030)

Libya: 3% generation (2015); 7% (2020); 10% (2025)

Morocco: 42% installed power generation by 2020

Tunisia: 11% generation (2016); 25% (2030)

Targets - *East Mediterranean*

Egypt: 20% generation (2020) - 12% wind

Israel: 5% generation (2014); 10% (2020)

Jordan: 7% primary energy (2015); 10% (2020)

Lebanon: 12% electrical and thermal energy (2020)

Palestine: 25% energy from RES (2020)- 10% of electricity

Targets – *The Gulf States*

Bahrain: 5% (2020)

Iraq: 2% generation (2016)

Kuwait: 5% generation (2015); 10% (2020)

Oman: 10% generation (2020)

Qatar: 2% generation solar (2020)

Saudi Arabia: 50% electricity non-hydrocarbon (2032)

54 GW RES, 17 GW nuclear

UAE: Dubai: 5% electricity (2030);

Abu Dhabi: 7% generation capacity (2020)

Yemen: 15% generation (2025)

2015 RCREEE Arab Future Energy Index

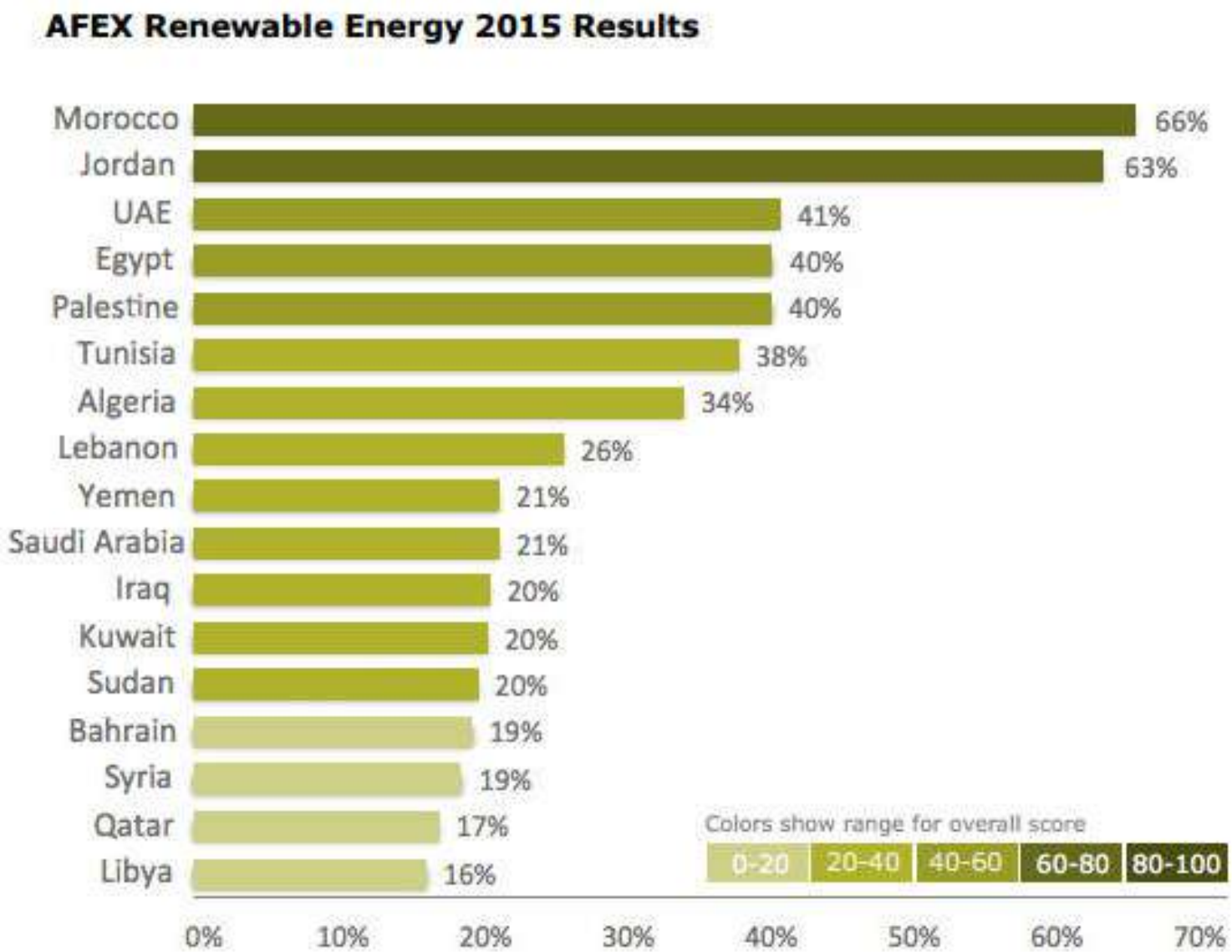


Table 1: AFEX Renewable Energy Conceptual Framework

Category	Factors	Indicator	Score/Measuring Unit
Market Structure	Independent Power Producers	Utility Suppliers	Utility supply authorized by law. Utility suppliers exist in practice. Utility suppliers of RE exist in practice.
		Third-party Suppliers	RE third-party supply is authorized by law. RE third-party suppliers exist in practice.
		Direct Export	Direct export of RE authorized by law. Direct exporters of RE exist in practice.
	Grid Access	Guaranteed Access to Grid	Priority access guaranteed by law. Priority access guaranteed in practice. Priority dispatch guaranteed by law. Priority dispatch guaranteed in practice.
		Grid Code for RE	Technical guidelines to connect distributed smaler PV systems to low-voltage grid adopted. Technical guidelines to connect utility-scale PV systems to medium- and high-voltage grids adopted. Technical guidelines to connect wind parks to medium and high-voltage grids adopted.
Policy Framework	RE Commitment	RE Targets	RE targets are officially adopted as part of RE strategy or action plan by higher political authorities. RE targets are formulated, but not officially adopted yet by higher political authorities or scattered in various documents. No targets are adopted.
		RE Share Operational	Percentage of total installed capacity (MW).
		RE Projects under Construction	Percentage of total installed capacity (MW).
		RE Projects under Tendering	Percentage of total installed capacity (MW).
	Supporting Policies	IPP Public Competitive Bidding	Resources identified for private development. Tenders announced. PPA signed (MW).
		Direct Proposal Submission	Policy adopted by law. Proposals selected for private development. PPA signed (MW).
		Feed-in Tariffs	Officially adopted. RE projects implemented through feed-in tariffs (MW installed).
		Net Metering	Officially adopted. RE projects implemented through net metering scheme (MW).
	Energy Subsidies	Electricity Subsidies Residential	Percentage of Palestinian residential retail prices (benchmark).
		Electricity Subsidies Commercial	Percentage of Palestinian commercial retail prices (benchmark).
		Electricity Subsidies Industrial	Percentage of Palestinian industrial retail prices (benchmark).

2015 RCREEE Arab Future Energy Index

Institutional Capacity	RE Institutions	Independent Regulator	Established by law or similar sovereign act. Under establishment. Not considered yet.
		RE Agency	Established by law. Under establishment. Non-existent.
		Capacity of RE institutions	Expert assessment from 1 to 10.
	Project Support	Resource Quality Assessment	Detailed wind atlas published and available to public. Detailed solar atlas published and available to public.
		Land Access	Land allocated for private development of large-scale wind projects. Land allocated for private development of large-scale solar projects.
		Project Lead Time	
	Governance Quality	World Bank Ease of Doing Business Index	Rank under World Bank Ease of Doing Business Index.
		Global Competitiveness Index	GCI scores.
		Bertelsmann Stiftung's BTI Status Index	BTI Status Index scores.
Finance and Investment	Financial Support	Fiscal Incentives	Number of fiscal incentives for RE projects.
		RE Fund	RE fund established by law; sources of financing are clearly defined; disbursement procedure is clearly defined; RE fund has collected and disbursed funds.
	RE Investment Growth	Share of Private Investment	Percentage of total installed capacity.
		Growth Rate of Private Investment	Percentage increase in installed capacity of RE.

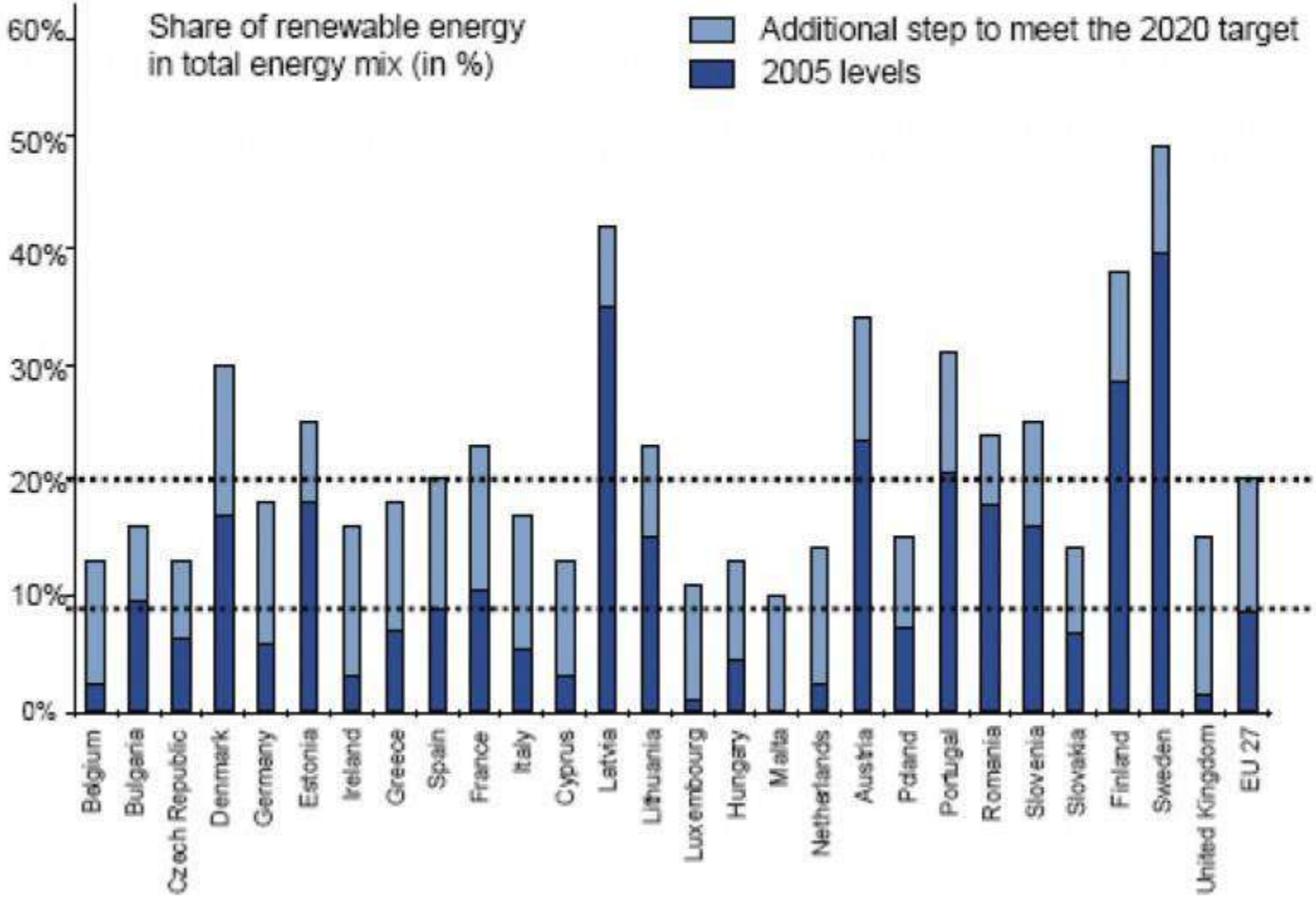
RES integration

	Final Score	Market Structure	Policy Framework	Institutional Capacity	Finance and Investment
Morocco	66	48	66	62	87
Jordan	63	51	68	58	77
UAE	41	28	38	58	40
Egypt	41	43	43	50	26
Palestine	40	29	60	49	24
Tunisia	38	23	46	46	37
Algeria	34	36	29	39	33
Lebanon	26	11	33	36	23
Yemen	21	12	33	29	12
Saudi Arabia	21	12	23	39	10
Iraq	21	17	24	26	16
Kuwait	20	12	16	44	10
Sudan	20	12	21	29	16
Bahrain	19	12	11	31	23
Syria	19	16	20	29	10
Qatar	17	12	17	30	10
Libya	16	10	20	24	10

Some conclusions (RCREEE)

- Egypt, Jordan and Tunisia implemented energy subsidy reforms in the electricity. Along with Morocco, Sudan and Yemen all six increased prices of oil products.
- More than 2,500 MW of renewable energy projects under construction. 2,500 MW under tendering.
- Tunisia and Jordan implemented net metering and installed more than 30 MW of distributed generation.
- Morocco and UAE advanced in their IPP public competitive bidding of large-scale solar projects.

EU Energy and Climate Policy 2020



EU 2020

EU 2005

2015 European Commission RES Report

25 EU countries to meet 2013/2014 interim targets

In 2014 share of RES in the gross final consumption 15%

2020 RES target – 326Mt avoided CO2 (2012) and 388 (2013)

Reduction EU demand for fossil fuels 116 Mtoe (2013)

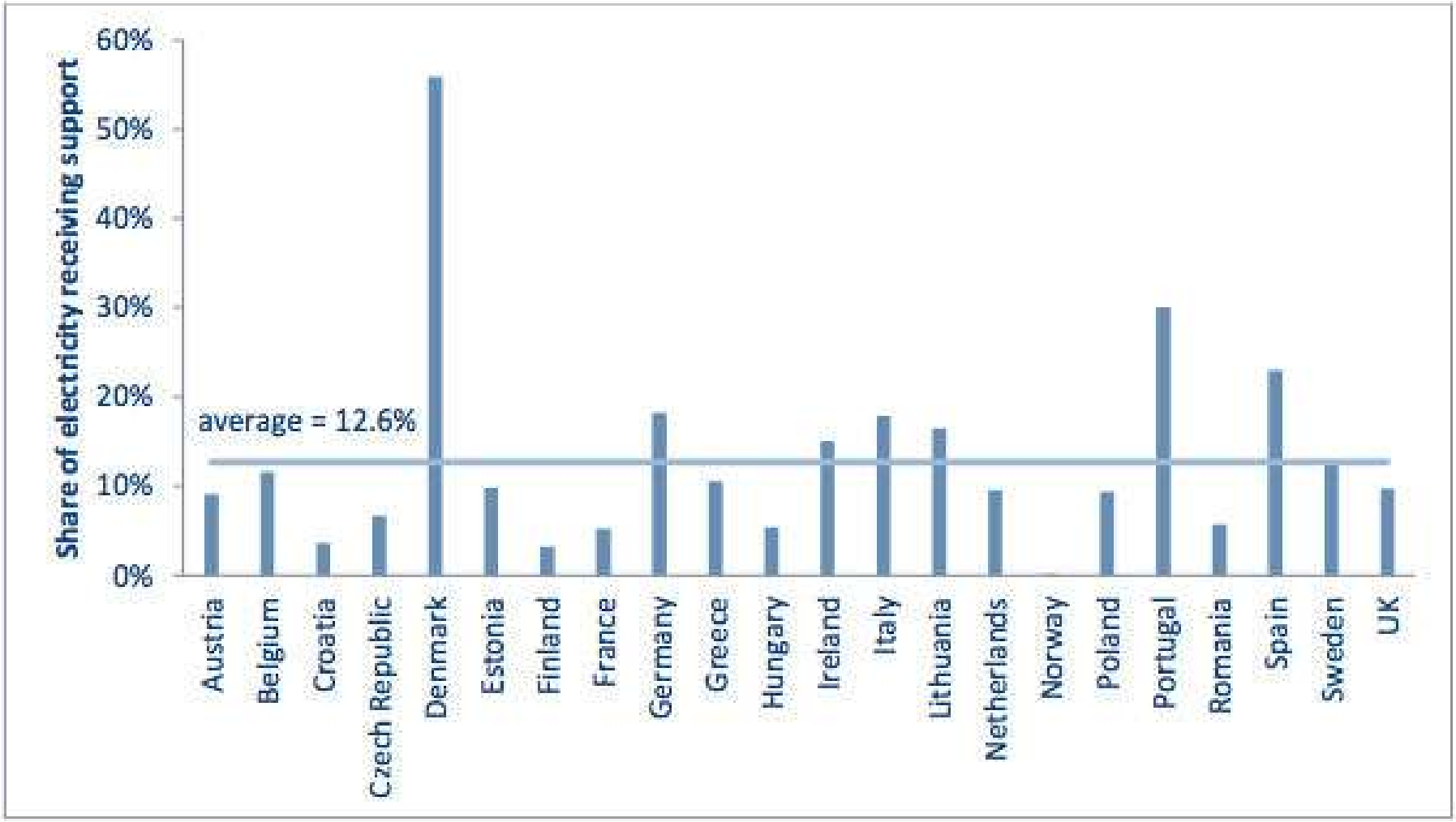
2014 share of RES in transport is 5.7% (2020 target feasible)

2015 CEER Status Review RES

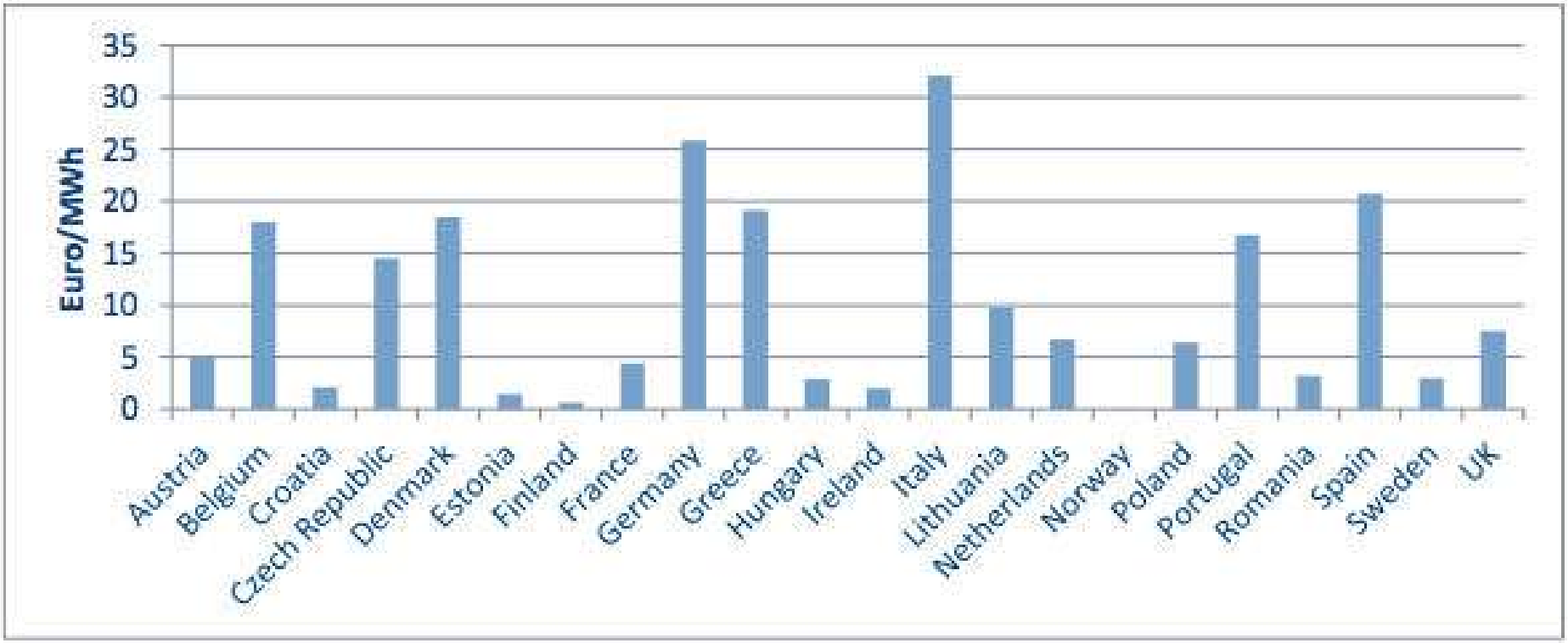
- Electricity volumes receiving RES support
- Expenditure on RES support schemes
- Market integration

Share of total electricity produced receiving RES support (2012)

CEER Status Review of Renewable and Energy Efficiency Support Schemes



RES-electricity support per unit of gross electricity produced (2012)



Weighted average support level by technology (€/MWh) 2013

	Bioenergy	Geo-thermal	Hydro	Other	Solar	Wind - onshore	Wind - offshore	Total
Minimum support	10.56	17.54	6.27	8.42	10.56	10.56	44.80	10.56
Maximum support	147.25	201.31	96.12	113.30	448.04	84.27	135.50	194.51
Weighted average across 21 countries								110.65[36]

Market integration

- RES electricity channels to market: same as non-RES or through suppliers or system operators

- Financial responsibility for imbalances: as non-RES, or more flexible, e.g. offshore wind, only hydro >10 MW…

- RES connection non-discriminatory and granted priority or guaranteed access and priority dispatching

- Charges when connecting and using the grid (generators pay or generators and operators share the costs)

Shortcomings

- National schemes hinder market integration and reduce cost-efficiency
- Affects competitiveness of other energy sources (i.e. backup)
- RES benefits to be exploited in a market-driven way

EU Climate and Energy Framework 2030

40% GHG – main target, should encourage other targets

27% RES – EU target, greater flexibility nationally

27% Savings

New governance – national plans for competitive, secure and sustainable energy

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Thank you!

ernesto.bonafe@encharter.org

فرص و تحديات و معوقات التكامل بين مصادر الطاقة المتجددة و الشبكات الكهربائية

Economic And Social Commission For Western Asia

ورشة العمل التدريبية حول

تكامل الطاقات المتجددة مع شبكات النقل و التوزيع في المنطقة العربية

الدكتور المهندس وليد الدغيلي

استشاري الاسكوا

UNITED NATIONS

الاسكوا

ESCWA

عمان/الأردن 2 و3 أيلول/سبتمبر 2015

المحتويات

مقدمة

أولاً- امكانات الدول العربية و فرصها في الاستفادة من الطاقة المتجددة لانتاج الكهرباء

ثانياً- قواعد تجهيز وادارة الأنتاج على الشبكات الكهربائية

ثالثاً- أشكاليات و تحديات تغذية الشبكات الكهربائية بالطاقة المنتجة من الطاقة الشمسية و طاقة الرياح

خلاصة

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-1- مقدمة

@الطاقة ضرورية للبشرية منذ القدم / حاجة المستهلك النهائي الى:

--- الطاقة الحرارية و الطاقة الضوئية:الأضاءة :

-------الطاقة الشمسية الحرارية-عمليات احتراق الوقود : الفحم النباتي و الكتلة الأحيائية

--- الطاقة الميكانيكية: طاقة الرياح-الطاقة المائية

محركات الأحتراق الداخلي و العنفات

@حصلت الثورة الصناعية عبر الأعتماد على الطاقة الكامنة في البخار المنتج بأستعمال الفحم الحجري

@بعد الطاقة الحرارية و الطاقة الميكانيكية ، جاءت الطاقة الكهربائية المنتجة من الطاقة المائية و الطاقة الحرارية كشكل أنبل: لسهولة النقل و التحويل و الأستهلاك

@النفط و الغاز(أمكانيات نقل و تخزين) أحدثا نقلة نوعية في أنتاج و استخدامات الطاقة الكهربائية

@خطر النضوب و أرتفاع الأسعار و أنقطاع الأمدادات

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-2- مقدمة

@الدول الصناعية استعانت بالطاقة النووية، لكن هناك تخوف من تكرار حوادث تشيرنوبيل

@التلوث و الهموم البيئية..... الأحترار العالمي و تغير المناخ والأنبعاثات...

@التنمية المستدامة/صراع البقاء /تقدم البشرية/....الخ/

@ أمن الطاقة ??

@أستدامة الطاقة؟

@الطاقات المتجددة: الطاقة المائية/ الطاقة الشمسية/ طاقة الرياح/ طاقة الكتلة الأحيائية..الخ

لا مركزية

لا تخزين - باستثناء حالة السدود و الخزانات-

@الطاقة الكهربائية قابلة للأستعمال و لأنتاج كافة أشكال الطاقة: الطاقة الحرارية الطاقة الميكانيكية.....

القرن 19 كان الفحم الحجري، القرن 20 كان النفط و الغاز،والآن القرن 21 للكهرباء

@خدمات الطاقة الحديثة عبر الكهرباء: احتمالان: مركزية أو لامركزية الأنتاج؟

الشبكة الموحدة او الشبكات المنعزلة ؟

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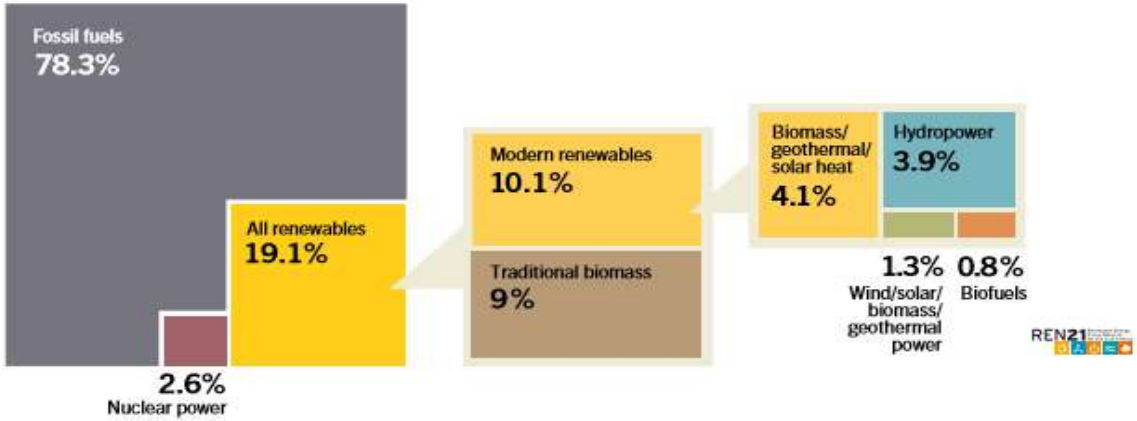
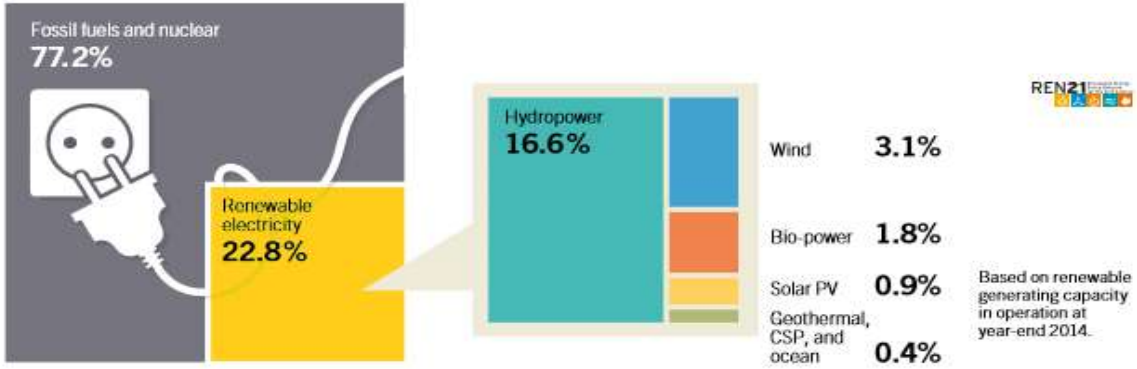
-3- مقدمة

Estimated Renewable Energy Share of Global Final Energy Consumption, 2013



Estimated Renewable Energy Share of Global Electricity Production, End-2014



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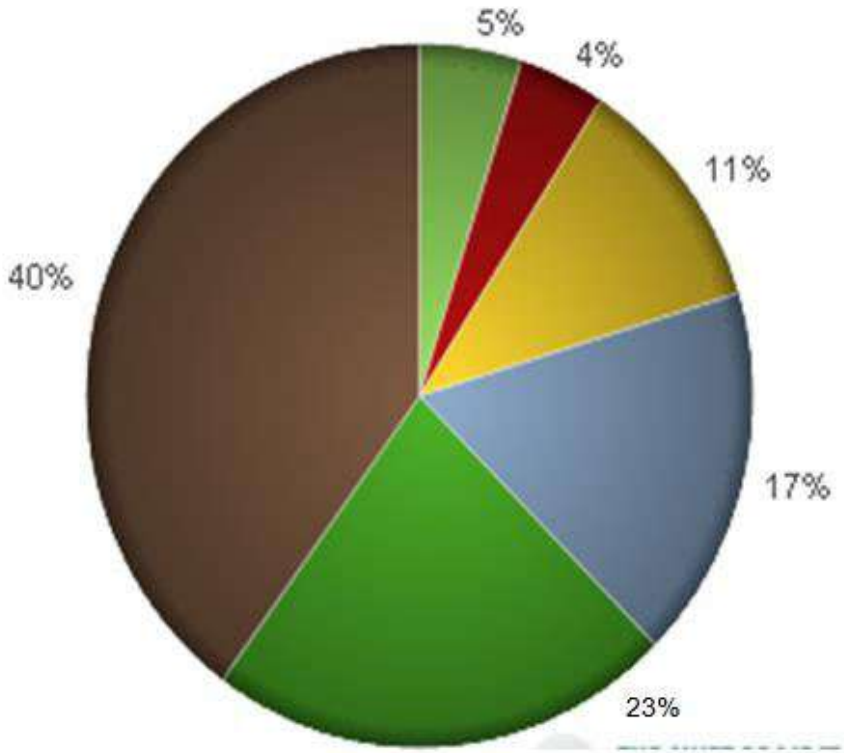
-4- مقدمة

World Electricity Production from All Energy Sources in 2012 (TWh)

Electricity Source	TWh
Others	1 042
Oil	879
Nuclear	2 344
Hydroelectric	3 619
Gas	4 744
Coal	8 390



Total = 21016 TWh

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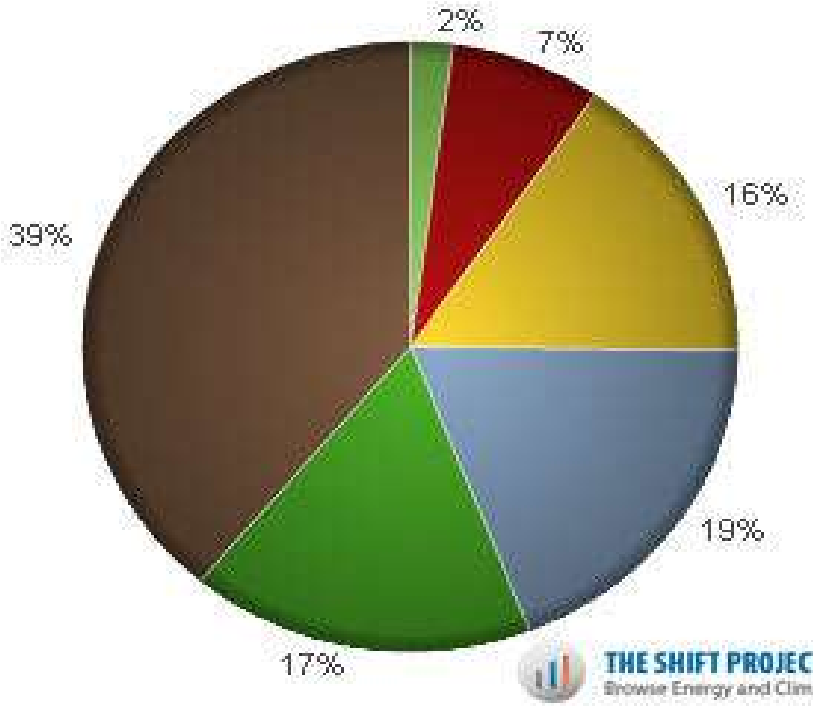
-5- مقدمة

World Electricity Production
from All Energy Sources from 1980 to 2012 (TWh)

Electricity Source	TWh
Others	9 089
Oil	32 093
Nuclear	67 539
Hydroelectric	81 597
Gas	73 545
Coal	167 989



Total = 431853 TWh

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مقدمة -6-

@في الدول العربية لم تتجاوز حصة الطاقة المتجددة في العام 2014 3.85٪ (2.97 طاقة مائية +0.5 طاقة شمسية + 0.36 طاقة رياح)

@أنتاج الطاقة الكهربائية من مصادر الطاقة المتجددة : مرحلة النضوج الفني والاقتصادي والاستثمار التجاري بكميات قابلة للتزايد مستقبلاً،- إضافة الى الطاقة المائية الاسبق تاريخياً-:

- طاقة الرياح:
- الطاقة الشمسية الحرارية المركزة CSP
- الطاقة الشمسية الضوئية: بالخلايا الكهرضوئية Photovoltaic cells "PV" العادية منها و المركزة CPV.

@إتساع نطاق الشبكات الكهربائية وتزايد قدراتها تم في ظروف مركزية انتاج الطاقة الكهربائية بواسطة منوبات متزامنة

@اعتماد مصادر الطاقة المتجددة لا سيما طاقة الرياح والطاقة الشمسية بنسب أكبر ، يفرض اعادة نظرو تطويراً في الاساليب والتقنيات، لتلافي الصعوبات وتجاوز العقبات

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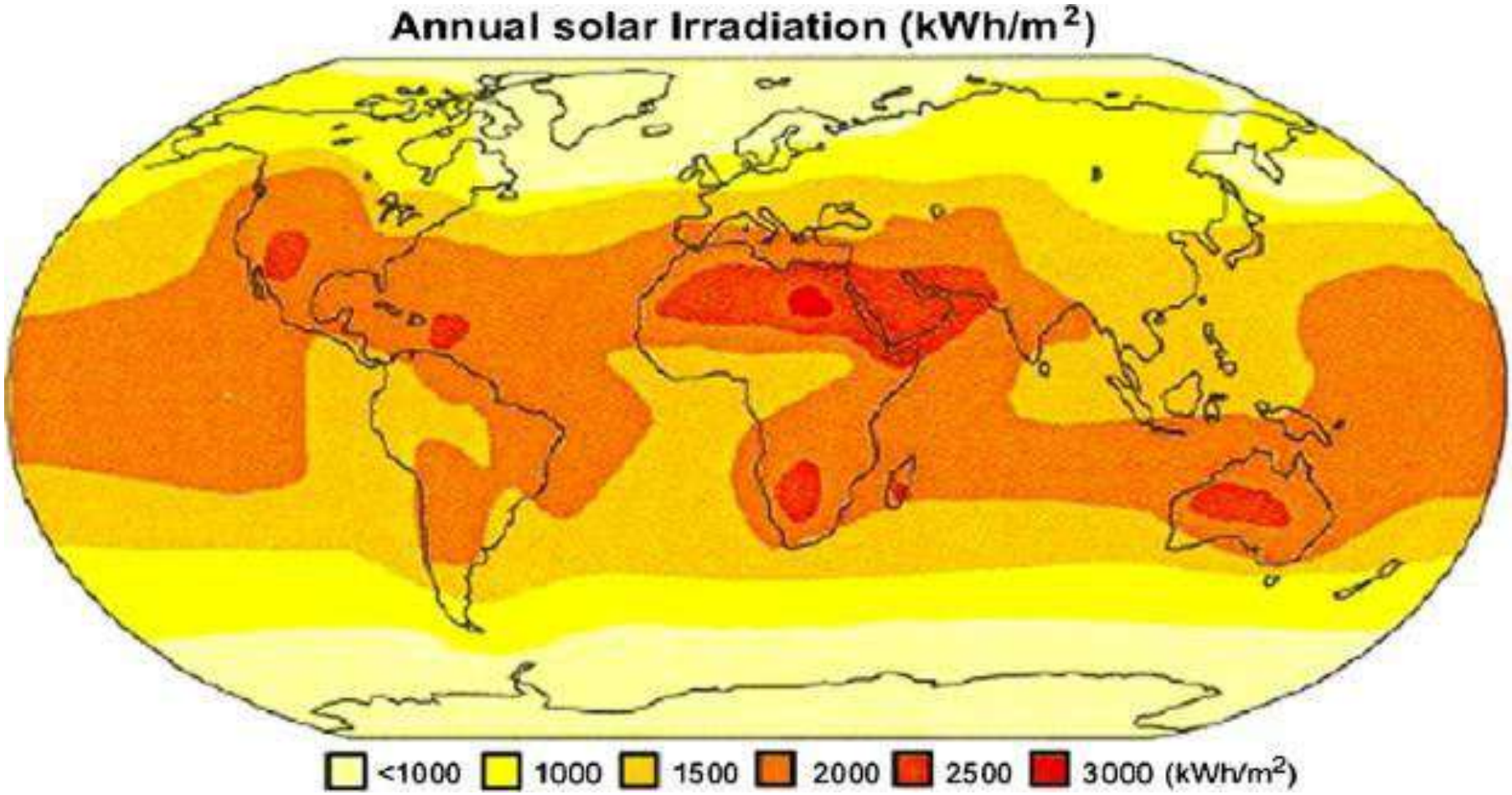
أولاً-امكانات الدول العربية و فرصها في الاستفادة من الطاقة المتجددة لانتاج الكهرباء -1-



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أولاً-امكانات الدول العربية و فرصها في الاستفادة من الطاقة المتجددة لانتاج الكهرباء -2-

كل كيلومتر مربع من الصحراء يتلقى سنوياً طاقة شمسية معادلة لطاقة مليون ونصف المليون من براميل النفط

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أولاً-امكانات الدول العربية و فرصها في الاستفادة من الطاقة المتجددة لانتاج الكهرباء -3-

Freie Universität Berlin

Policy Challenges for the Promotion of Renewable Energy in the MENA-Region

Source: Hans Müller-Steinhagen & Franz Trieb/German Aerospace Center (DLR): Renewable Energies in the MENA Region: Potential for Sustainable Energy Provision and Export to Europe

أولاً-امكانات الدول العربية و فرصها في الاستفادة من الطاقة المتجددة لانتاج الكهرباء -4-

البلد	الاشعاع الشمسي المباشر* Direct Normal Radiation DNR -كيلووات ساعة/متر مربع/سنة-	الجدوى الفنية الاقتصادية المؤكدة لانتاج سنوي* -مليون ميغاوات ساعة-	الطاقة المقدرة المطلوبة في العام 2025** -مليون ميغاواط ساعة-
البحرين	2050	33	26
العراق	2000	28647	212
الاردن	2700	6429	35
الكويت	2100	1525	116
لبنان	2000	14	19
عمان	2200	19404	71
قطر	2000	792	61
المملكة العربية السعودية	2500	124560	617
سوريا	2200	10210	79
الامارات العربية المتحدة	2200	1988	268
اليمن	2200	5100	13
الجزائر	2700	168972	111
مصر	2800	73656	399
ليبيا	2700	139477	67
المغرب	2600	20146	64
تونس	2400	9244	29

أولاً-امكانات الدول العربية و فرصها في الاستفادة من الطاقة المتجددة لانتاج الكهرباء -5-

Country	Global Horizontal Irradiance (kWh/m²/year)	Direct Normal Radiation (kWh/m²/year)	Wind - Full Load Hours/year	Geothermal - Temperature (°C) at 5 000 m
Algeria	1 970	2 700	1 789	213
Bahrain	2 160	2 050	1 360	100
Comoros	N/A	N/A	N/A	N/A
Djibouti	N/A	N/A	N/A	N/A
Egypt	2 450	2 800	3 015	180
Iraq	2 050	2 000	1 789	100
Jordan	2 320	2 700	1 483	100
Kuwait	1 900	2 100	1 605	100
Lebanon	1 920	2 000	1 176	100
Libya	1 940	2 700	1 912	100
Mauritania	N/A	N/A	N/A	N/A
Morocco	2 000	2 600	2 708	281
Oman	2 050	2 200	2 463	100
Palestine	N/A	N/A	N/A	N/A
Qatar	2 140	2 200	1 421	100
Saudi Arabia	2 130	2 500	1 789	275
Somalia	N/A	N/A	N/A	N/A
Sudan	N/A	N/A	N/A	N/A
Syria	2 360	2 200	1 789	100
Tunisia	1 980	2 400	1 789	188
UAE	2 120	2 200	1 176	100
Yemen	2 250	2 200	1 483	295

Source: German Aerospace Centre (2005)

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أولاً-امكانات الدول العربية و فرصها في الاستفادة من الطاقة المتجددة لانتاج الكهرباء -6-

اتساع المنطقة العربية من الخليج الى المحيط، يتيح:

- الاستفادة من الطاقة الشمسية من سلطنة عمان شرقاً الى موريتانيا والمغرب غرباً/ فرق التوقيت 4 ساعات. دول الخليج العربية (ونسبة استهلاكها من اجمالي الدول العربية هي 55٪) وتونس و الجزائر، تستهلك اكثر خلال ساعات النهار، وساعات ذروة الاستهلاك على شبكاتها الكهربائية هي خلال اشهر الصيف وخلال فترة سطوع الشمس
- الاستفادة من طاقة الرياح في مناطق متباعدة، تتضاءل معها امكيانات غيابها في نفس الوقت
- استثمار الطاقة المتجددة، وانتاج الكهرباء للحاجات الوطنية المحلية، وللتصدير الى الدول الأوروبية، وتأمين عوائد مالية للدول المنتجة
- تعزيز فرص نجاح الربط الكهربائي -الاستفادة من الطاقة الكهرمائية التي يمكن انتاجها في دول حوض النيل (مشروع سد انجا البالغة قدرته المئة جيغاواط) مما يساهم أيضاً في تحقيق وإزالة الاحتقان السياسي.

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أولاً-امكانات الدول العربية و فرصها في الاستفادة من الطاقة المتجددة لانتاج الكهرباء -7-

أوقات ذروة أستهلاك الكهرباء في عامي 2013 و2014

	2013			2014		
الدولة	التوقيت المحلي	التاريخ	التوقيت وفق GMT	التوقيت المحلي	التاريخ	التوقيت وفقGMT
الاردن(*)	18:10	17/12	16:10	17:25	28/12	15:25
الامارات العربية المتحدة	16:39	06/08	12:39	15:30	10/07	11:30
البحرين	14:39	04/09	11:39		25/08	
تونس	13:30	29/07	12:30	14:30		13:30
الجزائر	21:00	07/08	20:00	15:30	11/08	14:30
سوريا(*)	17:00	24/01	15:00	18:30	18/02	16:30
عمان	15:00	25/07/2012	11:00			
قطر	14:04	18/08	11:04	15:15	07/09	12:15
الكويت	14:30	17/07	11:30	14:30	11/06	11:30
العربية السعودية				15:00	31/08	12:00
مصر(*)	21:00	16/07/2012	18:00	20:00	06/08	17:00
المغرب	21:00	09/07	21:00	21:30	27/08	21:30

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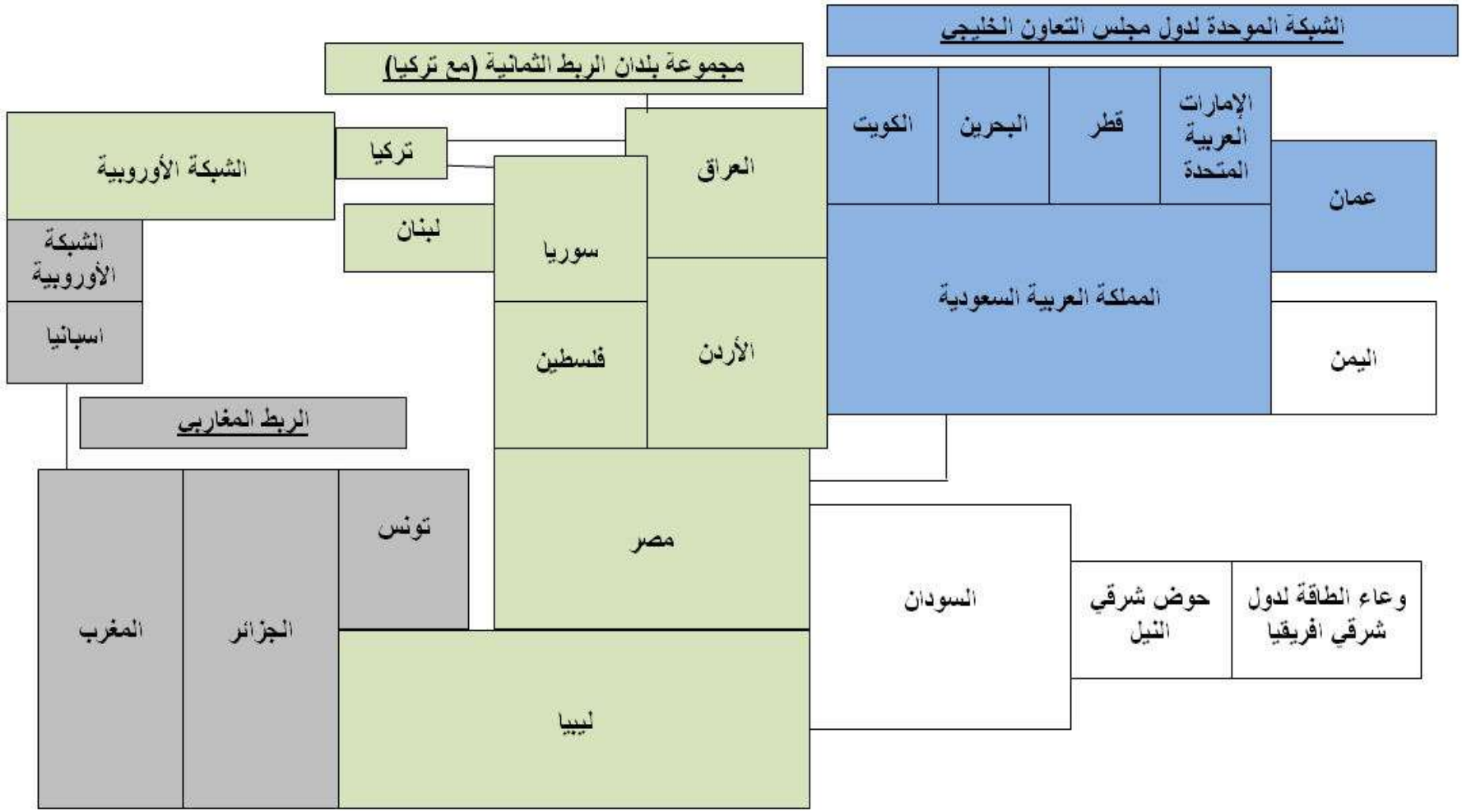
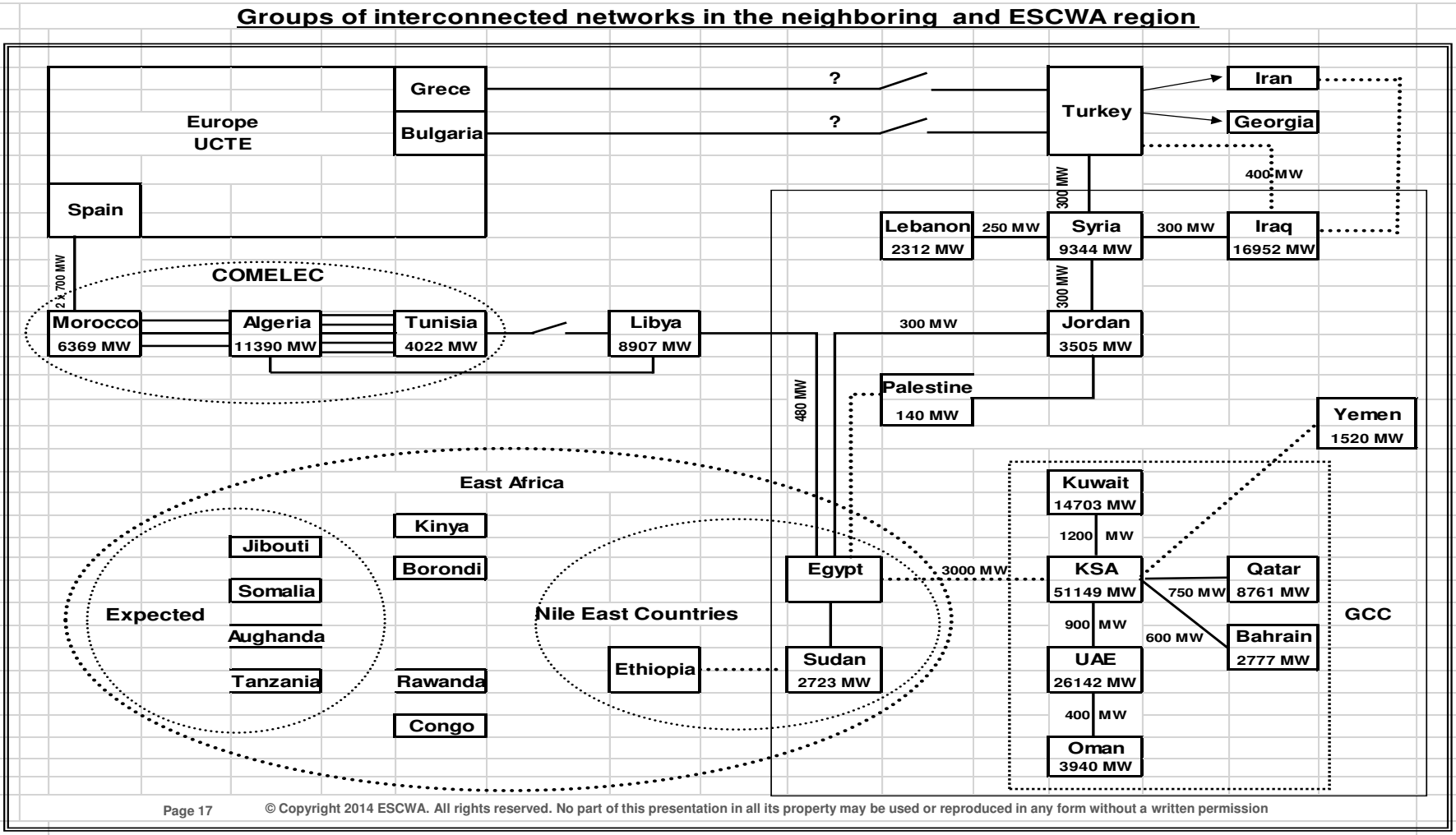
أولاً-امكانات الدول العربية و فرصها في الاستفادة من الطاقة المتجددة لانتاج الكهرباء -8-



أولاً-امكانات الدول العربية و فرصها في الاستفادة من الطاقة المتجددة لانتاج الكهرباء -9-



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أولاً-امكانات الدول العربية و فرصها في الاستفادة من الطاقة المتجددة لانتاج الكهرباء -10-

ايجابيات ودوافع أخرى عامة لاعتماد الطاقة المتجددة لانتاج الكهرباء:

- ضرورة التجاوب مع سياسات الحد من تغير المناخ، الذي ستعاني الدول العربية منه أكثر من سواها، وتخفيض الانبعاثات الناتجة عن حرق الوقود الاحفوري لانتاج الطاقة.

- تخفيف التلوث الناتج عن غازات الاحتراق، بهدف الحد من النتائج السلبية على صحة الانسان والنبات، والحد من الاضرار بالمنشآت، لان الطاقة المتجددة نظيفة.

- تحقيق وفر في كميات النفط والغاز، تسمح بتصديرها الى الخارج وبيعها والحصول على موارد مالية (الدول العربية المصدرة للنفط)، وتحقيق وفر في ميزان مدفوعات الدول العربية المستوردة للنفط والغاز، وتخفيف العبء عن كاهل الموازنات العامة والعملة الوطنية في هذه الدول

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أولاً-امكانات الدول العربية و فرصها في الاستفادة من الطاقة المتجددة لانتاج الكهرباء -11-

- الطاقة المتجددة ثروة وطنية حيث توجد، وهي تساهم في الاستقلال الطاقي وأمن الطاقة، و التنويع في مزيج الطاقة.

- الطاقة المتجددة، غير معرضة لخطر النضوب لملايين السنين، تحرر الانسان من هاجس استنزافه للوقود الاحفوري، و تجعل أسعار الطاقة الكهربائية غير متأثرة بتأرجحات أسعار النفط.

- كلفة صيانة تجهيزات أنتاج الكهرباء من مصادر الطاقة المتجددة ضئيلة بالمقارنة مع المجموعات الحرارية التقليدية.

- أمكانية الأستفادة من آليات التمويل الأخضر المتوفرة و تجارة الكربون.
- كلفة أنتاج الكيلووات ساعة كهرباء من الطاقة الشمسية ومن طاقة الرياح معقولة و مرشحة للأنخفاض.

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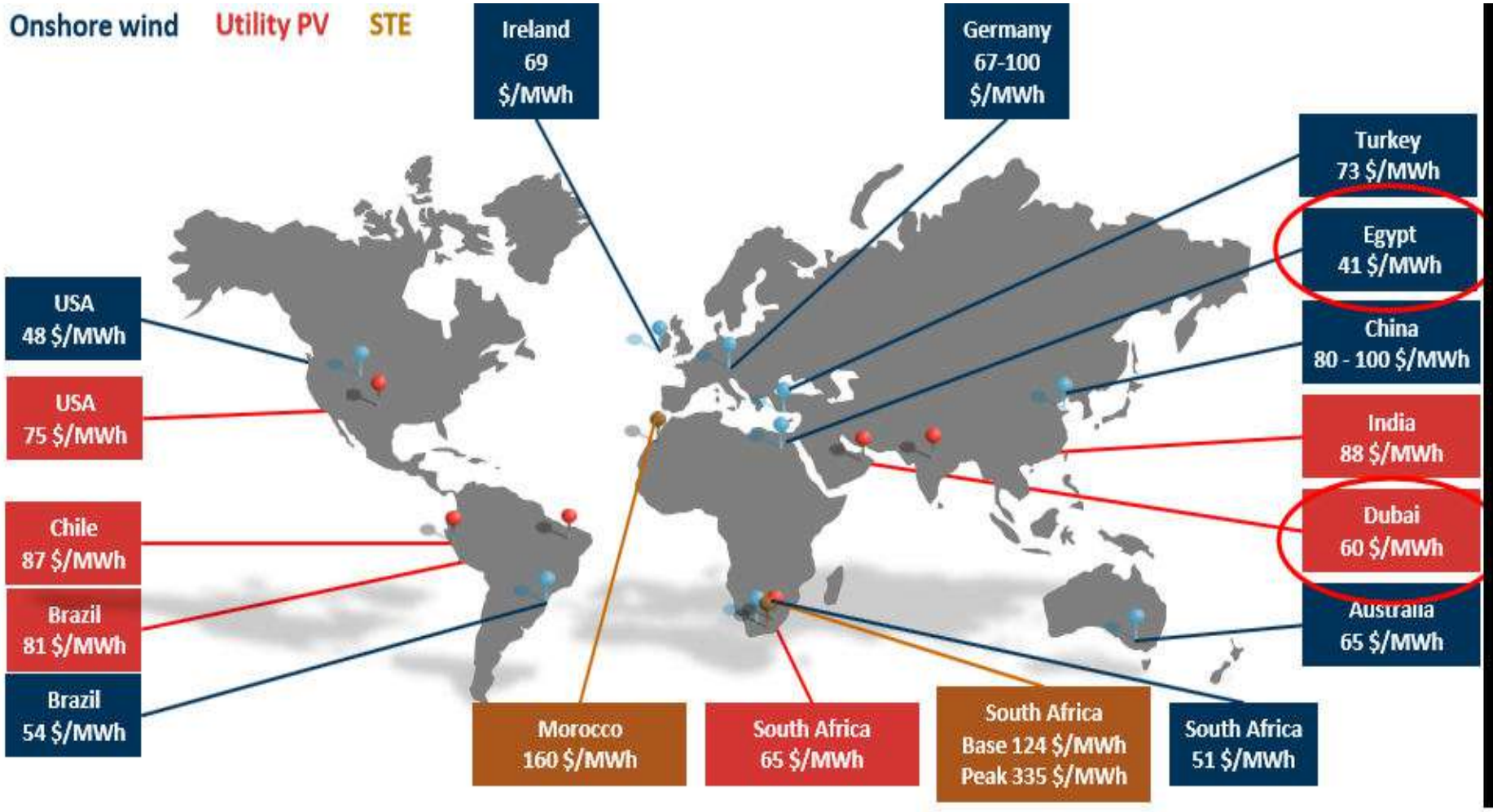
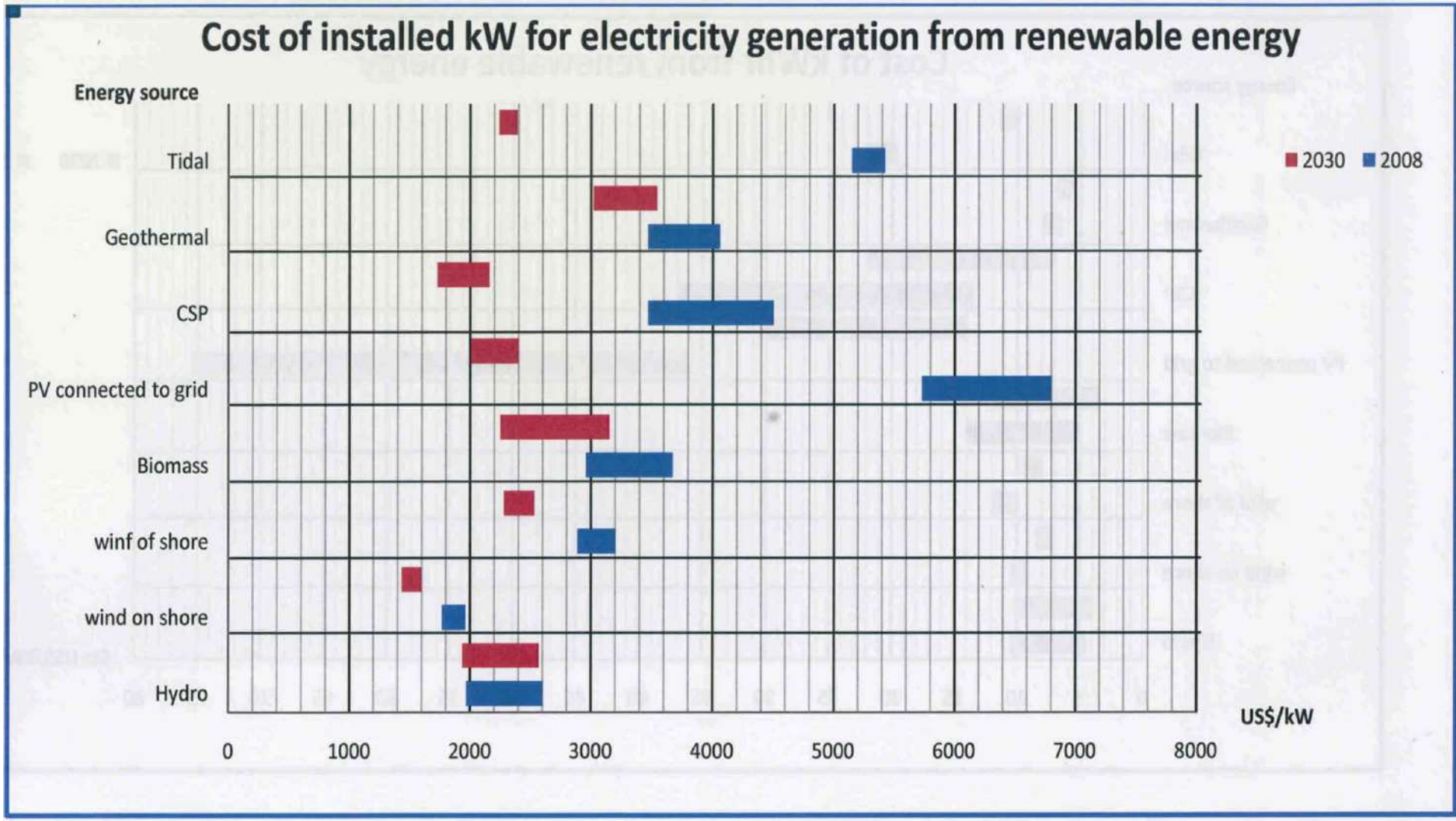
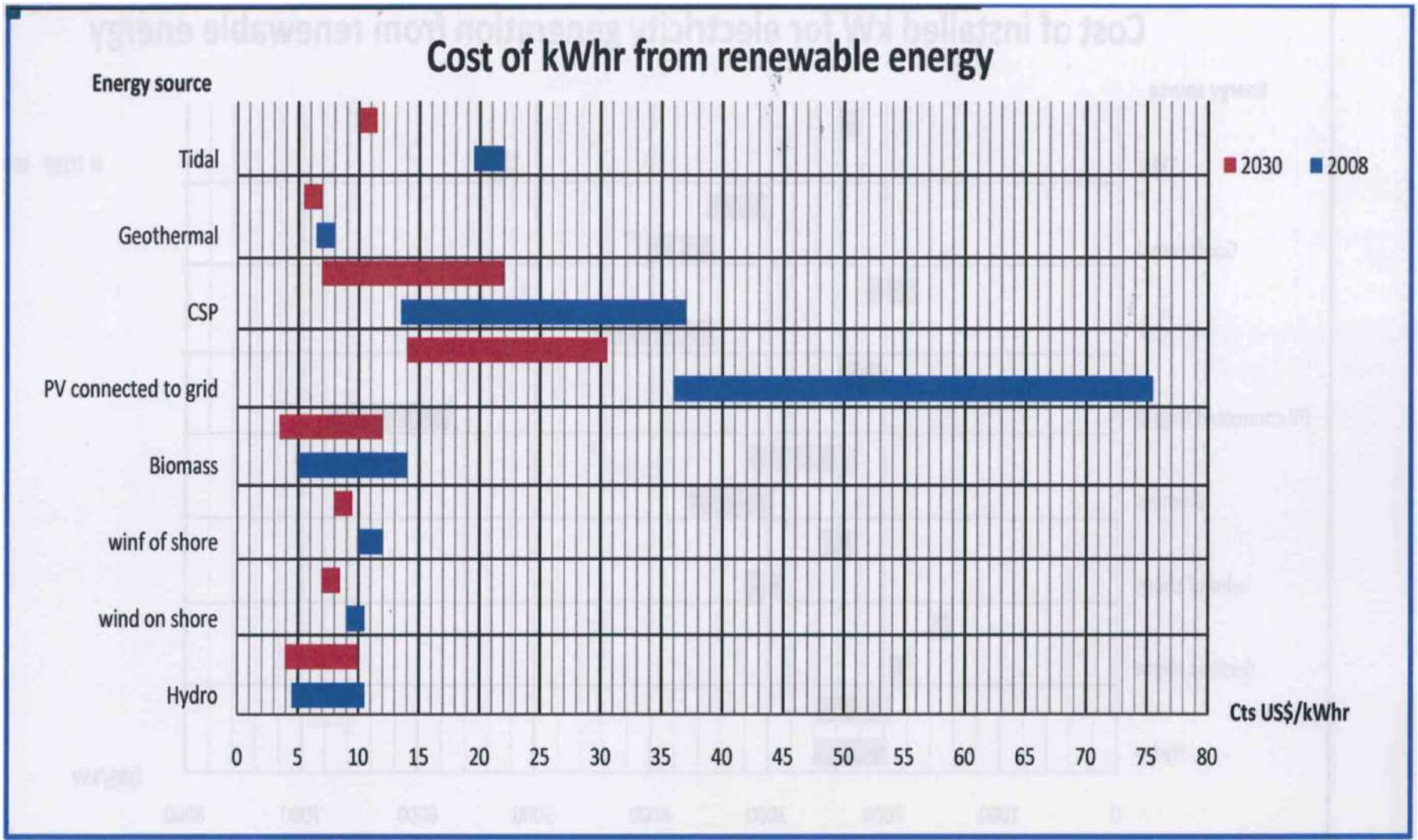
أولاً-امكانات الدول العربية و فرصها في الاستفادة من الطاقة المتجددة لانتاج الكهرباء -12-



أولاً-امكانات الدول العربية و فرصها في الاستفادة من الطاقة المتجددة لانتاج الكهرباء -13-

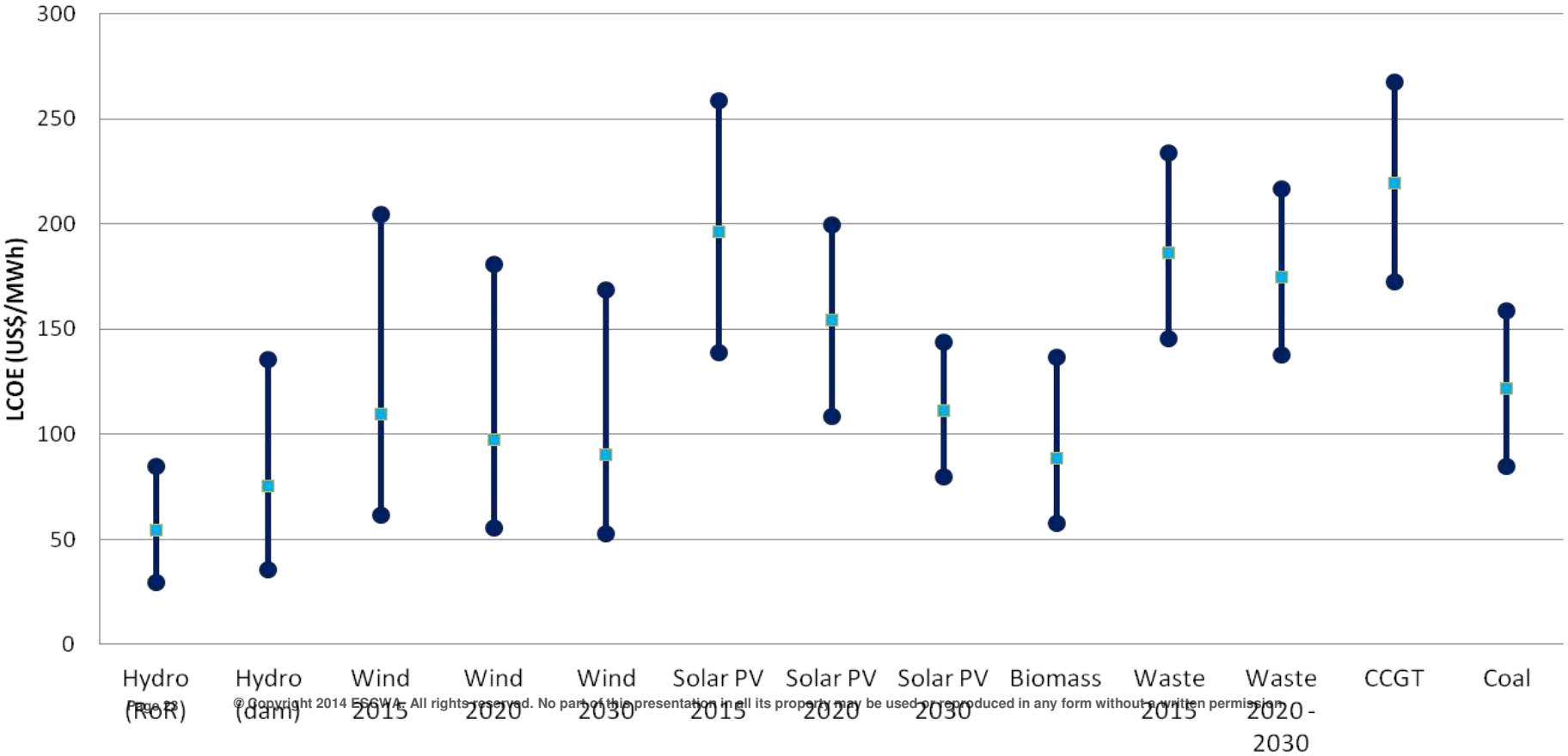


أولاً-امكانات الدول العربية و فرصها في الاستفادة من الطاقة المتجددة لانتاج الكهرباء -14-



أولاً-امكانات الدول العربية و فرصها في الاستفادة من الطاقة المتجددة لانتاج الكهرباء -15-

EDF-Jamaique 2013



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أولاً-امكانات الدول العربية و فرصها في الاستفادة من الطاقة المتجددة لانتاج الكهرباء -16-

@الإستراتيجية العربية الإقليمية للاستهلاك والإنتاج المستدامين (مجلس الوزراء العرب المسؤولين عن شؤون البيئة/ 2010

- تحسين إمكانية الحصول على الطاقة
- زيادة حصة الطاقة المتجددة في مزيج الوقود
- نشر تكنولوجيات الطاقة المتجددة

@الأستراتيجية العربية لأستخدامات الطاقة المتجددة (مجلس الوزراء العرب المسؤولين عن شؤون الكهرباء)/2011

@وجود عدة قرارات للقمم العربية الاقتصادية والتنموية والاجتماعية منذ قمة الكويت الكويت /2009

توافر القرار السياسي على أعلى المستويات

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ثانياً- قواعد تجهيز وادارة الأنتاج على الشبكات الكهربائية -1-

@الشبكات الكهربائية :مجموعة ممرات لحركة الطاقة الكهربائية، من مصادر انتاجها الى نقاط استهلاكها. والتوازن بين الانتاج والاستهلاك مطلوب بشكل مستمر، وهو الذي يحكم مفاهيم وآليات ادارة الشبكة وما يعرف بحركة الطاقة.

@الشبكات الكهربائية الوطنية تعمل بالتيار المتردد، ما يتوجب ضبطه في حدود معينة هو:

- التوتر أو الجهد (وحدة القياس هي الفولت أو الكيلوفولت)
- الذبذبة أو التردد (وحدة القياس هي الهرتز)

@ المطلوب نوعية كهرباء مقبولة وفق الانظمة والقواعد الفنية /سلعة تباع وتشترى بمواصفات ونوعية محددة مع درجات سماح محددة.

@ التوازن بين الانتاج والاستهلاك تتم متابعته عبر مراقبة التردد، الضبط الاولي والثانوي والثلاثي للتردد Primary-Secondary-Tertiary ويكون عبر التدخل على مجموعات الانتاج التقليدية أوتوماتيكياً AGC و/أو يدوياً.

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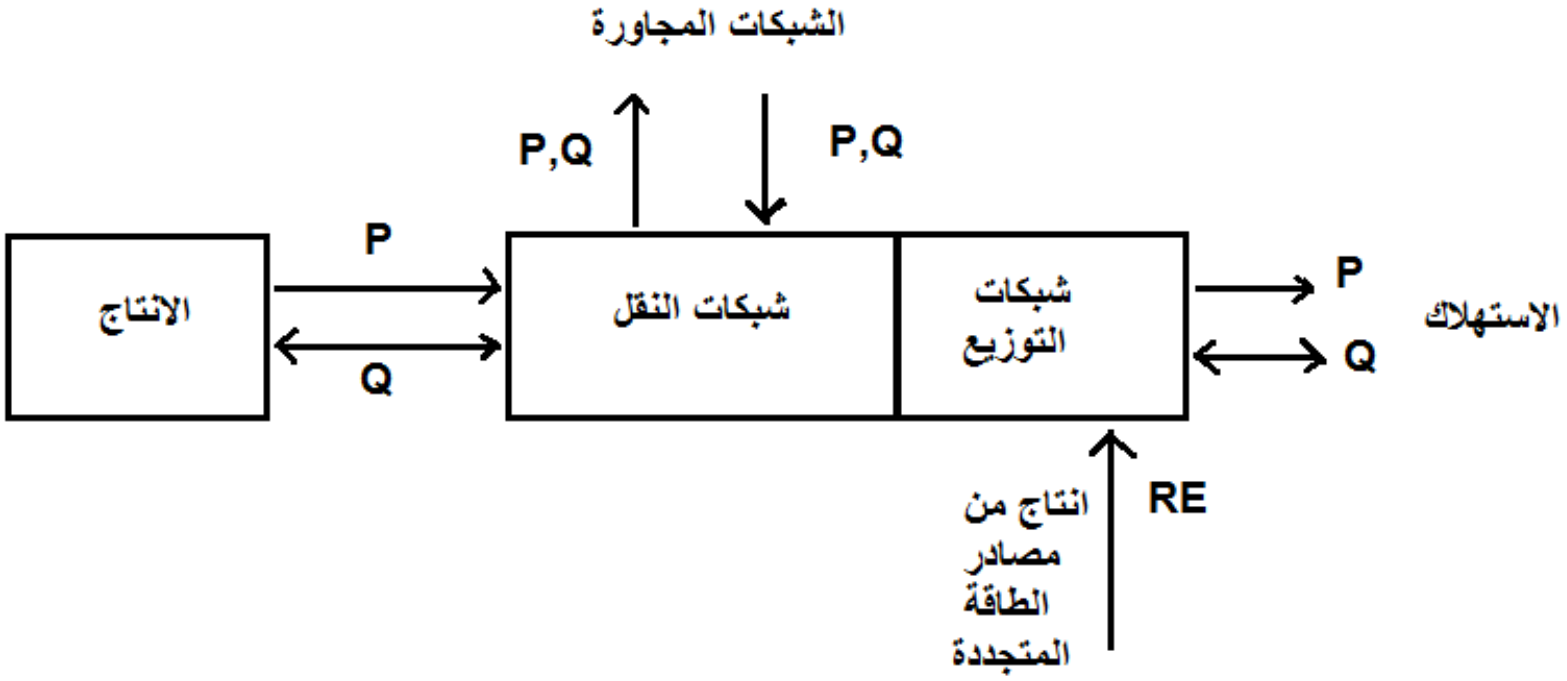
ثانياً- قواعد تجهيز وادارة الأنتاج على الشبكات الكهربائية -2-



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ثانياً- قواعد تجهيز وادارة الأنتاج على الشبكات الكهربائية -3-

@أنتاج القدرة الفعالة الفعلية لتلبية الأستهلاك : عبر متابعة التردد / الذبذبة

@تأمين التوتر/الجهد : عبر أنتاج القدرةالعكسية/ الردية

@نوعية الكهرباء

@المولدات الدوارة المتزامنة

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ثانياً- قواعد تجهيز وادارة الأنتاج على الشبكات الكهربائية -4-

ألف- لناحية القدرة الانتاجية المتوجب تجهيزها في محطات الانتاج:

اجمالي القدرات المجهزة اللازمة = القدرة المطلوبة اثناء ذروة الاستهلاك + احتياطي دوار + احتياطي ثابت + القدرة المراد توريدها أو تصديرها الى الشبكات المجاورة المرتبطة مع هذه الشبكة (أو – القدرة المراد استيرادها من هذه الشبكات المجاورة)

-كل ذلك بالطبع اثناء ساعات الذروة-

@الاحتياطي الدوار: مجموعة أو مجموعات التوليد التي يمكنها تلبية الطلب فور الحاجة اليه

@الاحتياطي الثابت :مجموعة او مجموعات التوليد التي تكون جاهزة للعمل،خلال فترة وجيزة لا تتجاوز عدة ساعات

@المجموعات المائية : ضرورة تحليل واقع هذه المجموعات

يمكن أعتمادها كإحتياطي دوار وكاحتياطي ثابت، عبر بناء سدود وخزانات بسعة ملائمة

@ضرورة التمييز بين تأمين القدرة و تأمين الطاقة

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ثانياً- قواعد تجهيز وادارة الأنتاج على الشبكات الكهربائية -5-

@لن يكون لوحدات إنتاج الطاقة الكهربائية من الطاقة الشمسية أو من طاقة الرياح امكانية القيام بدور الاحتياطي الثابت والاحتياطي الدوار، بل بالعكس سيفرض وجود هذه الوحدات لحظ احتياطي دوار و ثابت لها.

@فكرة وضع حد أعلى لا يمكن تجاوزه لقدرة مزارع الرياح و المحطات الشمسية.

@عامل الدخول Capacity Penetration Factor يتراوح بين 20٪ و40٪ ؟!

@غياب طاقة الرياح كلياً أو جزئياً عن انتاج الطاقة الكهربائية: تتضاءل فرصه عندما تكون الشبكة الكهربائية أكثر إتساعاً ومزارع الرياح أكثر انتشاراً. و كذلك انتاج الكهرباء من الطاقة الشمسية بواسطة الخلايا الكهرضوئية اثناء فترات النهار.

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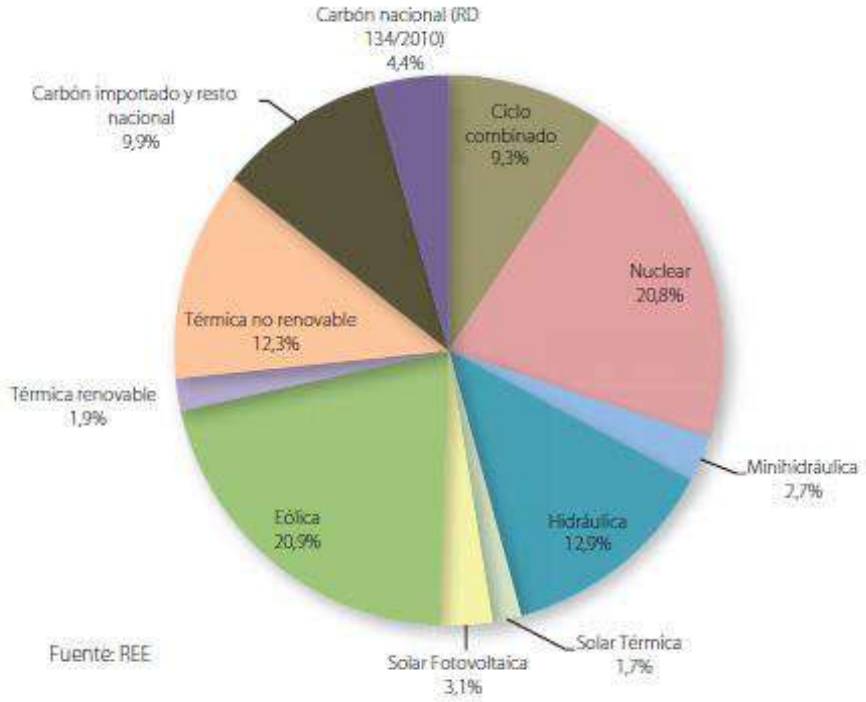
Wind Energy in Spain

Installed Power (31/12/2013)

	Sistema peninsular (MW)
Hidráulica	17.765
Nuclear	7.866
Carbón (1)	11.131
Fuel/gas	520
Ciclo Combinado	25.353
Total RÉGIMEN ORDINARIO	62.635
Hidráulica RE	2.057
Eólica	22.790
Solar fotovoltaica	4.438
Solar termoeléctrica	2.300
Térmica renovable	979
Térmica no renovable	7.127
Total RÉGIMEN ESPECIAL	39.647
TOTAL GENERAL	102.326

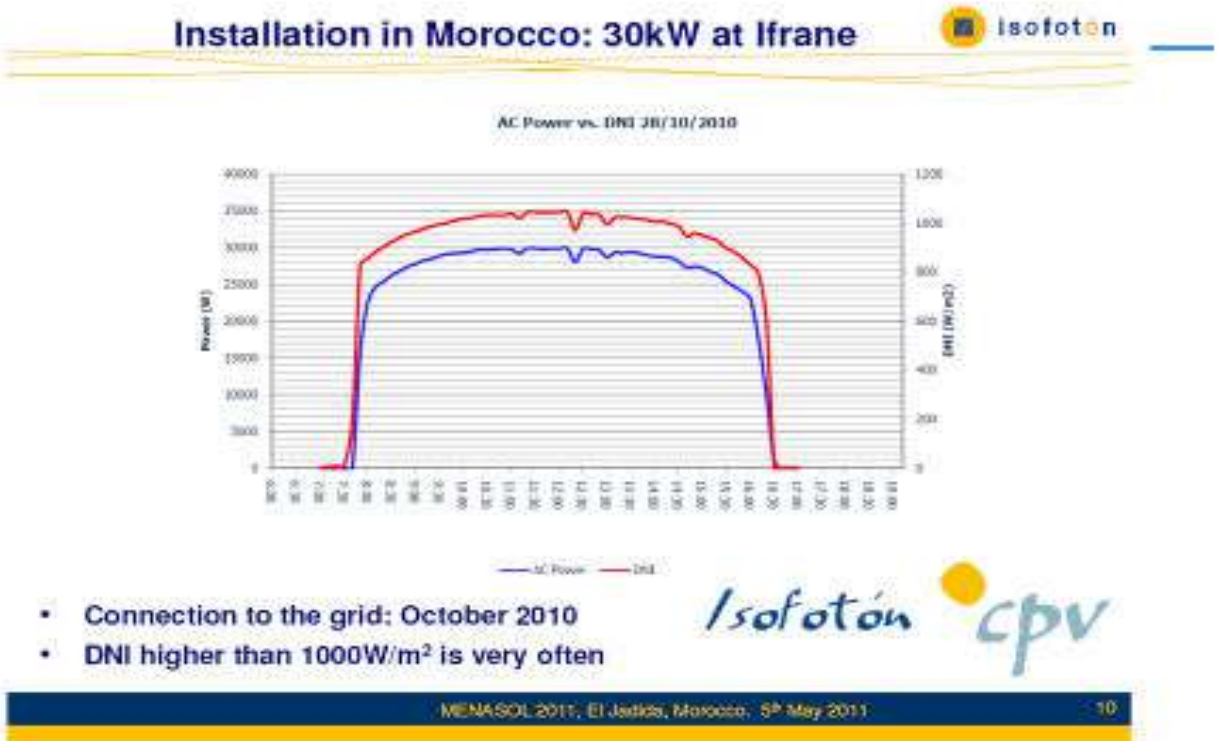


2013 Production (total 260 TWh; Wind 54,3 TWh)

- First country in Europe in production, 2nd in capacity
- Wind Power instant coverage record Dec, 25th, 2013 2:56AM: 68,4%
- Wind Power monthly coverage record,Nov,2013: 31%

ثانياً- قواعد تجهيز وادارة الأنتاج على الشبكات الكهربائية

-7-



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ثانياً- قواعد تجهيز وادارة الأنتاج على الشبكات الكهربائية -8-

باء- لناحية تلبية ما يطلبه المستهلكون، عبر انتاج قدرة معادلة وتأمين استمرار التوازن بين الاستهلاك والانتاج، والحفاظ على استقرار التردد : يمكن ملاحظة اشكال منحنيات استهلاك متنوعة، ومتغيرة ولو بالحد الادنى، لكن ادارة الشبكة تفرض تلبية الطلب على الطاقة،في جميع الأوقات.

-يتولى عادة مركز التحكم الوطني أو مركز التنسيق للشبكة الكهربائية برمجة تشغيل محطات التوليد، لتأمين الانتاج وفق المنحنى اليومي المطلوب لـ 365 يومياً في السنة: فهناك محطات التوليد الأساسية العاملة على مدار الاربعة والعشرين ساعة بالاجمال، وهناك محطات التوليد نصف الاساسية، وهناك مجموعات التوليد لفترات الذروة، وهناك المجموعات الاحتياطية.

-كانت المجموعات الحرارية مصنفة لتلبية ادوارها وفق نماذج فنية واقتصادية.

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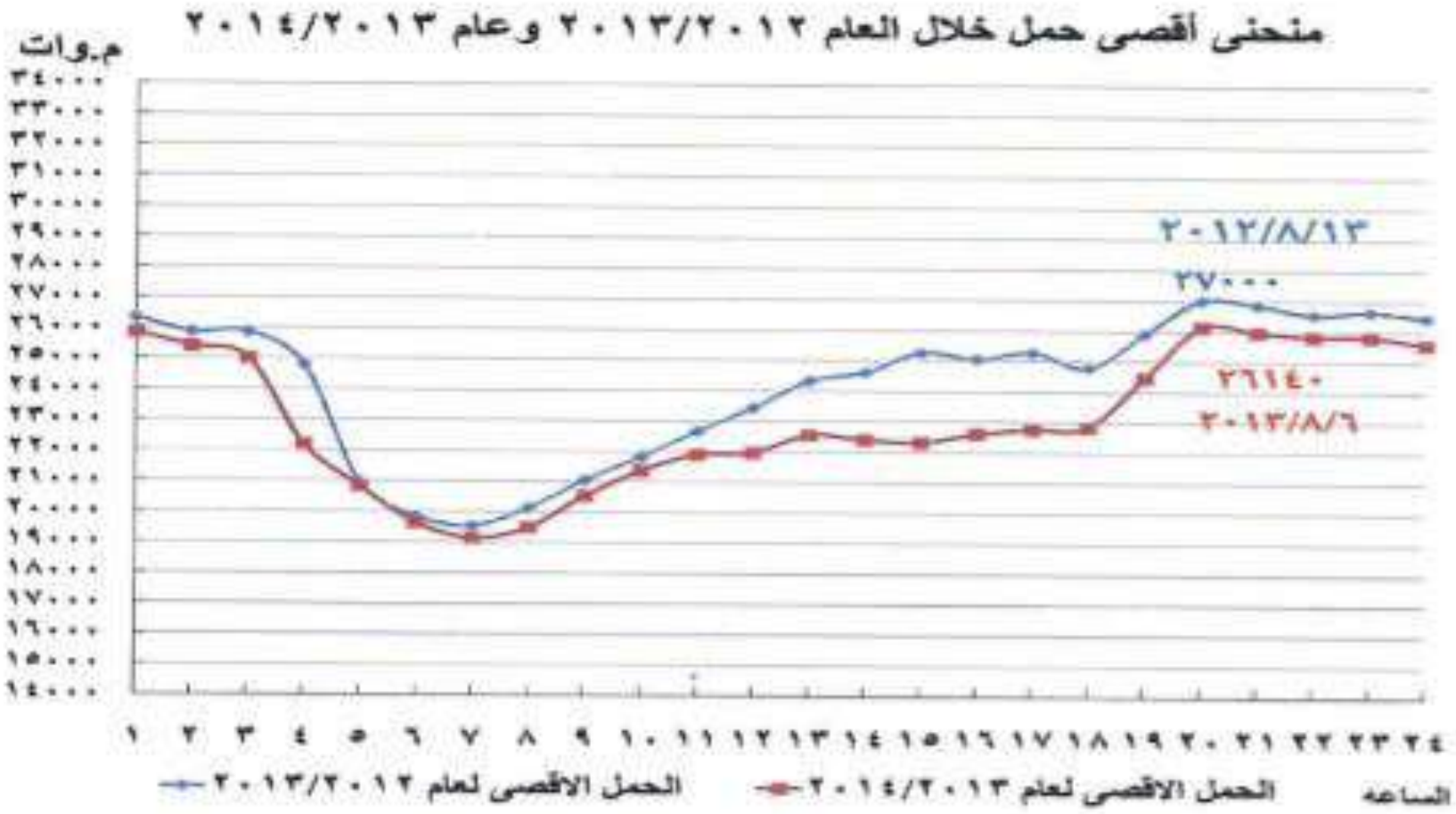
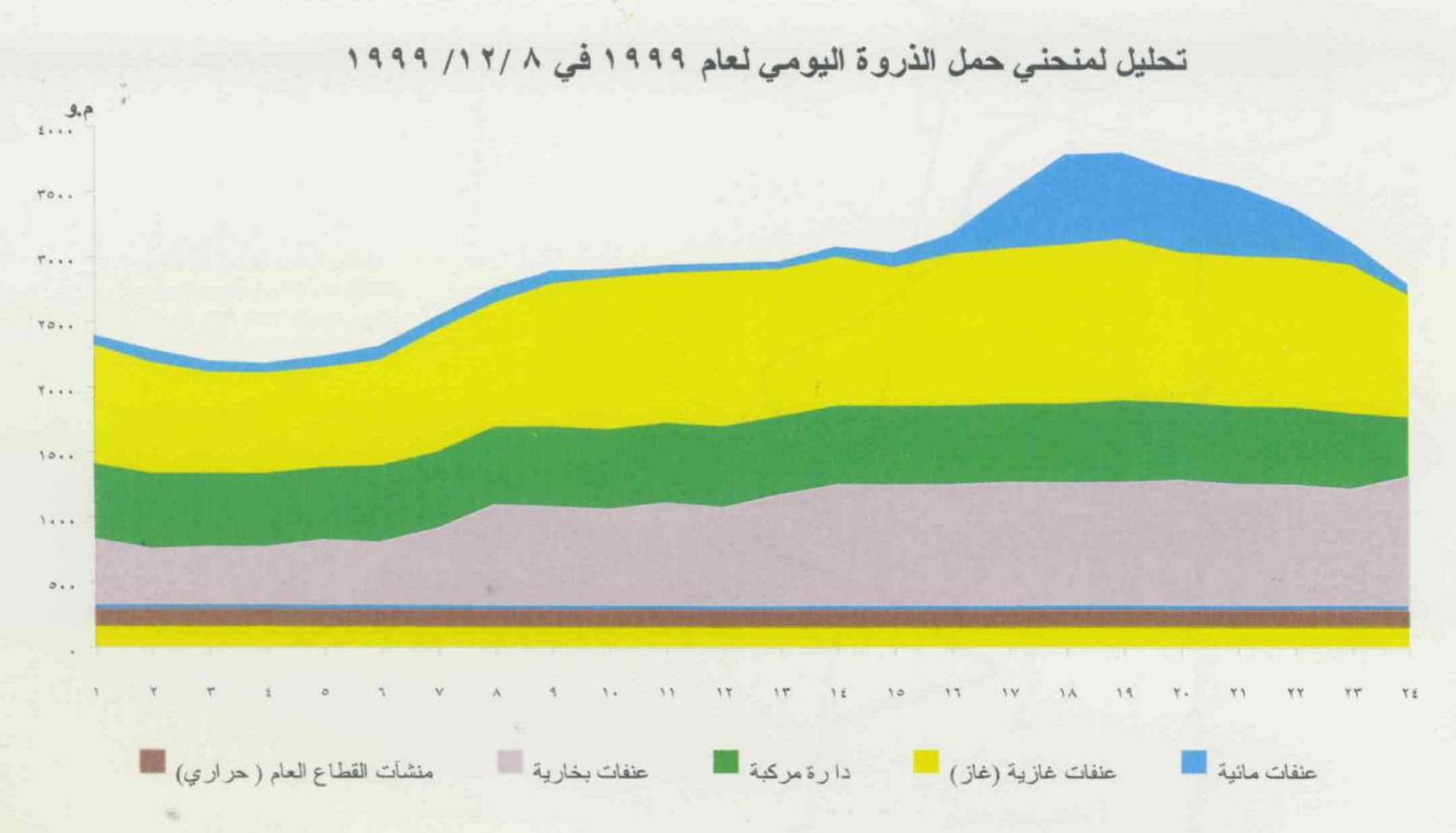
ثانياً-قواعد تجهيز وادارة الأنتاج على الشبكات الكهربائية

-9-



ثانياً- قواعد تجهيز وادارة الأنتاج على الشبكات الكهربائية

-10-



ثالثاً- أشكاليات و تحديات تغذية الشبكات الكهربائية بالطاقة المنتجة من الطاقة الشمسية و طاقة الرياح -1-

يتواجد التوليد بواسطة الخلايا الكهرضوئية والطاقة الشمسية الحرارية وطاقة الرياح، دون ارادة ادارة الشبكة، وله الأولوية والأفضلية.

ألف- لناحية العلاقة بين القدرة الأسمية المجهزة والطاقة المنتجة: تتميز المجموعات الحرارية التقليدية منها والنووية، لانتاج الطاقة الكهربائية بكونها قادرة على العمل بعامل جهوزية مرتفع يصل الى حدود 90٪، /تشغيلها عند الحاجة اليها بقدرة انتاج تصل الى القدرة الاسمية المجهزة، ويمكن للميغاواط المجهز أن ينتج خلال العام الواحد ما يصل الى 8000 MWh

@المجموعات المائية لانتاج الطاقة الكهربائية، قادرة على العمل وفق توافر المياه في مجاري الأنهار/ وفق تواجد سدود التخزين وسعتها ومصادر تغذيتها: يضطر المسؤول عن ادارة الشبكة الى متابعة الظروف المناخية وتطور كميات الامطار ومنحنيات ملء السد و تفريغه، قبل اتخاذ قرار بتشغيل المجموعة او عدمه.
في الدول العربية : الميغاواط المجهز قد لا ينتج في العام الواحد 1000 ميغاواط ساعة في سنة جافة/شحيحة، وقد يتجاوز الانتاج حدود 5000 ميغاواط ساعة (الانتاج الكهرمائي في لبنان على سبيل المثال في سنة شحيحة كعام 2014 كان 190 جيغاواط ساعة، فتدنى انتاج الميغاواط المجهز الى 688 ميغاواط ساعة، وكان سابقاً في سنة غنية بالامطار - حيث حصل انتاج سنوي 1363 جيغاواط ساعة- قد وصل الى 4938 جيغاواط ساعة) .

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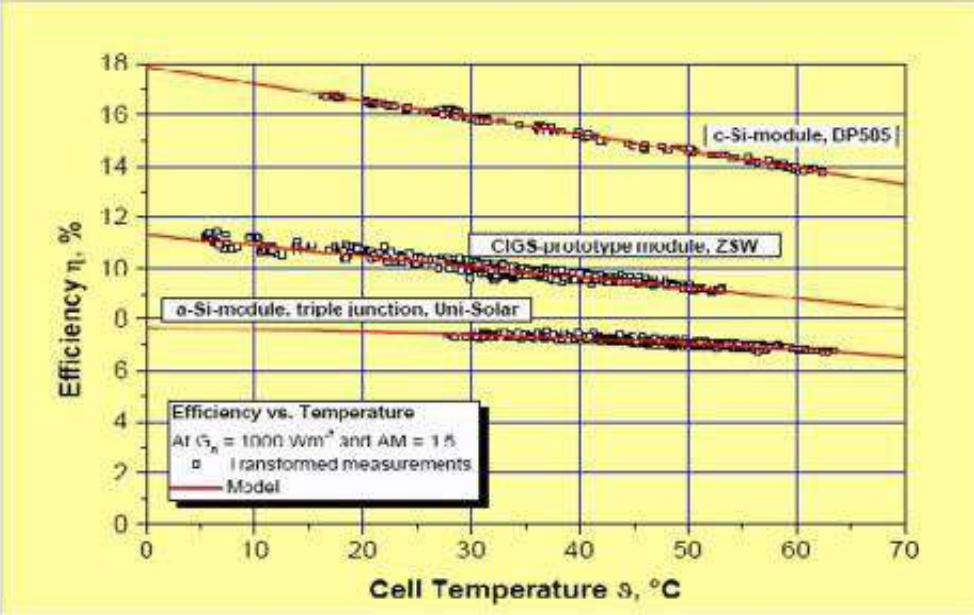
ثالثاً- أشكاليات و تحديات تغذية الشبكات الكهربائية بالطاقة المنتجة من الطاقة الشمسية و طاقة الرياح -2-

@الخلايا الكهرضوئية :يتم تحديد القدرة المجهزة بالكيلووات ذروة: محقق في ظروف قياسية: تم تحديدها عالمياً بما يعرف بـ STC Standard Testing Conditions، وهي ظروف التجربة القياسية لامتحان قدرة الخلايا:

-اشعاع شمسي يبلغ الف وات في المتر المربع

-حرارة الخلية = 25 درجة مئوية

-عامل كتلة الهواء = AM1.5



@عملياً تنخفض القدرة و الكفاءة عندما ترتفع الحرارة.

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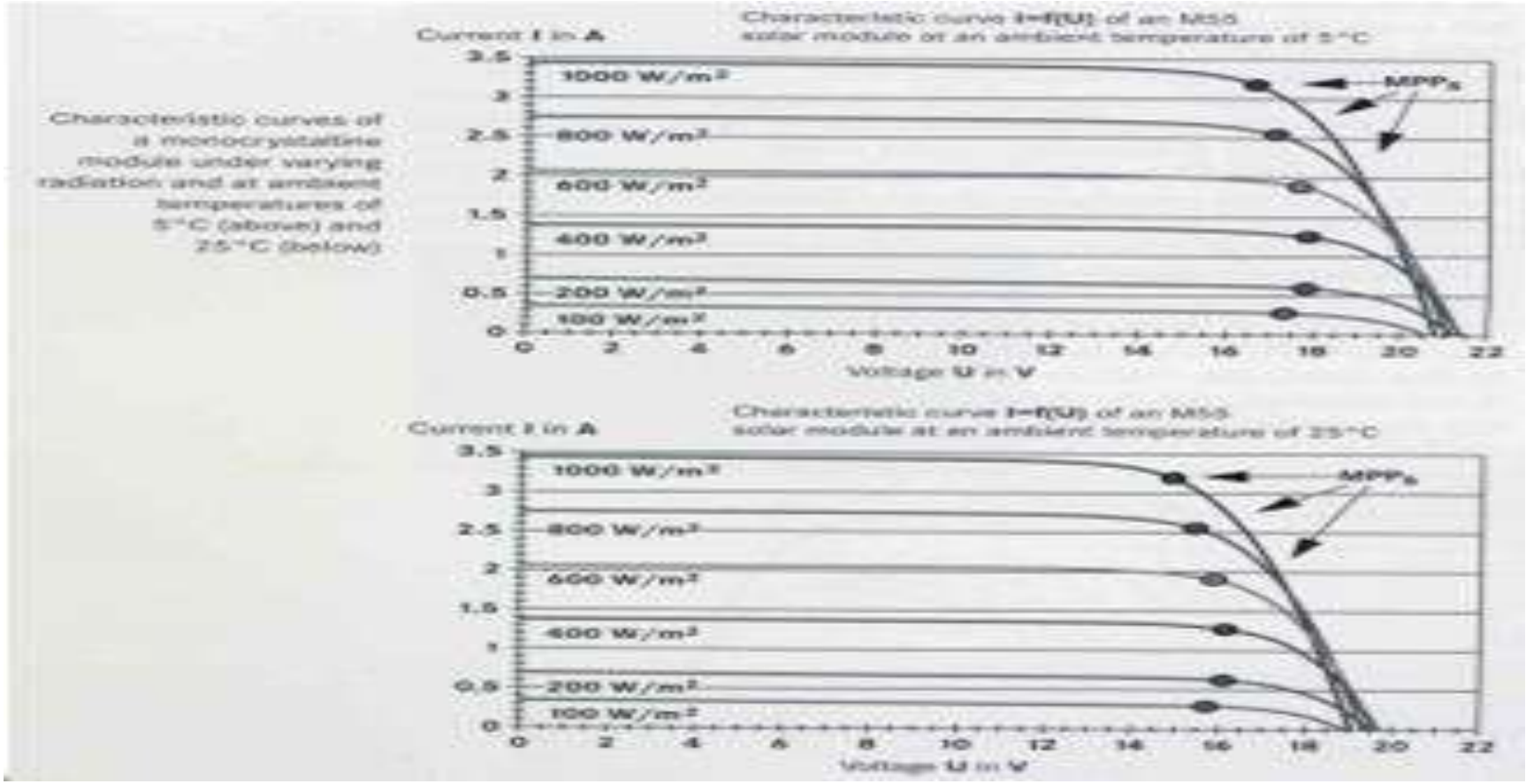
ثالثاً- أشكاليات و تحديات تغذية الشبكات الكهربائية بالطاقة المنتجة من الطاقة الشمسية و طاقة الرياح -3-



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ثالثاً- أشكاليات و تحديات تغذية الشبكات الكهربائية بالطاقة المنتجة من الطاقة الشمسية و طاقة الرياح -4-

Efficiency reduction rate with the increasing per 1 °C cell temperature of PV module of different investigations.

Authors, year, time and location	Irradiation (W/m^2)		Operating temperature (°C)		Efficiency (%)		Maximum ambient temperature (°C)	Reduction of efficiency (%) per 1 °C increment of cell temperature
Experiment location	At starting period	At peak period	At starting period	At peak period	At starting period	At peak period		
Bahaidarah et al. [13] February 2012, KFUPM, Dhahran, Saudi Arabia. Latitude 26°18′N, longitude 50°08′E	240	979	25	44	15.7	15.2	21	0.03
Chandrasekar et al. [14], April, 2013, Anna University, BIT campus, Tiruchirappalli, India. Latitude 10°39′N, longitude 78°44′E	600	1300	37	65	10.3	9	37	0.05
In the current investigation, (2015)	1000	1000	32.1	88.1	7.63	4.5	27	0.06

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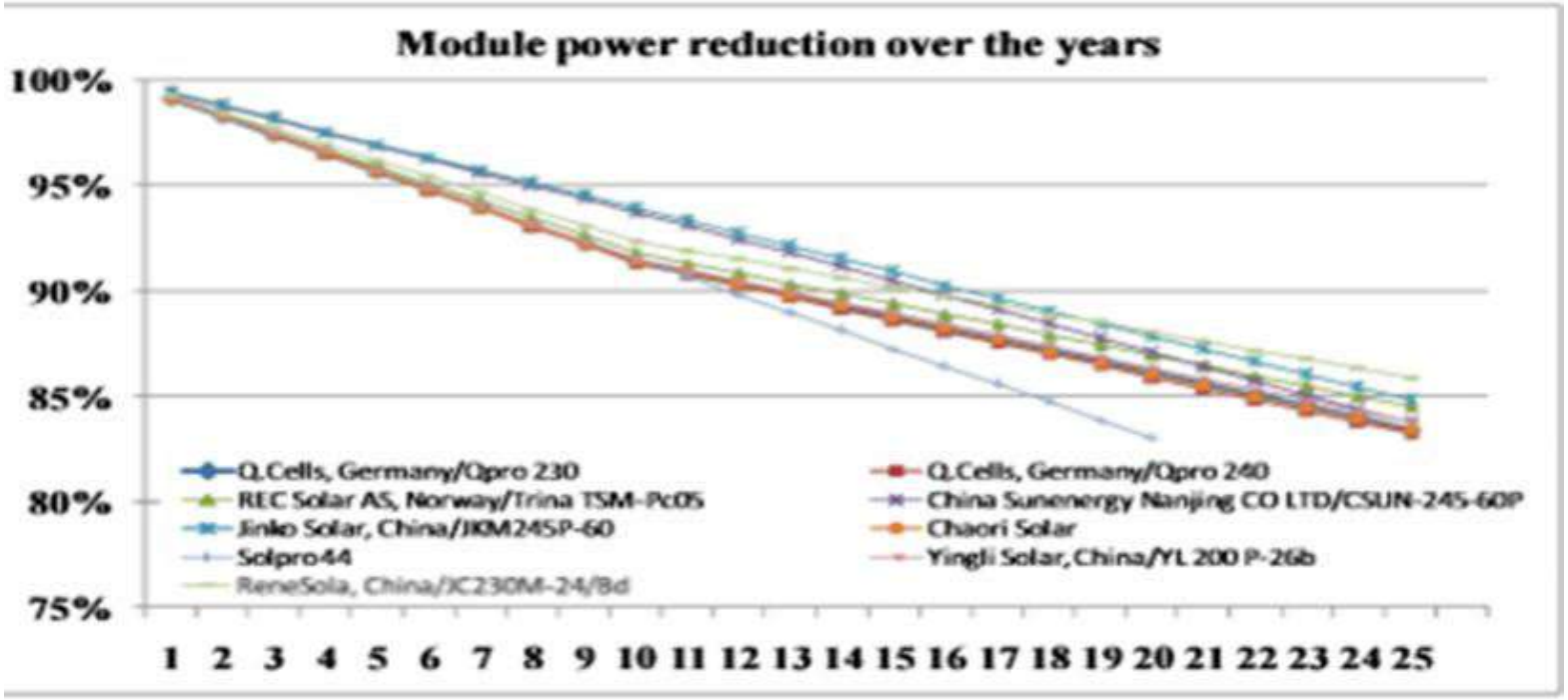
ثالثاً- أشكاليات و تحديات تغذية الشبكات الكهربائية بالطاقة المنتجة من الطاقة الشمسية و طاقة الرياح -5-

- أنخفاض الكفاءة و القدرة مع تقادم الخلايا ، فهي بحدود 90٪ من الارقام الاسمية في العشرة سنوات الأولى، وتستمر في الانخفاض لتصل الى حدود 80٪ بعد مرور 20-25 سنة من حياة الخلايا:



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ثالثاً- أشكاليات و تحديات تغذية الشبكات الكهربائية بالطاقة المنتجة من الطاقة الشمسية و طاقة الرياح -6-

نظام التوليد	القدرة الاسمية	الطاقة المنتجة سنوياً	عدد ساعات مكافئ سنوياً
وحدة طاقة رياح	5 MW	16000 MWh	3200
وحدة شمسة حرارية مركزة (اسبانيا Andasol)	50 MW	182000 MWh	3640
وحدة نووية (فرنسا Flamanville)	1300 MW	9600000 MWh	7385
مجموعة دارة مختلطة (زهراني او دير عمار لبنان)	435 MW	3277000 MWh	7532
خلايا كهرضوئية			1000-2500

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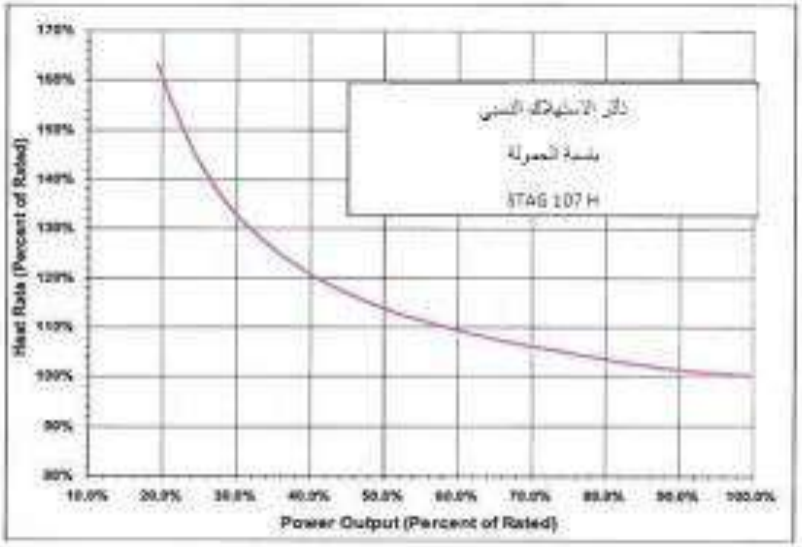
ثالثاً- أشكاليات و تحديات تغذية الشبكات الكهربائية بالطاقة المنتجة من الطاقة الشمسية و طاقة الرياح -7-

باء- لناحية التأثير على كفاءة المجموعات الأنتاجية الأخرى العاملة على الشبكة: تؤدي التغيرات في قدرات تجهيزات انتاج الكهرباء من الطاقة الشمسية و طاقة الرياح العاملة على الشبكة، الى تعديل العمل المبرمج للمجموعات التقليدية، و غالباً الى خفض الكفاءة و زيادة الأستهلاك النسبى للمحروقات



تأثير الحمولة على الكفاءة

تتأثر الكفاءة ومن خلالها استهلاك المحروقات لإنتاج الكيلووات ساعة بالحمولة. ويتم الحصول على الكفاءة الفضلى عند التشغيل على الحمولة الإسمية، وتنخفض الكفاءة مع انخفاض الحمولة. ويبرز ذلك بشكل كبير مع العنفات الغازية وبشكل أقل مع المجموعات البخارية، وبشكل وسطي مع مجموعات الدورة المركبة كما هو مبين :

Combined-Cycle Unit	Net Power MW	Net Heat Rate (LHV) BTU/kWh	Kj/kWh	Thermal Efficiency (LHV) %
STAG 107 H	400	5,687	6,000	60

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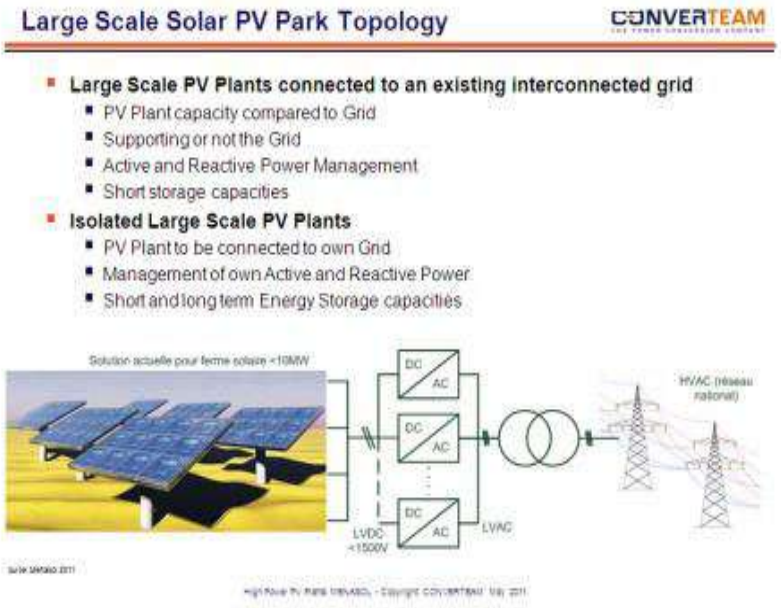
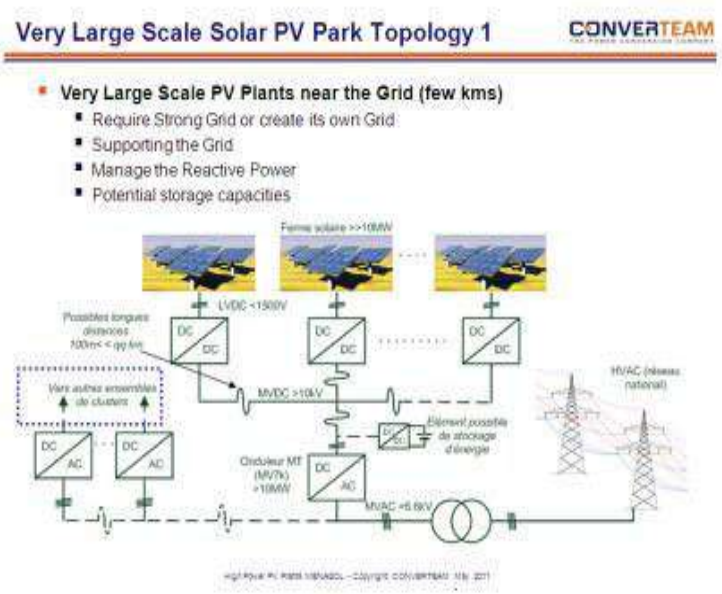
ثالثاً- أشكاليات و تحديات تغذية الشبكات الكهربائية بالطاقة المنتجة من الطاقة الشمسية و طاقة الرياح -8-

جيم - الحاجة الى ربط مجموعات الطاقة الشمسية وطاقة الرياح لانتاج الكهرباء على شبكة التوزيع (توتر متوسط أو منخفض): بسبب محدودية القدرات الأفرادية لهذه المجموعات، فيؤدي ذلك الى تعقيدات لجهة التوتر وقدرات التوزيع و التحويل والأختيار بين التيار المتردد و التيار المستمر.....



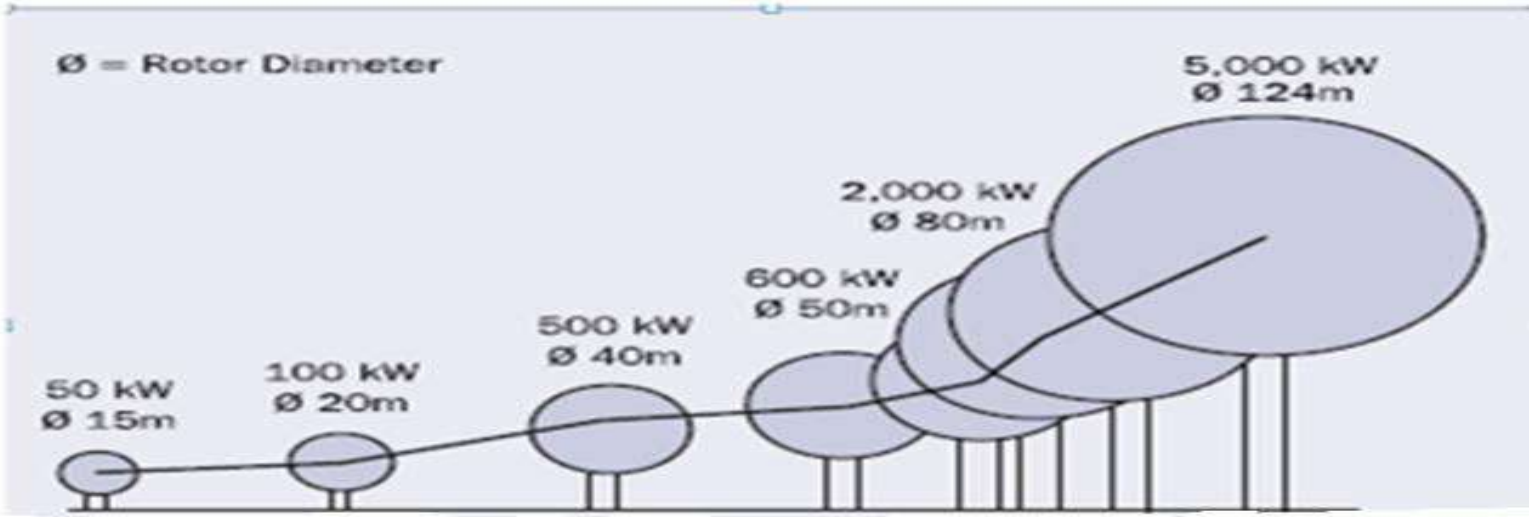


ثالثاً- أشكاليات و تحديات تغذية الشبكات الكهربائية بالطاقة المنتجة من الطاقة الشمسية و طاقة الرياح -9-

دال- لناحية ادخال متوافقات و التسبب بتشوه التيار و التوتر: كون تطبيقات الطاقة الشمسية الكهرضوئية وطاقة الرياح لانتاج الكهرباء تتضمن تجهيزات ألكترونية .

هاء- الحاجة الى مساحات واسعة أكبر: بالمقارنة مع المساحات التي تشغلها سواها:

-العنفات الريحية، من الضروري وجود مسافات كافية بين العنفات في الصف الواحد (ثلاث الى خمس مرات قطر ريش العنفة)، و بين صفوف العنفات (10 الى 14 مرة قطر ريش العنفة)،



المصدر: EWEA

ثالثاً- أشكاليات و تحديات تغذية الشبكات الكهربائية بالطاقة المنتجة من الطاقة الشمسية و طاقة الرياح -10-

$$M = \rho.S.V = \rho\left(\pi\frac{D.D}{4}\right).V$$

S: مساحة دوران رش العنفة، التي يبلغ قطرها D

ρ : الثقل النوعي او كثافة الهواء

وبالتالي فإن قدرة/ استطاعة العنفة هي نظرياً:

$$P = 0.5\left[\rho\left(\pi\frac{D.D}{4}\right).V\right]V.V$$

$$P_t = 0,3927\,\rho.\,D^2\,V^3$$

أي أن استطاعة/قدرة العنفة تتناسب طردياً:

- مع مكعب سرعة الرياح.
- مع الثقل النوعي للهواء.
- مع مربع قطر دائرة شفرات العنفة.

تتغير ρ مع درجة الحرارة، (بالتالي فإن استطاعة العنفة تكون افضل في الفترات الباردة نسبياً) والضغط الجوي (وبالتالي الارتفاع).

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ثالثاً- أشكاليات و تحديات تغذية الشبكات الكهربائية بالطاقة المنتجة من الطاقة الشمسية و طاقة الرياح -11-

$$P_t = 0.481 \,.\, D^2 V^3$$

واذا تم الاخذ بعين الاعتبار أن كفاءة تحويل الطاقة من طاقة حركة الرياح الى طاقة ميكانيكية دوارة هي نظرياً، وفق قانون Betz، تساوي 16/27 أي 59.3 بالمائة، فإن الاستطاعة المثالية القصوى تصبح:

$$Pr = 0.593 \times 0.481 \;\; D^2 V^3 = 0.285 \, D^2 V^3$$

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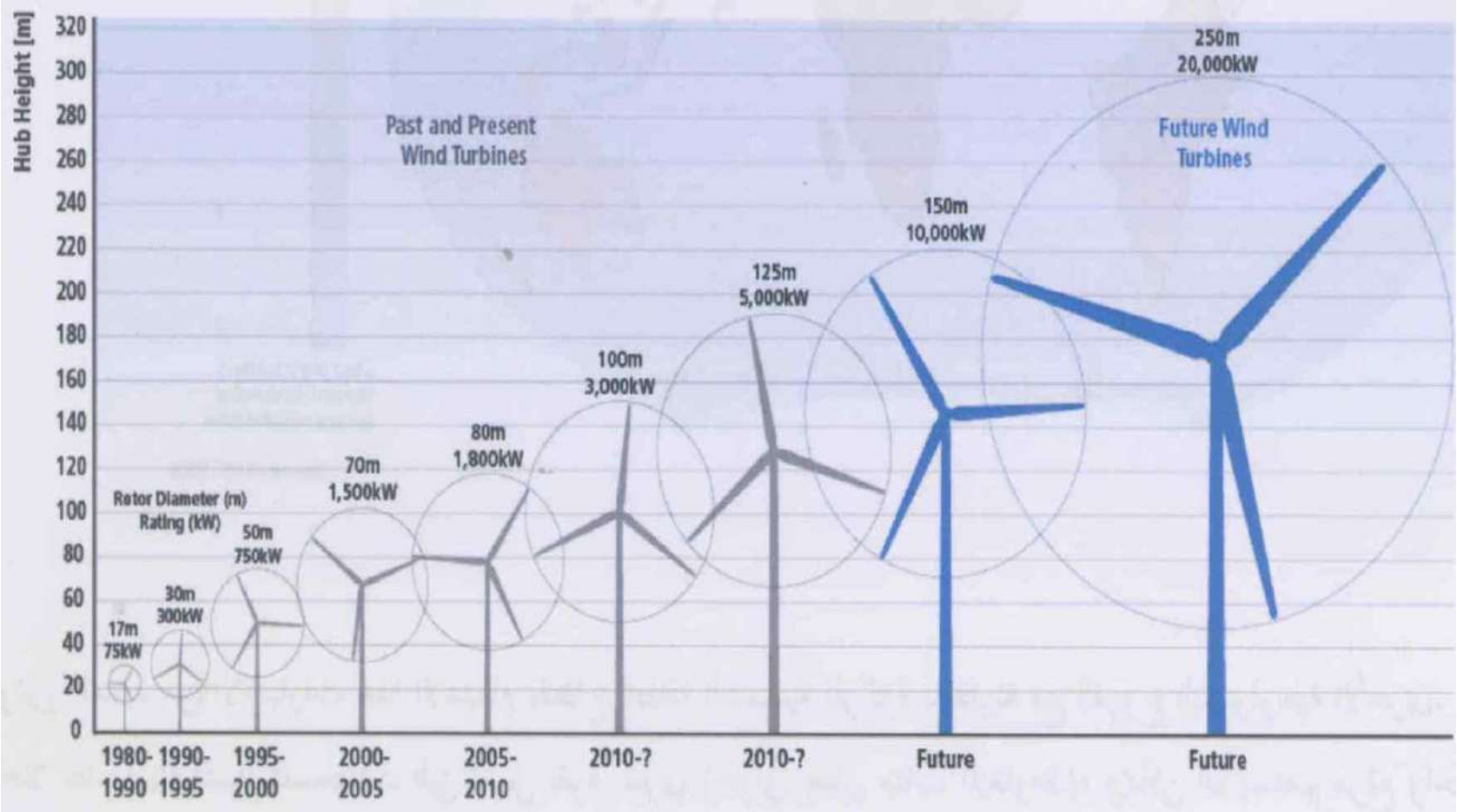
ثالثاً- أشكاليات و تحديات تغذية الشبكات الكهربائية بالطاقة المنتجة من الطاقة الشمسية و طاقة الرياح -12-



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ثالثاً- أشكاليات و تحديات تغذية الشبكات الكهربائية بالطاقة المنتجة من الطاقة الشمسية و طاقة الرياح -13-

- انتاج الكهرباء بواسطة الخلايا الكهرضوئية: المساحة المطلوبة للوحات الخلايا هي:

للخلايا من نوع السيليكون الأحادي البلور	7-9 متر مربع للكيلووات ذروة
للخلايا من نوع السيليكون المتعدد البلور	8-9 متر مربع للكيلووات ذروة
للخلايا من نوع السيليكون العشوائي	16-20 متر مربع للكيلووات ذروة

يضاف اليها التجهيزات المساعدة و المتممة من منوبات ومحولات وأجهزة حماية الخ...، اضافة الى ضرورة تحاشي التظليل وحجب أشعة الشمس في ساعات معينة، فتصبح المساحة بحدود 40 ألف متر مربع للميغاواط ذروة.

-الطاقة الشمسية المركزة: مساحات المرايا ضخمة ، للحصول على نسبة تركيز كافية للحصول على الحرارة اللازمة

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ثالثاً- أشكاليات و تحديات تغذية الشبكات الكهربائية بالطاقة المنتجة من الطاقة الشمسية و طاقة الرياح -14-

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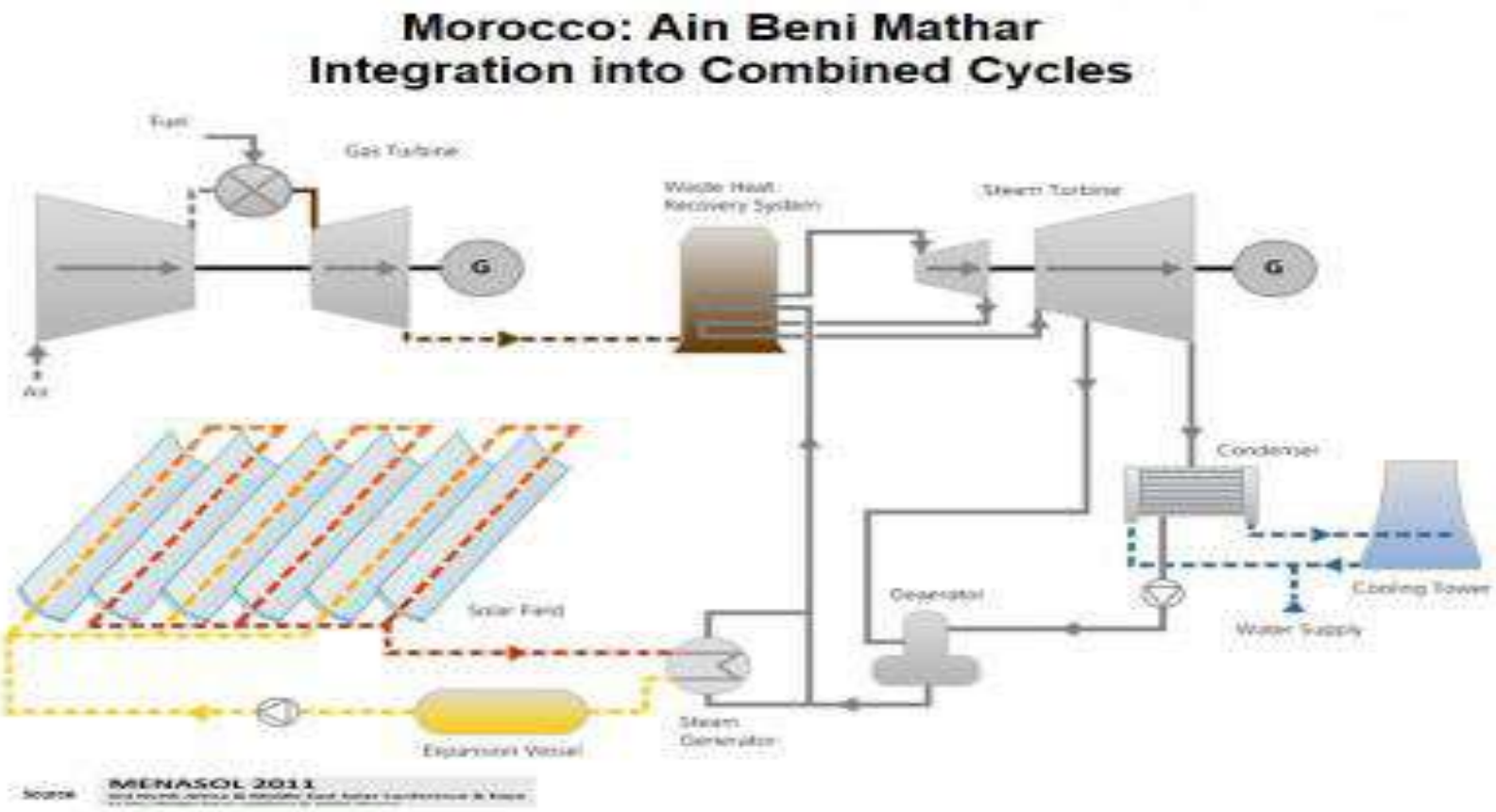
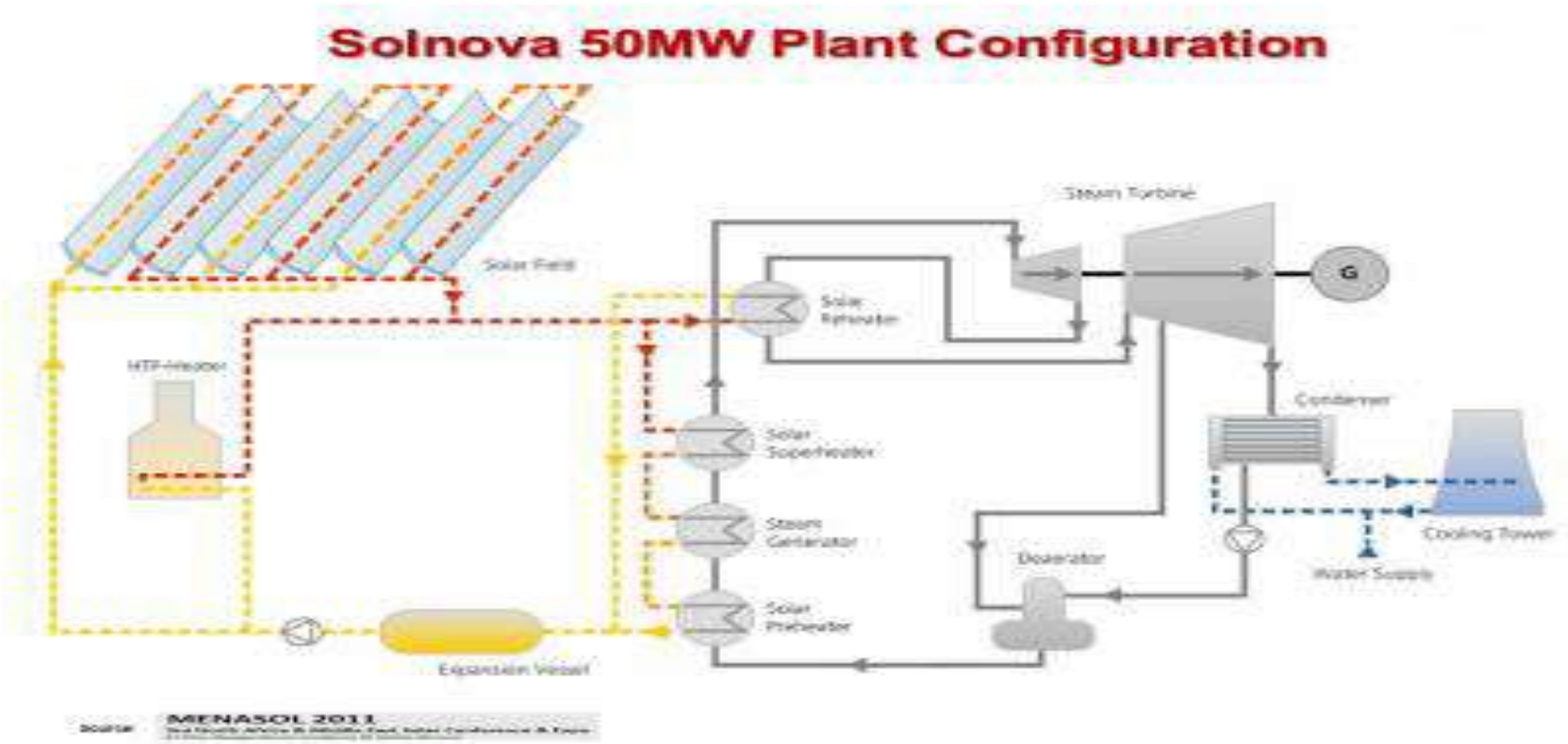
ثالثاً- أشكاليات و تحديات تغذية الشبكات الكهربائية بالطاقة المنتجة من الطاقة الشمسية و طاقة الرياح -15-



ثالثاً- أشكاليات و تحديات تغذية الشبكات الكهربائية بالطاقة المنتجة من الطاقة الشمسية و طاقة الرياح -16-



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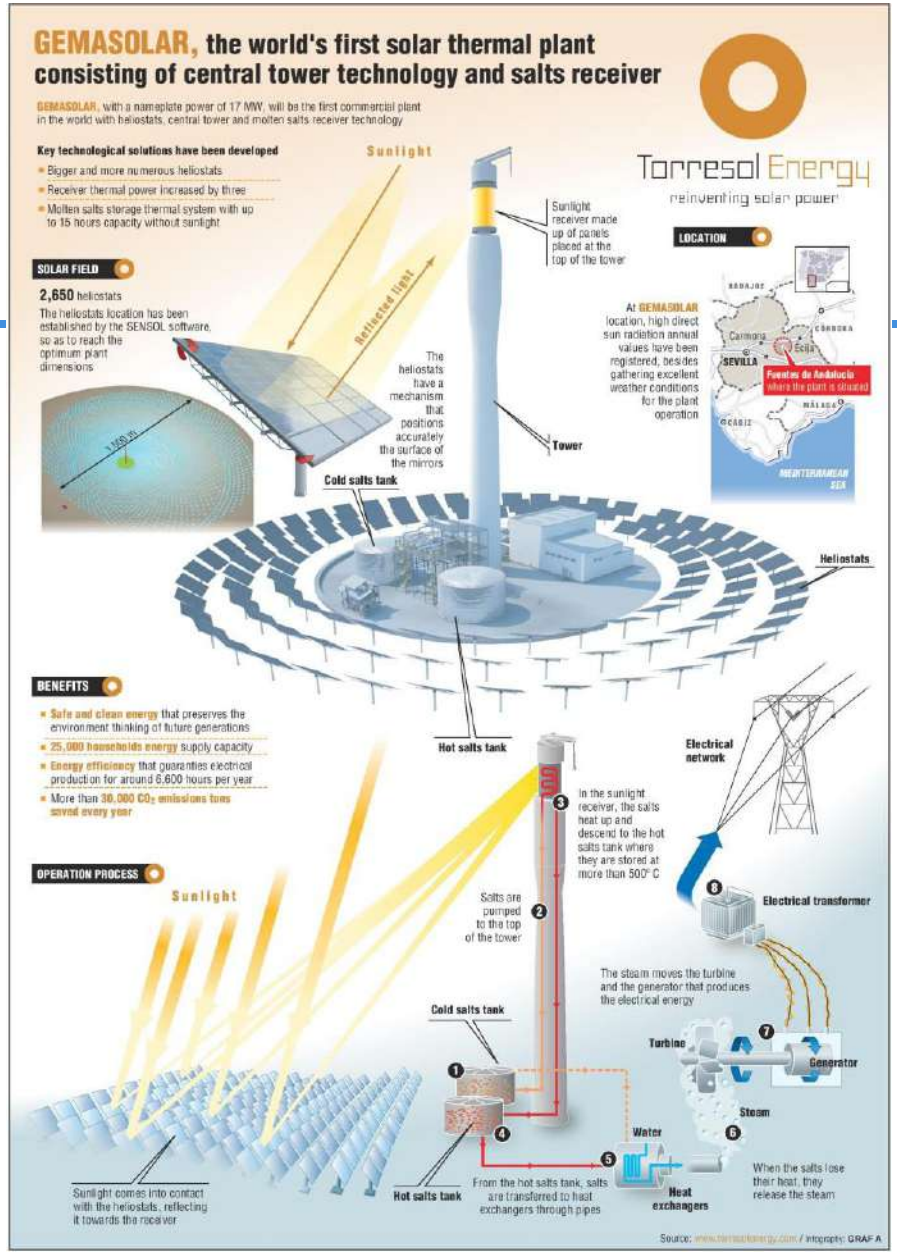

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ثالثاً- أشكاليات و تحديات تغذية الشبكات الكهربائية بالطاقة المنتجة من الطاقة الشمسية و طاقة الرياح -17-

-عندما تتوافر أشعة الشمس المباشرة: تقنيات الطاقة الشمسية المركزة: .....

-يوجد في الأسواق العالمية تجهيزات جاهزة مصممة بقدرات مختلفة (ابتداء من 250 كيلووات كهرباء)
-كفاءة المركزات (التحويل الى طاقة حرارية 50-55%)
-كفاءة التحويل الى طاقة كهربائية 20%
-الكفاءة الأجمالية 10-11%

-القدرة بالكيلووات :	1000	500	250
-المساحة بالمتر المربع:	23800	12000	620

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ثالثاً- أشكاليات و تحديات تغذية الشبكات الكهربائية بالطاقة المنتجة من الطاقة الشمسية و طاقة الرياح -18-

Site selection: solar technology requires more space....

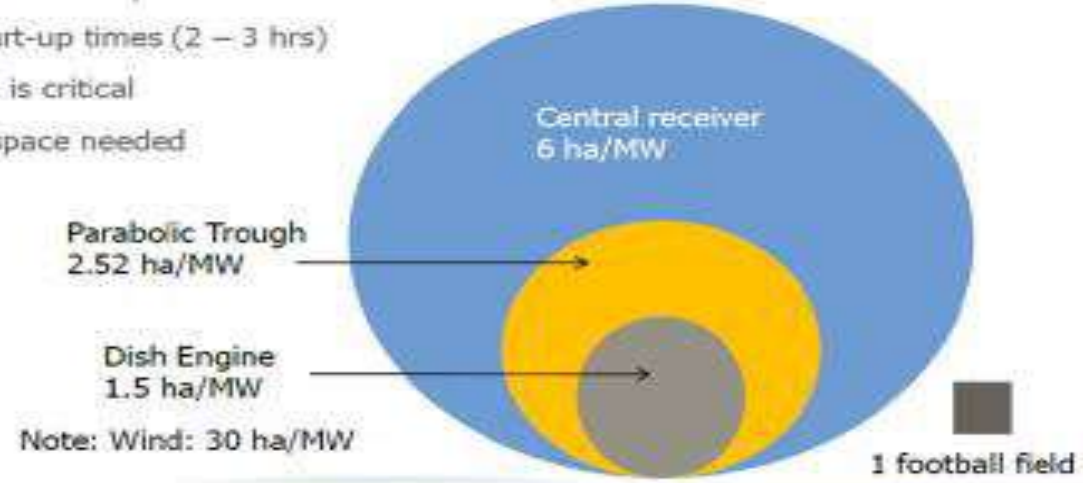
Large captital investment: 2000 – 5000 €/kW (dependent on technology, storage, ...)

Few data about operation and maintenance

Long start-up times (2 – 3 hrs)

Location is critical

Lots of space needed



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ثالثاً- أشكاليات و تحديات تغذية الشبكات الكهربائية بالطاقة المنتجة من الطاقة الشمسية و طاقة الرياح -19-

واو-الحاجة الى المياه: إضافة الى الحاجة لمياه التبريد اللازمة للمكثف في نظام الدارة البخارية الذي يعمل بالطاقة الشمسية المركزة، هناك حاجة اضافية للمياه لتنظيف المرايا من الغبار، بهدف تفادي انخفاض الكفاءة البصرية وبالتالي كفاءة الانتاج، مثلاً: لتنظيف مرايا نظام البرج المركزي 300 ألف متر مكعب من المياه سنوياً لمحطة بقدرة 50 MW. و كذلك لوحات الخلايا و ريش العنفات الريحية.

زين- صعوبات تخزين الطاقة: نقطة الضعف الاساسية للطاقة الشمسية ولطاقة الرياح وللطاقة الكهربائية.
---الحلول: التخزين الكيمائي في البطاريات (مع الليثيوم)، وانتاج الهيدروجين أو الهواء المضغوط لاستعمال طاقتهما لاحقاً، تكنولوجيات مكلفة ولم تستطع لتاريخه إثبات جدواها الاقتصادية والفنية.
---حلان معتمدان حالياً في حدود معينة:
- الحل الأول: التخزين الحراري في المحطات الشمسية الحرارية المركزة CSP حيث يصبح ممكناً عمل هذه المحطات على مدى الاربع وعشرين ساعة، عبر تخزين الحرارة في أملاح معدنية يصار الى تذويبها / تغير حالتها من الجامد الى السائل يسمح بتخزين كميات طاقة حرارية مرتفعة (مثال على ذلك أملاح الصوديوم و البوتاسيوم : NO3Na و NO2Na وNO3K)
- الحل الثاني : أسبق تاريخياً ، ثبتت جدواه الاقتصادية والفنية منذ سنين عديدة: تخزين الطاقة المائية

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ثالثاً- أشكاليات و تحديات تغذية الشبكات الكهربائية بالطاقة المنتجة من الطاقة الشمسية و طاقة الرياح -20-

حاء-الفجوات السياسية والتشريعية والتنظيمية والمؤسساتية و التمويلية:

1- ستكون هناك حاجة لمضاعفة القدرة المجهزه في العشر سنوات القادمة(أي قدرة بحدود 500 ألف ميغاواط) . هل مؤسسات الكهرباء قادرة على ذلك؟ كلفة التجهيزات الجديدة؟ أستبدال تجهيزات قديمة عند انتهاء حياتها؟ **الكلفة التأسيسية العالية لتجهيزات الطاقة الشمسية و طاقة الرياح !** القطاع الخاص لسد الفجوة التمويلية ؟ تهيئة الاجواء للاستثمار ولاعطاء الضمانات للقطاع الخاص للاقبال على الاستثمار في الدول العربية، ولن يتأمن ذلك سوى بالاستقرار الامني والسياسي والتشريعي ووجود الحكم الرشيد.

2-عدم وضوح الهدف المعلن في الاستراتيجية: نسبة مئوية من الطاقة الأولية/ نسبة من الطاقة الكهربائية المنتجة/ نسبة من القدرة المجهزة

3- عدم ترجمة الهدف المعلن في الاستراتيجية الى خطة عمل مع برنامج زمني، لتأمين هذا الهدف، او تضمينه في التشريعات الخاصة بقطاع الطاقة، باستثناء عدد قليل من الدول العربية.

4- القصور المؤسساتي و التمويلي : غياب هيئة ناظمة لقطاع الكهرباء و/أو لقطاع الطاقة، أو عدم تمتع هذه الهيئة بصلاحيات كافية. اضافة الى أن معظم شركات ومؤسسات الكهرباء تتلقى دعماً حكومياً لدعم تعريفات مبيع الطاقة الكهربائية الى المستهلكين، وتعاني من عجز مزمن في موازناتها الخاصة+شركات الكهرباء في الدول العربية المنتجة للنفط و/أو للغاز، تحصل على حاجاتها من الوقود بأسعار مدعومة وشبه مجانية، مما يعطي افضلية للانتاج الحراري التقليدي.

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ثالثاً- أشكاليات و تحديات تغذية الشبكات الكهربائية بالطاقة المنتجة من الطاقة الشمسية و طاقة الرياح -21-

5- في حالات التوجه الى إعطاء تعرفة أفضلية مميزة لشراء الطاقة الكهربائية المنتجة من مصادر طاقة متجددة:

تخوف من انتقال الدعم من المستهلكين/عموم المواطنين نظرياً، الى فئة أقل عدداً من المنتجين المستثمرين.

6- غياب ضمان استمرار اعطاء الافضلية للطاقة الكهربائية المنتجة من مصادر الطاقة المتجددة، لفترات طويلة من منتجين خاصين، و التخوف من عدم وجود استقرار تشريعي .

7- غياب أو ضعف دور منظمات المجتمع المدني المستقلة، التي يقع على عاتقها التأكد من صحة ما يقال ويكتب ويعلن من ارقام احصائية، أو خطط أو توجهات او مشاريع الخ....

8- إعتماد بعض الحكومات العربية على هبات ومساعدات للقيام بمشاريع الطاقة المتجددة.

9- نقص في وجود قواعد ربط لوسائل الانتاج الخاصة على الشبكة الكهربائية، وكود للشبكة، توضيحاً للمتطلبات والمواصفات الفنية، والحدود المقبولة للتردد والتوتر.

10-قصور الابحاث العلمية المواكبة لتوطين التكنولوجيات الملائمة، و نقص الكادرات الفنية المؤهلة لتركيب وصيانة التجهيزات ذات العلاقة وصولاً الى تصنيع جزئي أو كلي

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ثالثاً- أشكاليات و تحديات تغذية الشبكات الكهربائية بالطاقة المنتجة من الطاقة الشمسية و طاقة الرياح -22-

11-غياب العوامل الضرورية والمساعدة لنشوء الصناعة العربية المحلية لمعدات الطاقة المتجددة: توافر المعرفة والتكنولوجيا، مع امكانيات المتابعة والتطوير/ تأمين المناخ الملائم للاستثمار في انشاء مصانع عربية /وجود قاعدة صناعية محلية/وجود أسواق محلية مع إمكانيات التصدير الى الاسواق في الخارج /الشراكة بين شركات التصنيع العالمية و المحلية

12-عدم صلاحية البنية التحتية اللازمة على مستوى شبكات الكهرباء

13-حصرية أنتاج الطاقة الكهربائية في بعض الدول العربية

14- عدم وجود تشريعات و تنظيمات وضمانات لاصحاب العقارات او مستأجريها – لجهة أحترام مسافات التباعد بين العنفات- الذين يمكن أن يعمدوا الى الاستثمار وقيام مشاريع لانتاج الكهرباء من طاقة الرياح، فهذه الطاقة مورد عام.

15-تأثر الكلفة الى حد بعيد بفائدة الرأسمال و بالموقع الجغرافي للتجهيز.

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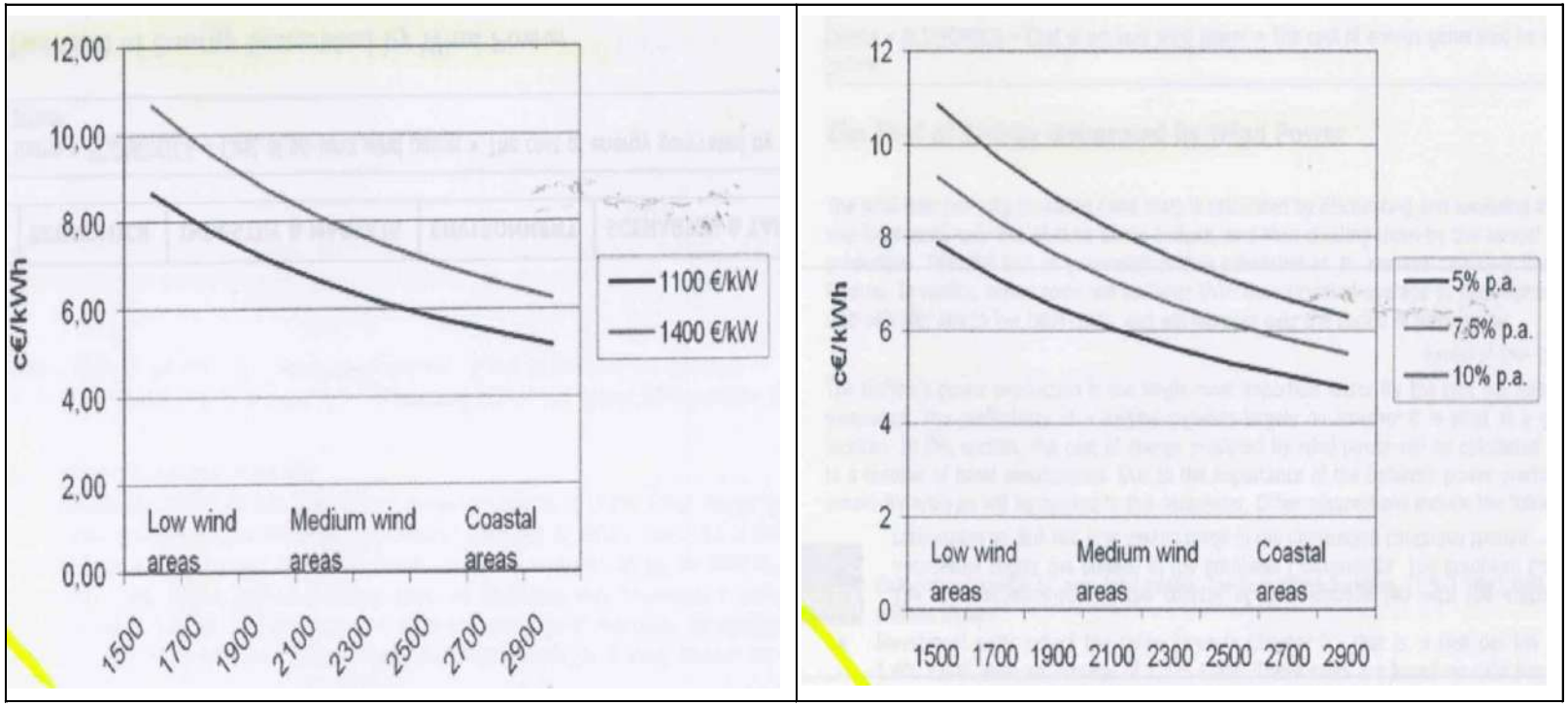
ثالثاً- أشكاليات و تحديات تغذية الشبكات الكهربائية بالطاقة المنتجة من الطاقة الشمسية و طاقة الرياح -23-



The cost of Wind – Produced power as a function of wind speed (Euro Cent/kWhr)
Number of full load hours per year

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خلاصة

@ لم يصل قطاع الكهرباء لنضوجه الفني والاقتصادي في بعض الدول العربية: كهربة الريف غير كاملة (اليمن- السودان...)، نوعية وامن الامدادات بالطاقة الكهربائية لم تصل الى المستوى اللائق (لبنان- العراق- مصر – سوريا....)، في حين ان دولاً عربية أخرى تؤمن الطاقة الكهربائية لكافة مواطنيها، لكنها هل تكون في المستقبل قادرة على الاستمرار بنفس المستوى اذا استمر الاعتماد على الوقود الاحفوري بشكل مطلق؟

@ الحل : اعتماد مصادر الطاقة المتجددة، وتحديداً الطاقة الشمسية وطاقة الرياح لانتاج الكهرباء للشبكات لوجود فرص وامكانات ومزايا ايجابية

@ دون ذلك صعوبات أهمها ضرورة لحظ ما يجب على صعيد الشبكات الكهربائية لاستيعاب وسائل انتاج الكهرباء من مصادر الطاقة المتجددة.

@ اضافة الى الصعوبات التكنولوجية والفنية التي لا تستحيل معالجتها، هناك صعوبات التمويل والبيئة التشريعية والمؤسساتية والتنظيمية اللازمة

@- أهمية وجود الحكم الرشيد والاستقرار الأمني والسياسي والتشريعي لخلق المناخ اللازم للاستثمار وللشراكة بين القطاعين العام والخاص .

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w-deghaili@hotmail.com

اللجنة الاقتصادية والاجتماعية لغربي آسيا

شكراً

الأمم المتحدة

الاسكوا

ESCWA

المنظومة الكهربائية و الطاقات المتجددة بالمغرب

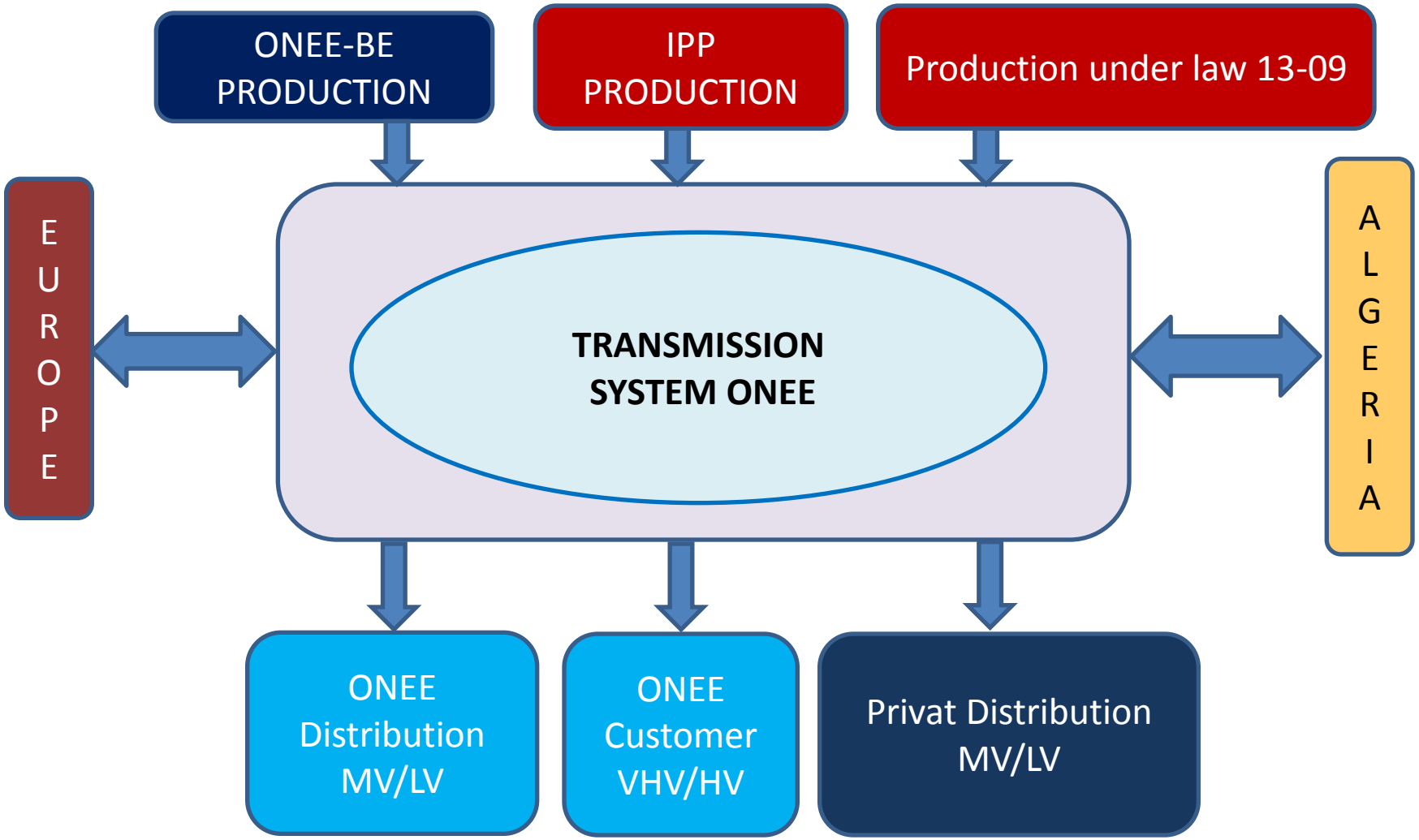
تحديات تنمية النظام الكهربائي المغربي

- ضمان توازن العرض والطلب مع الزيادة المستمرة في الطلب (7٪ سنويا)
- فاتورة الطاقة الثقيلة (التبعية للخارج)
- أسعار الطاقة المتقلبة
- ندرة المال العام
- احترام البيئة

استراتيجية تنمية و تطوير النظام الكهربائي المغربي

- **ضمان إمدادات الطاقة**: تحسين قدرة ومرد ودية نظم الإنتاج والشبكة الكهربائية
- **البحث عن كيلووات ساعة الأرخص**: تخطيط نظام الطاقة على عدة آفاق (طويلة ومتوسطة وقصيرة الأجل)،وتحسين الأداء الصناعي، وتشجيع الاستثمار الخاص، واستخدام التقنيات والاستفادة المثلى من الطاقة الأحفورية
- **تنويع مصادر الإنتاج**: تحسين مرونة النظام الكهربائي والبحث عن أرخص كيلووات ساعة
- **النهوض بالطاقات المتجددة**: الحد من التبعية للخارج، والحد من تكاليف التشغيل
- **التكامل الإقليمي** : تطوير الربط مع الدول المجاورة ، والانضمام للأسواق الكهربائية في المنطقة، والاستفادة من الفرص الاقتصادية

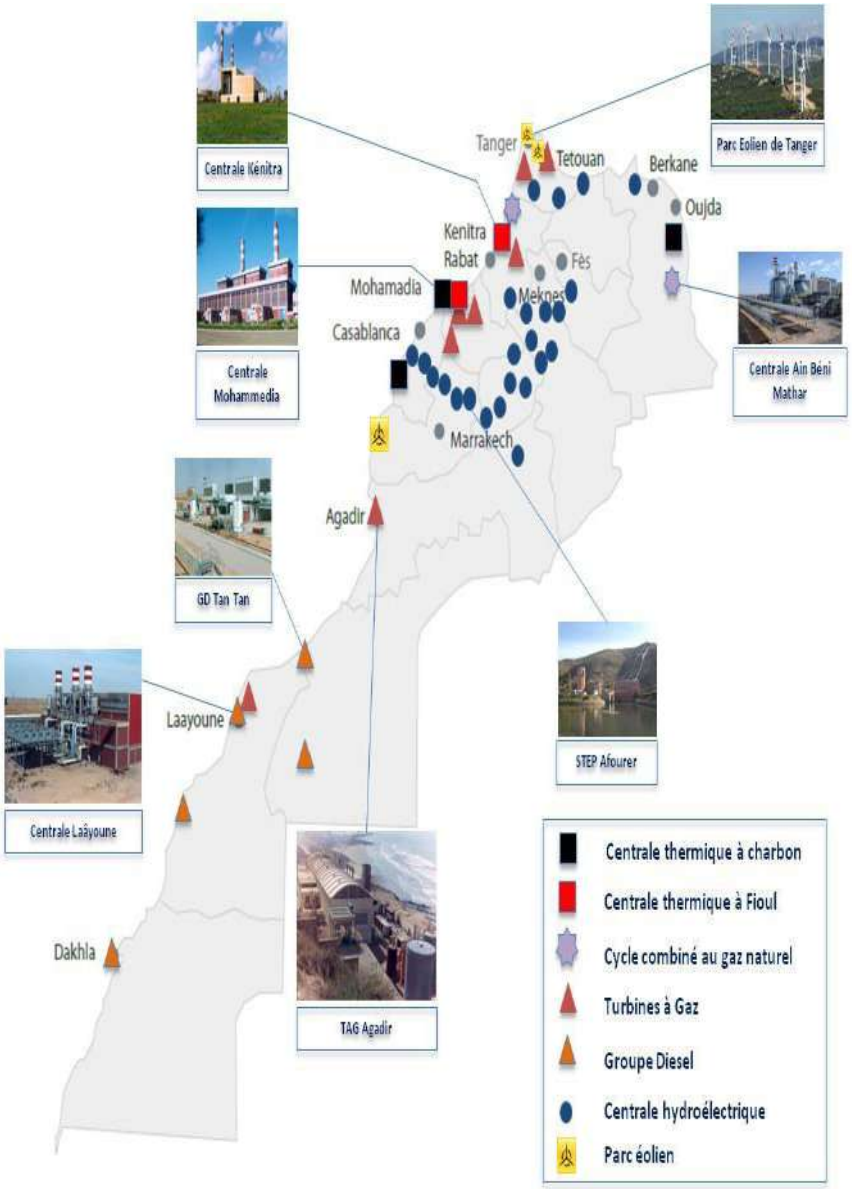
المنظومة الكهربائية بالمغرب



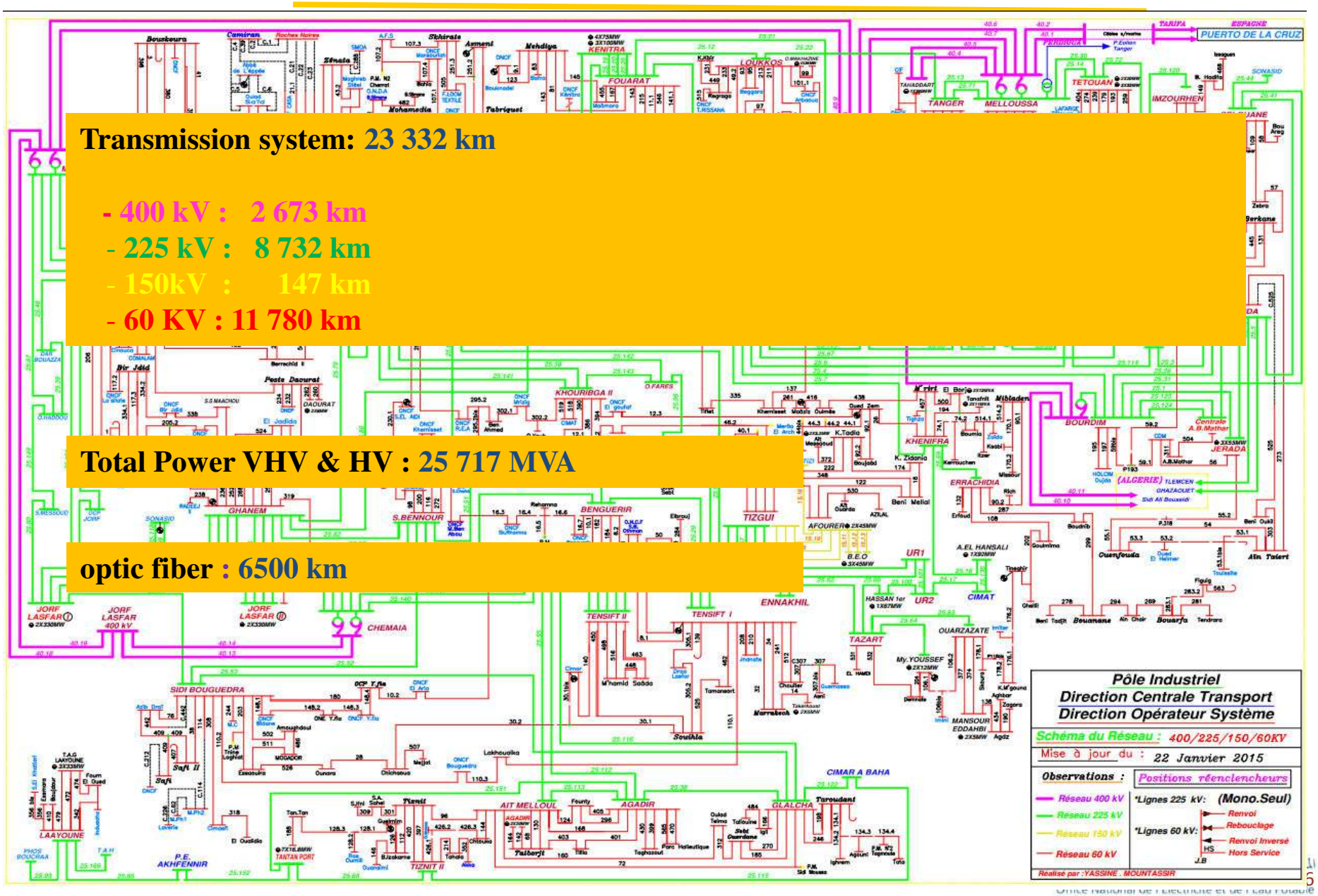
القدرة المنشأة الإجمالية 2014

%	ميغاواط	وسائل الإنتاج
32	2545	المحطات الحرارية ⟨الفحم ⟩
25	2032	المحطات الحرارية ⟨الديزل – فيول⟩
10	830	المحطات الحرارية ⟨الغاز الطبيعي⟩
68	**5407**	**مجموع الطاقة الحرارية**
22	1770	المحطات الكهرومائية
10	797	الحقول الريحية
0,25	20	المحطات الشمسية
32	**2587**	**مجموع الطاقة المتجددة**

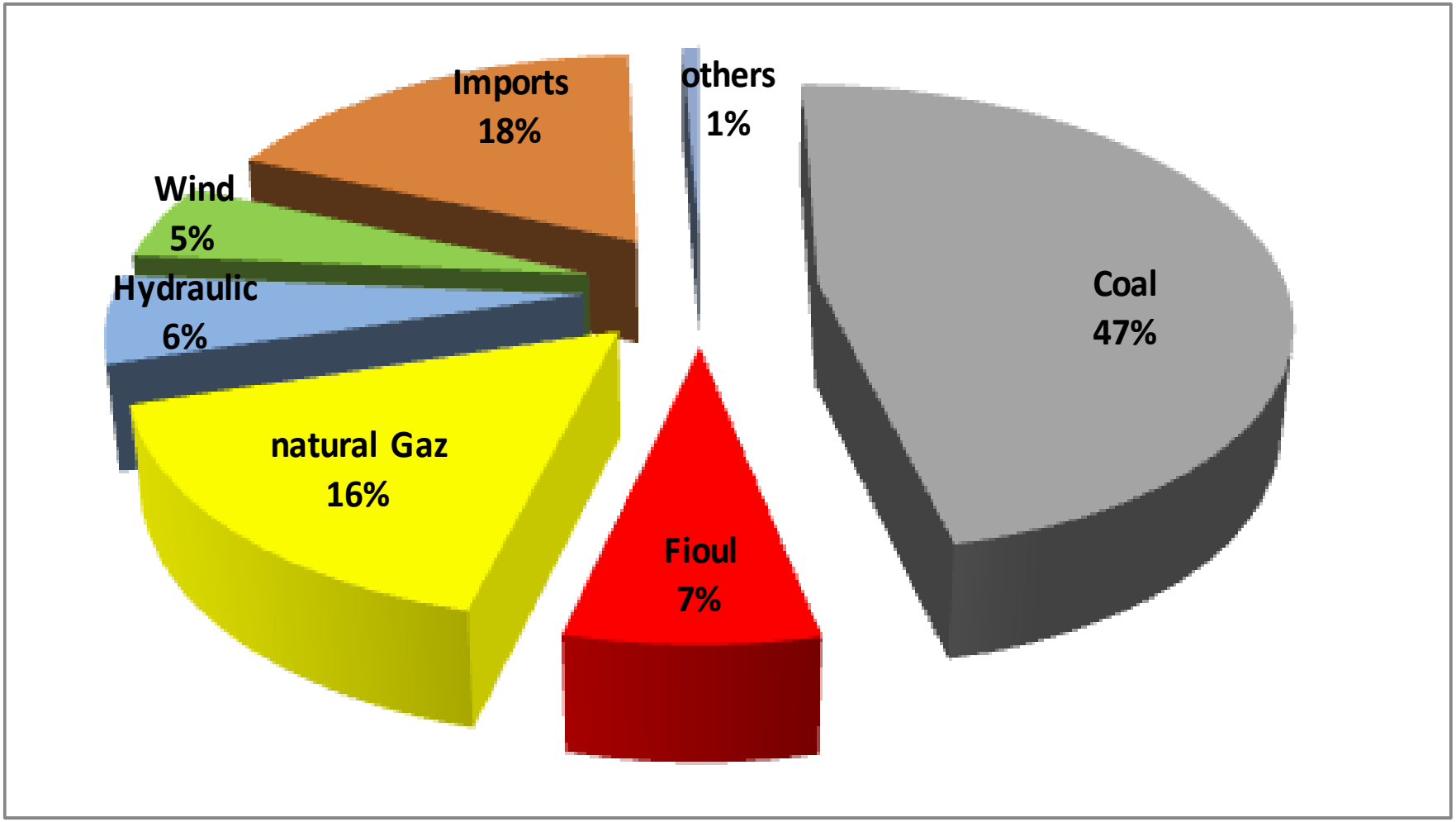
Installed Capacity: 7 994 MW



الشبكة الكهربائية


Pôle Industriel
Direction Centrale Transport
Direction Opérateur Système
Schéma du Réseau : 400/225/150/60KV
Mise à jour du : 22 Janvier 2015
Observations :
Positions réenclencheurs
Réseau 400 kV
Réseau 225 kV
Réseau 150 kV
Réseau 60 kV
*Lignes 225 kV: (Mono.Seul)
*Lignes 60 kV:
Renvoi
Rebouclage
Renvoi Inversé
HS Hors Service
Réalisé par : YASSINE . MOUNTASSIR
PUERTO DE LA CRUZ
TANGER
MELLOUSSA
TETOUAN
IMZOURHEN
KENITRA
FOUARAT
LOUKKOS
Mohamedia
Tabriquet
Sidi Kacem
Sidi Slimane
Mehdiya
Sidi Yahia
Sidi Bouknadel
Sidi Ben Ahmed
Sidi Bouzekri
Sidi Ifni
Sidi Bou Ali
Sidi Ali Bousaidi
Sidi Bou Said
Sidi Taibi
Sidi Kacem
Sidi Bouzid
Sidi Ali
Sidi Boulal
Sidi Bou Said
Sidi Ahmed
Sidi Bou Ali
Sidi Bou Said
Sidi Ali Bousaidi
Sidi Bou Said
Sidi Ali Bousaidi
Sidi Bou Said
Sidi Ali Bousaidi

مصادر تلبية الطلب



برنامج تطوير الطاقات المتجددة

- الإستراتيجية الطاقية الجديدة
- الإطار التشريعي والتنظيمي
- الإطار التقني
- حلول وبرامج لتسهيل تطوير الطاقات المتجددة

الإستراتيجية الطاقية الجديدة

- الإطار التشريعي والتنظيمي
- الإطار التقني
- حلول وبرامج لتسهيل تطوير الطاقات المتجددة

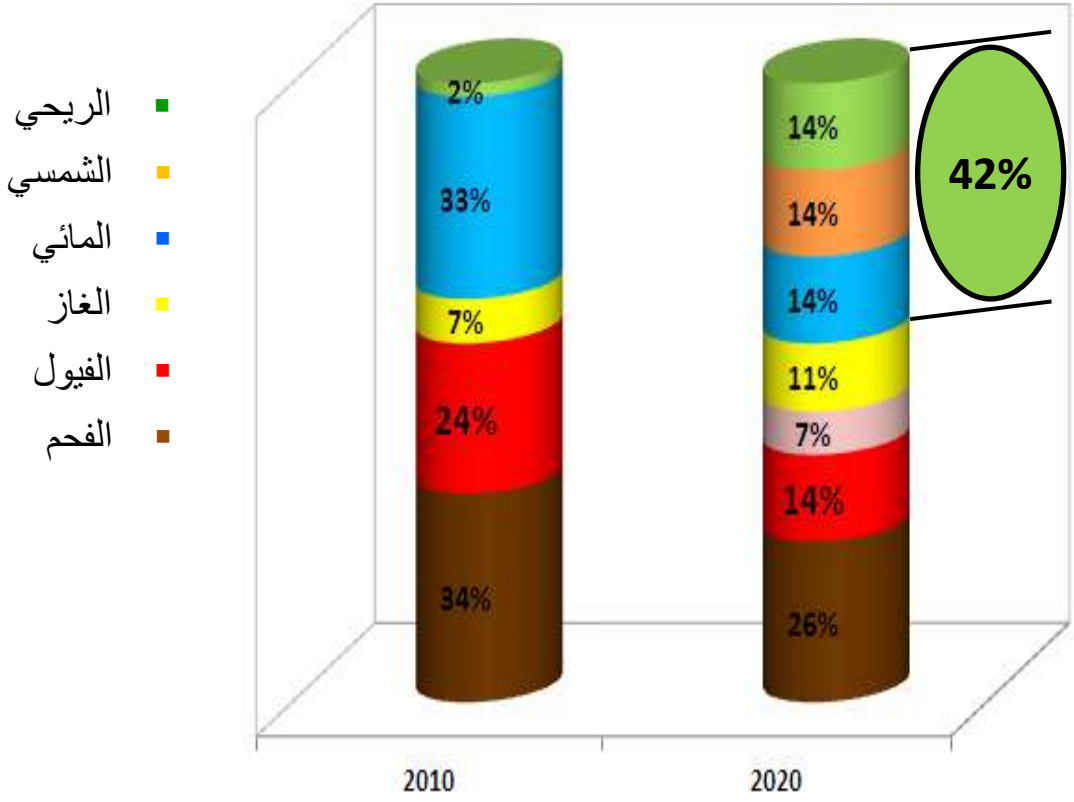
⇦ نمو اقتصادي و اجتماعي بوتيرة مرتفعة بفضل إنجاز و إعطاء انطلاقة أوراش كبرى مهيكلة في مجال البنيات التحتية ونجاح برامج التنمية البشرية والمستـــــدامة.

⇦ هذه التنمية، التي لم يعرف المغرب مثيلا لها، يترتب عنها التزايد القوي للحاجيات من الطاقة.

⇦ لرفع هذا التحدي الكبير و ضمان تنمية مسؤولة، قررت الحكومة إعداد مخطط جديد للتجهيز على أساس رؤية شاملة و مندمجة. يتضمن هذا المخطط إنشاء حظيرة كهربائية متنوعة، تحتل فيها الطاقات المتجددة مكانة مرموقة.

الإستراتيجية الطاقية الجديدة

مزيج كهربائي مع حصة مهمة للطاقات المتجددة
تصل إلى **42 %** في أفق **2020**



الإطار التشريعي والتنظيمي

الإطار التقني

حلول وبرامج لتسهيل تطوير الطاقات المتجددة

قانون الإنتاج المستقلIPP
(PPA : Power Purchase Agreement)

الإستراتيجية الطاقية الجديدة

الإطار التشريعي والتنظيمي

الإطار التقني

حلول وبرامج لتسهيل تطوير الطاقات المتجددة

اِلتزام شراء الطاقة الكهربائية خلال فترة العقد (20-30 سنة)

الضمانات الحكومية بدفع مبلغ إنهاء المشروع في حالة الإنهاء المبكر للعقدة

التصرف في موقع المشروع خلال فترة العقدة

القانون 14-54 : الإنتاج الذاتي

إلغاء قانون 2009 الذي يحد الإنتاج الذاتي بين 10- 50 ميكاوات

القانون 54-14: ترخيص الولوج إلى شبكة النقل لإنتاج ذاتي تتجاوز طاقته 300 ميجاوات

إنتاج ذاتي غير محدود

الإستراتيجية الطاقية الجديدة

الإطار التشريعي والتنظيمي

الإطار التقني

حلول وبرامج لتسهيل تطوير الطاقات المتجددة

القانون 09-13: الطاقات المتجددة

الإستراتيجية الطاقية الجديدة

الإطار التشريعي والتنظيمي

الإطار التقني

حلول وبرامج لتسهيل تطوير الطاقات المتجددة

تحرير إنتاج وتسويق الكهرباء المنتجة من الطاقة المتجددة

الولوج إلى الشبكة الكهربائية ذات الجهد العالي والعالي جِدًّا

فتح شبكة التوزيع في جدول الأعمال

القانون 09-47: النجاعة الطاقية

الإدارة المثلى للموارد الطاقية

السيطرة على الطلب

زيادة القدرة التنافسية للاقتصاد

السيطرة على الخيارات التكنولوجية

الاستخدام الرشيد للطاقة

قانون 09-16: إنشاء وكالة لتنمية الطاقة المتجددة والنجاعة الطاقية

الإستراتيجية الطاقية الجديدة

الإطار التشريعي والتنظيمي

الإطار التقني

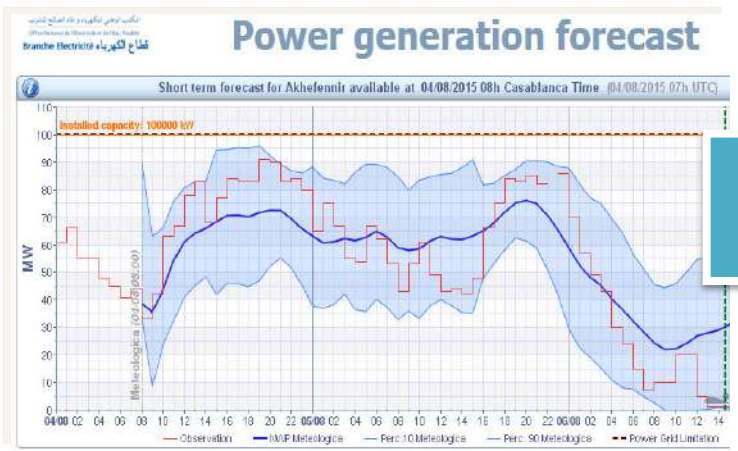
حلول وبرامج لتسهيل تطوير الطاقات المتجددة

الصعوبات التقنية

الطاقات المتجددة تؤثر على النظام الكهربائي بالكامل:

- نسبة الولوج
- نوع التكنولوجيا
- الموقع الجغرافي

الهدف: المحافظة على موثوقية الإمدادات



استحالة التنبؤ المضبوط

تزايد الحاجة إلى المرونة

الإستراتيجية الطاقية الجديدة

الإطار التشريعي والتنظيمي

الإطار التقني

حلول وبرامج لتسهيل تطوير الطاقات المتجددة

الصعوبات التقنية

الإستراتيجية الطاقية الجديدة

الإطار التشريعي والتنظيمي

الإطار التقني

حلول وبرامج لتسهيل تطوير الطاقات المتجددة

تزايد صعوبة تحقيق التوازن بين العرض و الطلب

الحاجة إلى توفر مرونة إضافية

الحاجة إلى تطوير و تنمية الشبكة و الترابطات

شروط الربط

الزيادة الكبيرة في القدرة المركبة الريحية مرهون بمدى قدرة هذه الحقول على الصمود في حالة الاضطرابات

مدونات شبكة (grid code)لشبكة النقل مهتمة

1- التحكم في النظام الكهربائي: التردد / الجهد

2 - سلوك الحقل في ظل ظروف الشبكة الغير الطبيعية

وعلى النقيض من وحدات الإنتاج الصغيرة على مستوىشبكة التوزيع، فمدونات فتهتم ب: (grid codeالشبكة)

جودة الطاقة

المساهمة في القدرة Pccنظم الحماية

الإستراتيجية الطاقية الجديدة

الإطار التشريعي والتنظيمي

الإطار التقني

حلول وبرامج لتسهيل تطوير الطاقات المتجددة

شروط الربط

منح /امتصاص الطاقة التفاعلية

يجب على الحقل الريحي ان يوفر إمكانية منح وامتصاص الطاقة التفاعلية

الإمتصاص بين 0 و 0,3Pn
المنح بين 0 و 0,4 Pn

تغيرات التردد

الوضع الطبيعي: 50 ± 0.1 هرتز
الظروف المتدهورة: 50 + 2 هرتز / -2،5

انخفاضات الجهد

يجب على الحقل الريحي ان يستمر في الإنتاج في انخفاض جهد يصل إلى 80% من الجهد العادي

تغيرات الجهد

- **400 KV : ±5%**
- **225 KV : +8.8 %/-10%**
- **60KV : ±10%**

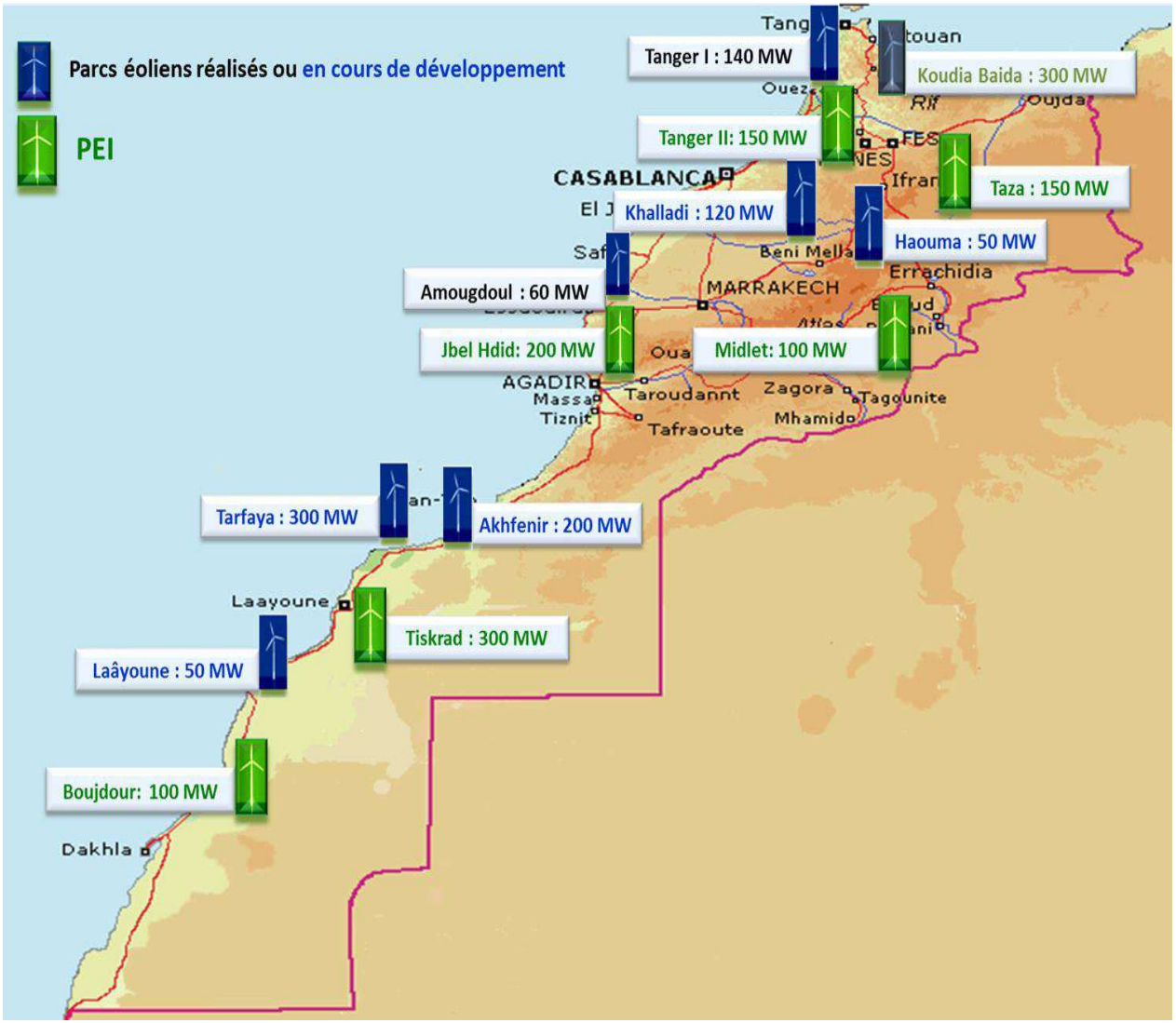
الإستراتيجية الطاقية الجديدة

الإطار التشريعي والتنظيمي

الإطار التقني

حلول وبرامج لتسهيل تطوير الطاقات المتجددة

البرنامج الريحي



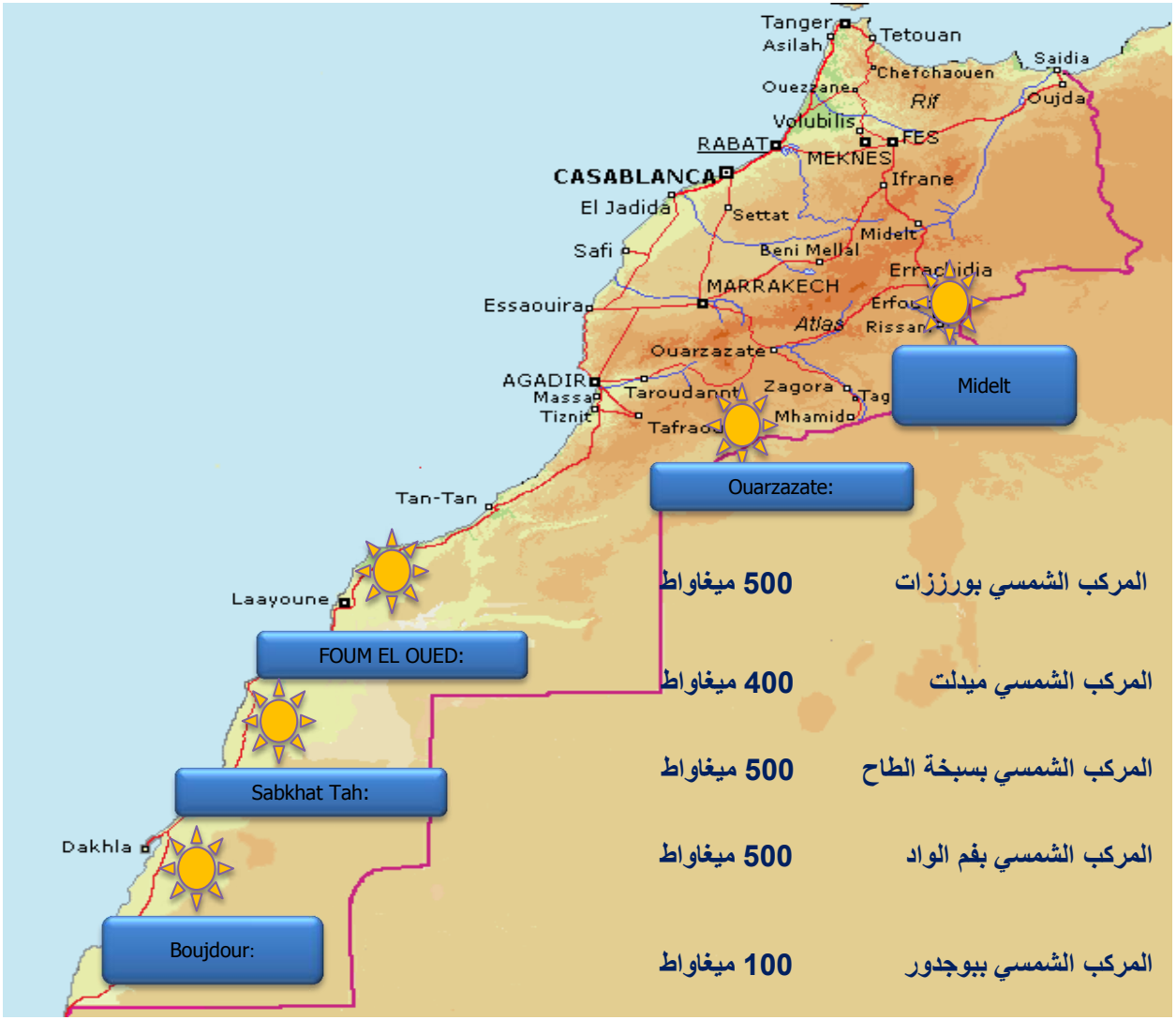
الإستراتيجية الطاقية الجديدة

الإطار التشريعي والتنظيمي

الإطار التقني

حلول وبرامج لتسهيل تطوير الطاقات المتجددة

البرنامج الشمسي المندمج



المركب الشمسي بورززات	500 ميغاواط
المركب الشمسي ميدلت	400 ميغاواط
المركب الشمسي بسبخة الطاح	500 ميغاواط
المركب الشمسي بفم الواد	500 ميغاواط
المركب الشمسي ببوجدور	100 ميغاواط

الإستراتيجية الطاقية الجديدة

الإطار التشريعي والتنظيمي

الإطار التقني

حلول وبرامج لتسهيل تطوير الطاقات المتجددة

البرنامج الكهرمائي

- **مشاريع كهرومائية طور الإنجاز**
  - المعمل المائي المنزل 125 ميغاواط
  - المعمل المائي مدز 45 ميغاواط
  - محطة توليد الطاقة بواسطة الضخ عبد المومن 350 ميغاواط
  - المعمل المائي ولجة السلطان 12 ميغاواط (قانون 09-13)
- **مشاريع كهرومائية طور الدراسة**
  - محطة توليد الطاقة بواسطة الضخ إفحصة 300 ميغاواط
  - مشاريع أخرى 274 ميغاواط

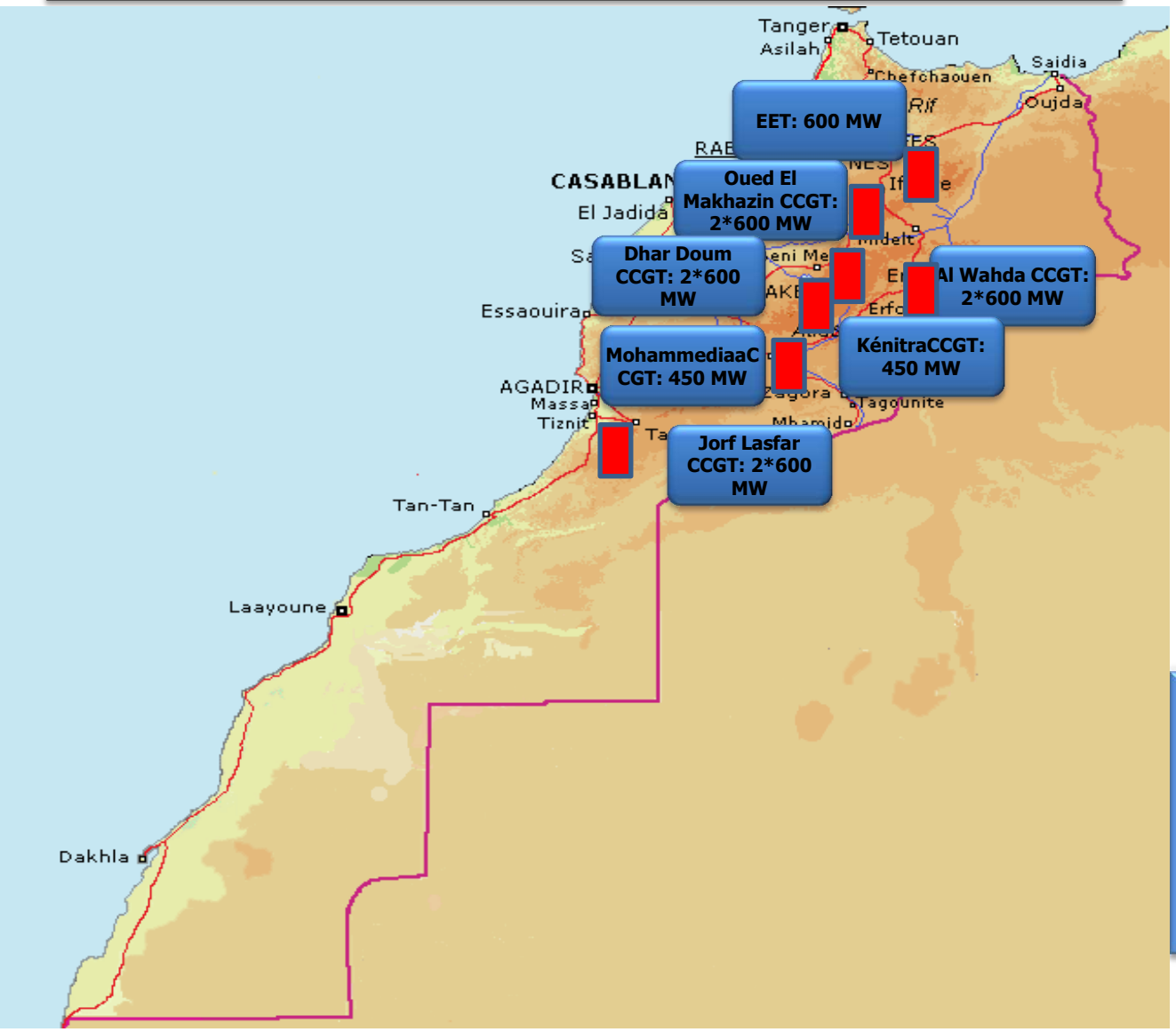
الإستراتيجية الطاقية الجديدة

الإطار التشريعي والتنظيمي

الإطار التقني

حلول وبرامج لتسهيل تطوير الطاقات المتجددة

برنامج الغاز الطبيعي السائل



الإستراتيجية الطاقية الجديدة

الإطار التشريعي والتنظيمي

الإطار التقني

حلول وبرامج لتسهيل تطوير الطاقات المتجددة

أدوات التسيير و التحكم في انتاج الطاقات المتجددة

الإستراتيجية الطاقية الجديدة

الإطار التشريعي والتنظيمي

الإطار التقني

حلول وبرامج لتسهيل تطوير الطاقات المتجددة

أدوات تخطيط الإنتاج على عدة آفاق

برنامج لتنبؤ انتاج الطاقات المتجددة

مركز الضبط والتحكم في الطاقات المتجددة

شكـــرا
على انتباهـــكم

Capacity Building Workshop on: "Integration of RES In Transmission and Distribution Networks in the Arab Region

Approach and Requirements for Integration of RES with the Electricity Grid in the Arab region: Legislative, Regulatory and Economic Considerations

Eng. Marwa Mostafa

Egyptian Electric Utility and Consumer Protection Regulatory Agency (EgyptERA)

Amman – Sep. 2015

Contents

- Introduction .. Where are we?
- Regional initiatives to promote RE in the Arab region
- Process Outlines
- RE Policy Making

  I. Legislative Considerations

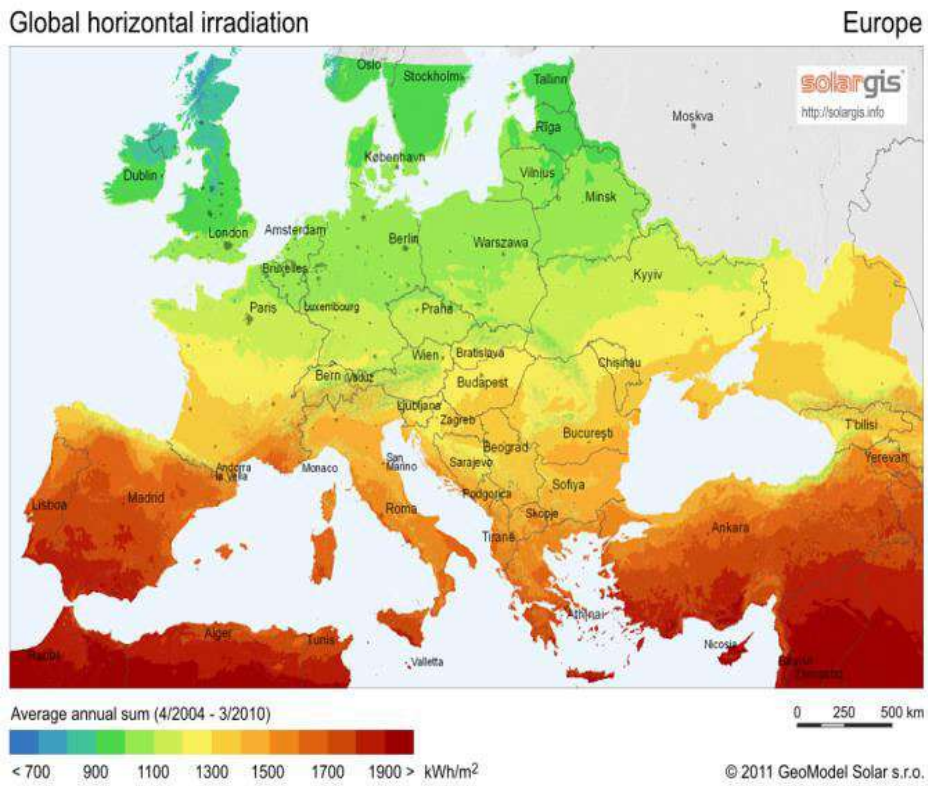
  II. Regulatory Considerations

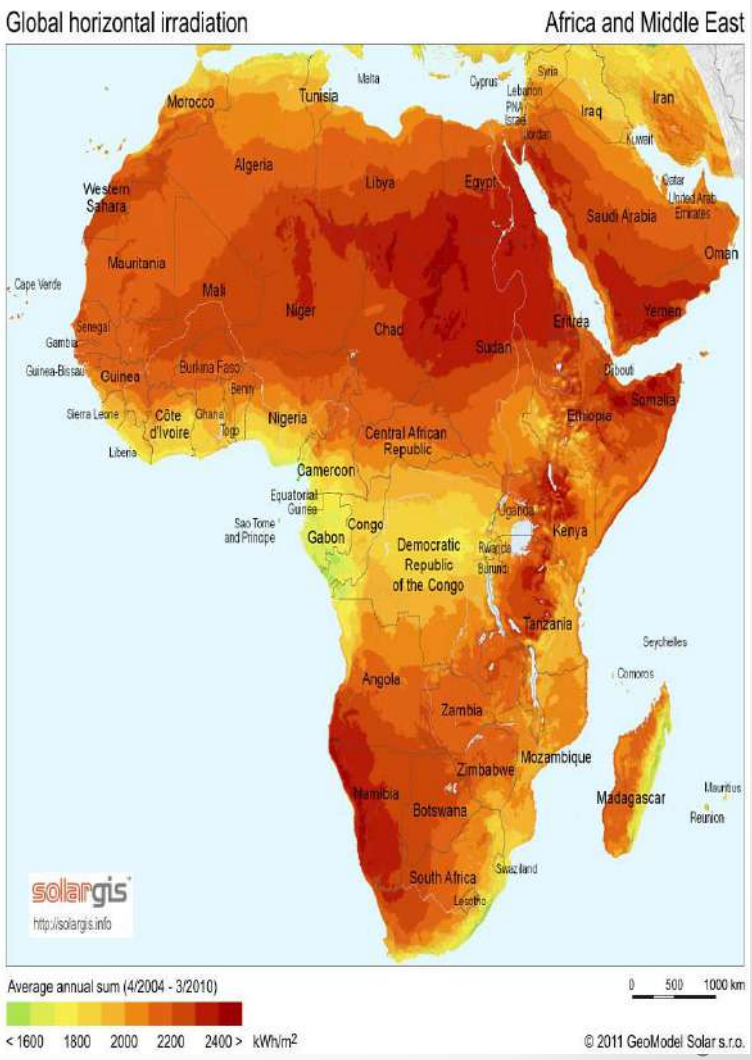
  III. Economics considerations

  IV. The Egyptian Case: Dealing with challenges

Introduction

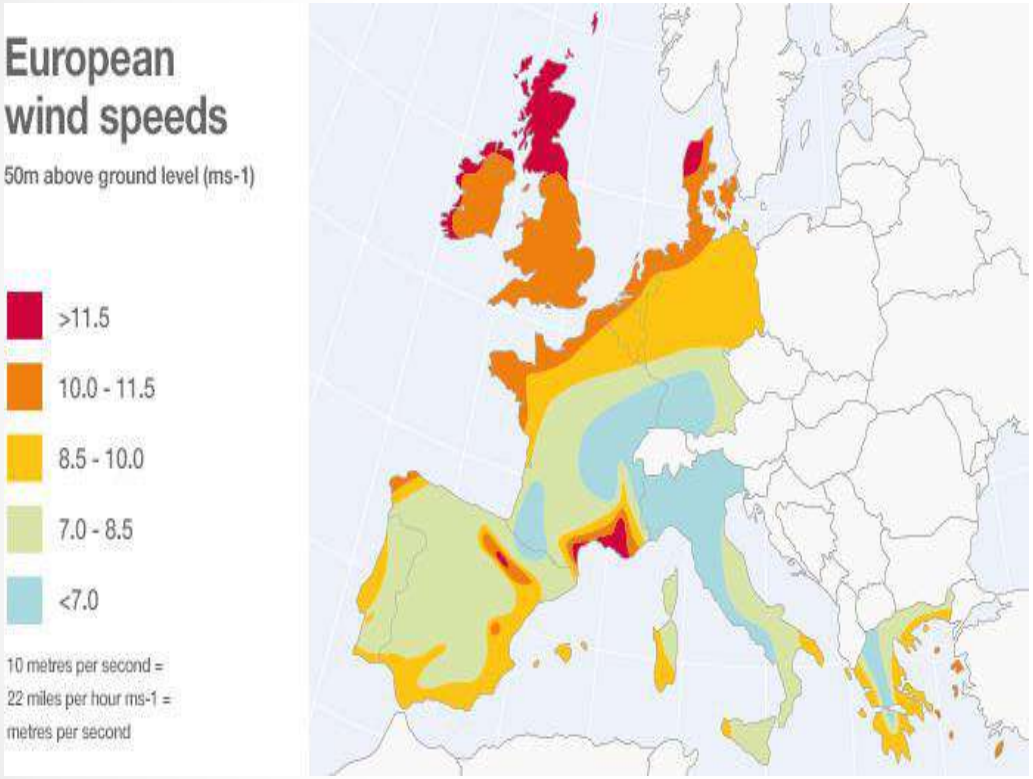
RES potential - Solar

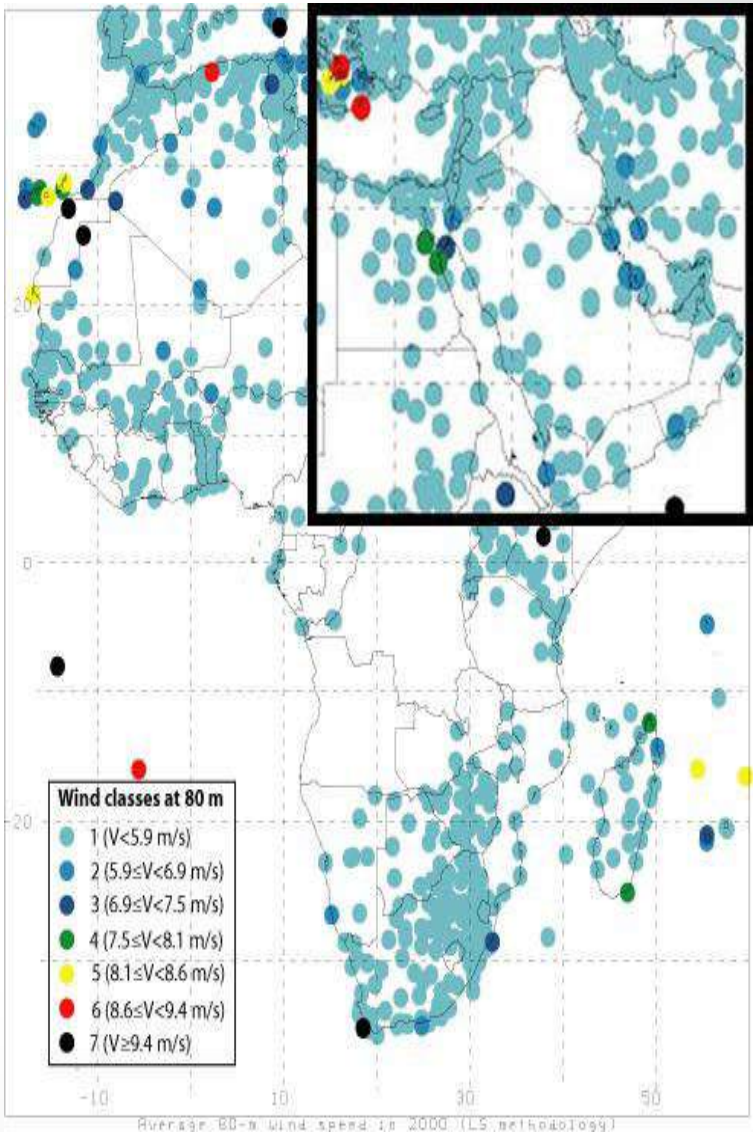




Introduction

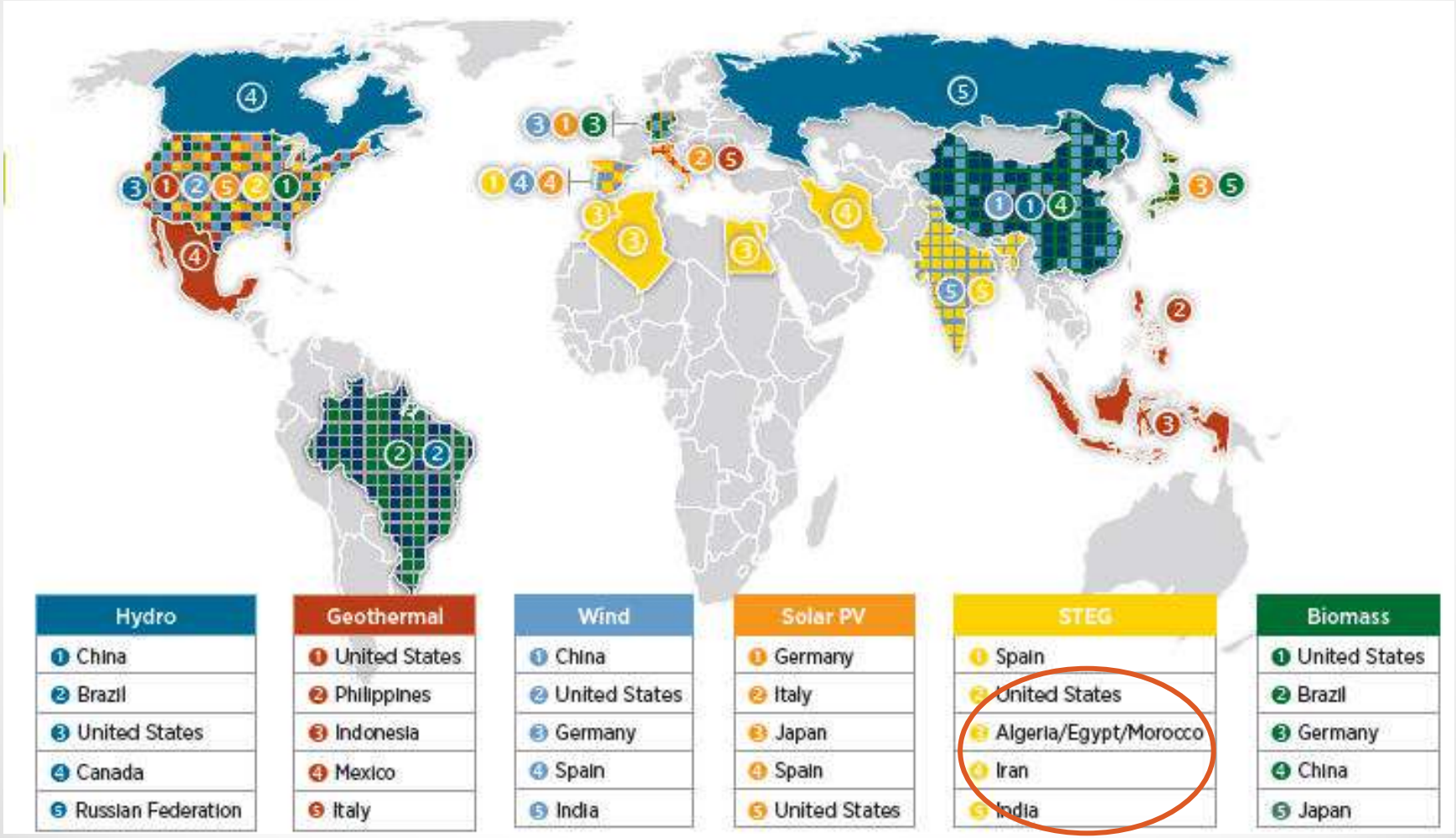
RES potential - Wind





In 2011

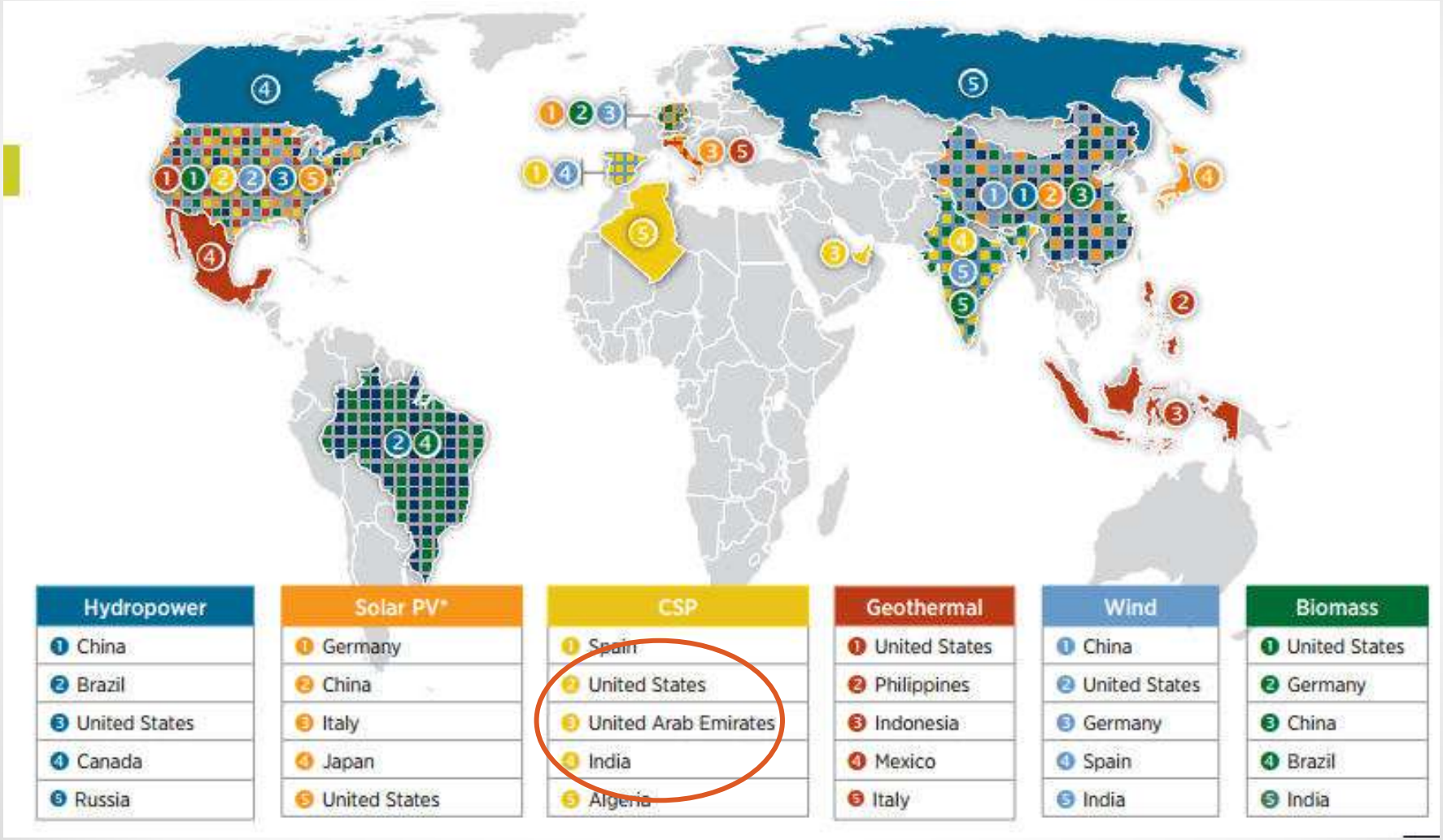
Top countries in RE installations



Source EIA, Bloomberg New Energy Finance, revised 2013

In 2013

Top countries in RE installations



Sources: REN21 *Grid-connected

Regional Initiative to promote RE

Pan-Arab Strategy for the Development of RE Applications: 2010 – 2030

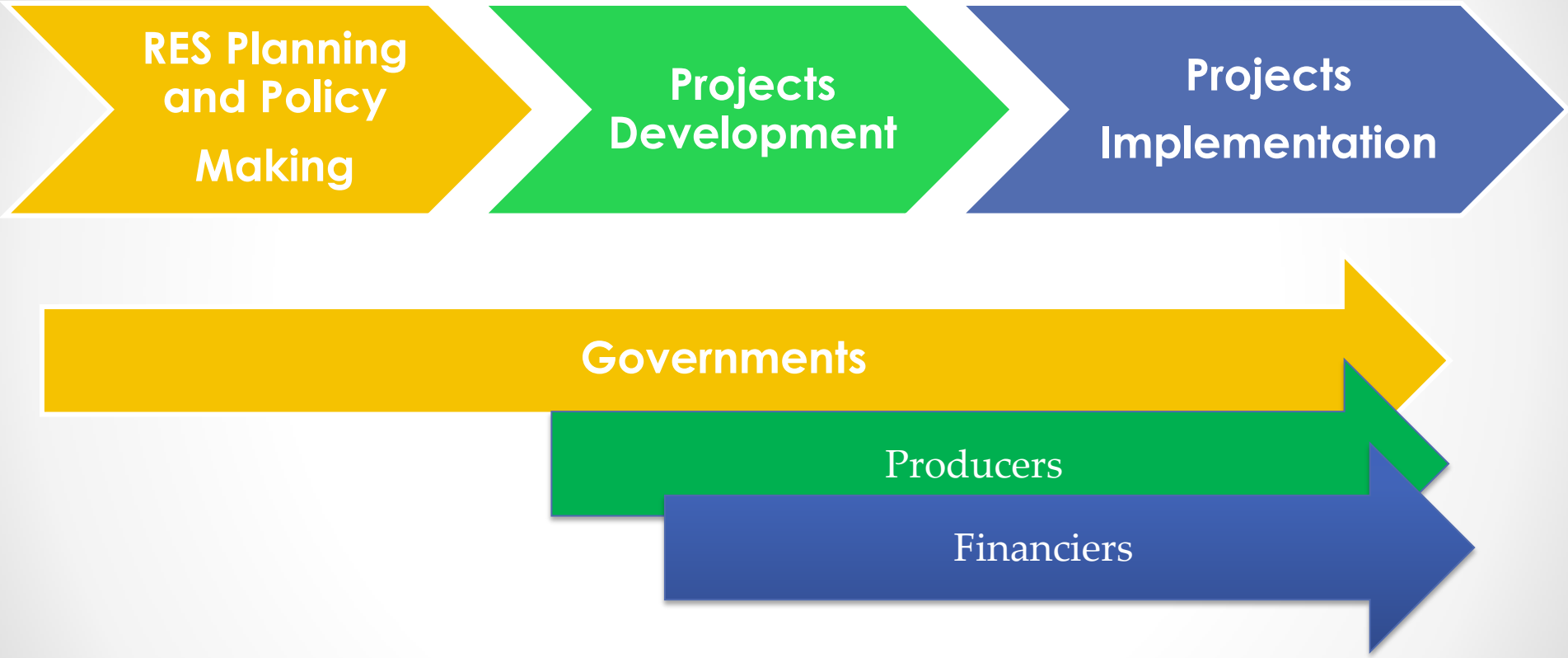
- **Objective:**
  "tap into the region's significant RES to supplement the existing electricity supply"[1].

- **Scope**:
  The electricity sector.

- **Implementation:**
  The Arab Renewable Energy Framework (AREF) provides guidance to the Arab countries in developing their medium to long-term national RE action plans (NREAP).

[1] Pan Arab Renewable Energy Strategy

Process Outline ….



RE Policy Making

RE Policy Making

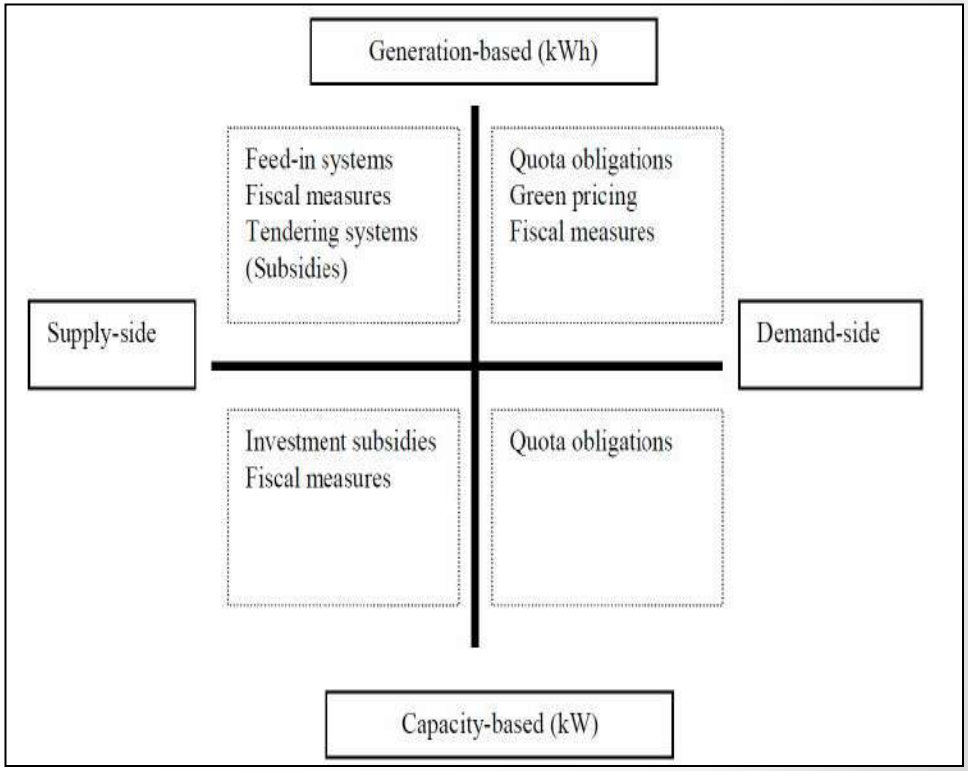
Definition of Targets	Definite target as % of the electricity from RES by certain year

RE Policy Making

Definition of Targets

↓

Choice of policies / instruments



RE Policy Making

Definition of Targets

↓

Choice of policies / instruments

↓

Concrete design of instruments

Getting the prices right:

- Details on cost . Tax levels
- Tariff levels . Inflation rates

Inappropriate instrument design either leads to failure in achieving the targets or – if the support level is too high – targets could possibly be met at the expense of welfare losses for the whole economy.

RE Policy Making

Definition of Targets

↓

Choice of policies / instruments

↓

Concrete design of instruments

↓

Implementation

- Institutional setup
- Drafting of laws and regulations
- Assignment of responsibilities

•

RE Policy Making

Definition of Targets

↓

Choice of policies / instruments

↓

Concrete design of instruments

↓

Implementation

↓

Administration, monitoring, and adjustment

- Monitoring of actual developments
- Measuring contribution to target achievement
- Re-assessing policies
- Adjustment of targets, strategies, policies and instrument design

Legislative, Regulatory & Economic Considerations

There are different considerations that need to be considered in setting up the different strategies that support the chosen policy

- Legislative
- Regulatory
- Economic

Further more:

- Technical
- Financial
- Risk Assessment

I. Legislative Considerations

Setting adequate legislations is a major success factor. The following considerations must be cogitated:

- Legislations must have clear objective and scope
- A law is not a detailed document, it determines and reinforces basic principles .. bylaws and regulations are detailed and explanatory
- Cross cutting legislations must be neither be scattered nor overlapping

I. Legislative Considerations

- Interrelated issues between multiple legislations must be clearly stated, referred to, or at least concerted to avoid confusion and contradiction
- Possible interrelated issues usually occur between Investment law, Taxes law, ..etc.
- Reconciliation articles are often very useful especially when implementation of some schemes precedes issuance of the legislations

I. Legislative Considerations

Legislations are not targets in themselves, they must reflect the market needs,

thus

Legislations must not only be in place but also they have to be enforced

II. Regulatory Considerations

- Regulations are basically the way the legislation is enforced by regulators
- Regulations are specific, informative, transparent, and non discriminating
- They are more subject to change than laws; being easier to adapt to new market conditions
- Although regulations are binding, they are not necessarily of legal nature. Examples of different RE regulations include;
    - Licenses (legal aspects)
    - RE pricing (Financial and economic aspects)
    - Power Purchase Agreements, contracts (contractual aspects)
    - Technical codes (Technical specifications)

II. Regulatory Considerations

The following are crucial issues for consideration:

- RE planning is an integral part of the power system planning (not imposed on it)
- Long term planning is crucial because RE projects have long economic life
- Electricity sector/market structure, Electricity prices
- Lack of stakeholder involvement in decision making
- Insufficient coordination between relevant authorities
- Monitoring of actual developments and measuring achievements against certain benchmarks

III. Economic Consideration

- The levelized cost of electricity produced (LCOE) is a key metric that measures the economic feasibility of RE projects (in addition standard economic metrics, such as installed rated power, the market price of energy and the interest rate)
- It is considered a major criteria for RE policy selection, namely the choice of the type of technology.
- The LCOE is calculated as the present value of periodical costs of an RE power plant divided by the present value of the respective periodical electricity generation from the plant.

III. Economic Consideration

- The LCOE of a power generation technology reflects multiple factors:
  - resource quality,
  - equipment cost,
  - capacity factor,
  - the balance of project costs,
  - fuel costs (if any),
  - operation and maintenance costs,
  - the economic lifespan of the project,
  - and the weighted average cost of capital (WACC).

III. Economic Consideration

- In proving their economic feasibility, RE projects are assessed with respect to either the retail cost of electricity or the wholesale market (utility scale).
- Providing RE fiscal incentives shall add to the economic advantage of the RE projects.

IV. The Egyptian Case: Dealing with challenges

- Legislative challenges
- Regulatory challenges
- Economic Challenges

Thanks for your attention

Marwa Mostafa Mohamed
Head of Planning Dept.
Egyptian Electric Utility and Consumer Protection Regulatory Agency(***EgyptERA***)
Phone + (202) 23421475 Ext. (139)
Fax + (202) 23423482
E-mail marwa.mostafa@egyptera.org,
marwa_mostafa75@yahoo.com
Website www.egyptera.org

Requirements for RES in the future European Grid Codes drafted by ENTSO-E

Pascal BERTOLINI

ESCWA Capacity building workshop, Amman, Jordan, 2-3 Sept 2015

www.rte-international.com

REQUIREMENTS FOR RES

IN THE FUTURE EUROPEAN GRID CODES DRAFTED BY ENTSO-E

1. Why Grid Codes and Who is ENTSO-E?
2. Challenges ahead relevant to RES requirements
3. Technical requirements for RES connection to the grid
4. Connection procedures and compliance monitoring

WHY GRID CODES AND WHO IS ENTSO-E?

Grid codes or equivalent are required by DIRECTIVE 2009/72/EC at least at national level

- The regulatory authorities where Member States have so provided or Member States shall ensure that technical safety criteria are defined and that
- technical rules establishing the minimum technical design and operational requirements for the connection to the system of generating installations, distribution systems, directly connected consumers' equipment, interconnector circuits and direct lines are developed and made public.
- Those technical rules shall ensure the interoperability of systems and shall be objective and non-discriminatory.

REGULATION (EC) No 714/2009 on conditions for access to the network for cross-border exchanges in electricity

Moreover, the EU Commission requests ENTSO-E to develop network codes covering the following areas, taking into account, if appropriate, regional specificities:

- (a)network security and reliability rules including rules for technical transmission reserve capacity for operational network security;
- (b)network connection rules;
- (c) third-party access rules;
- (d) data exchange and settlement rules;
- (e) interoperability rules;
- (f) operational procedures in an emergency;
- (g) capacity-allocation and congestion-management rules;
- (h) rules for trading related to technical and operational provision of network access services and system balancing;
- (i) transparency rules;
- (j) balancing rules including network-related reserve power rules;
- (k)rules regarding harmonised transmission tariff structures including locational signals and inter-transmission system operator compensation rules;
- (l)energy efficiency regarding electricity networks.

Grid codes or equivalent : main features

They are publicly available sets of rules for developing and operating network following principles of transparency and non-discrimination

– They apply to TSOs and DSOs (planning and operating rules…)

– They apply to grid users and service providers (connection of generators, consumers, interconnectors; exchanges of information…)

– They define common processes (metering, ancillary services)

– Requirements are brought together in a single code or can be split in various regulations or various levels of regulation (case of France)

– Public consultation is largely used for establishing and updating network codes.

Who is ENTSO-E ?

ENTSO-E, the European Network of Transmission System Operators: 41 electricity transmission system operators (TSOs) from 34 countries across Europe.

ENTSO-E was established and given legal mandates by the EU's Third Legislative Package for the Internal Energy Market in 2009, which aims at further liberalising the gas and electricity markets in the EU.

ENTSO-E promotes closer cooperation across Europe's TSOs to support the implementation of EU energy policy and achieve Europe's energy & climate policy objectives, which are changing the very nature of the power system

entsoe

Reliable Sustainable Connected

Who is ENTSO-E ?

The main objectives of ENTSO-E centre on the integration of renewable energy sources (RES) such as wind and solar power into the power system, and the completion of the internal energy market (IEM), which is central to meeting the European Union's energy policy objectives of affordability, sustainability and security of supply.

The drafting of network codes is one of the main contributions of ENTSO-E to the achievement of these objectives.

entsoe

Reliable Sustainable Connected

The Draft European Network Codes

Connection codes

- Requirements for generators
- Demand connection
- HVDC Connections and DC-connected Power Park Modules

Operational Security

- Operational Security
- Operational Planning and Scheduling
- Load Frequency Control & Reserves
- Emergency and restoration

Market network codes or regulations

- Capacity calculation & Congestion management
- Forward Capacity Allocation
- Electricity Balancing

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CHALLENGES AHEAD

RELEVANT TO RES REQUIREMENTS

The European electricity system is going through a period of unprecedented change.

The generation mix is changing fundamentally, the potential for the demand side to become much more involved is vast and the market is becoming genuinely pan European. For Europe to achieve its trio of objectives of ensuring and enhancing security of supply; creating competitive markets; and facilitating the transition to a low carbon economy **there will need to be a significant change in the role of network users,** of Distribution System Operators and of Transmission System Operators.

It is becoming increasingly important that **all types of users** (i.e. generation, demand, distribution networks, and interconnections) **play an active role in providing the capabilities and services which are needed to maintain the security of the pan European transmission system.**

Increasing the controllability and the flexibility of all power system elements, including RES

Operating conditions with the highest RES injection (typically in windy / sunny conditions with moderate demand) present major system challenges, particularly where the high RES penetration extends to a total control area or even more if covering a total synchronous area.

The move towards a more RES dominated system implies a gradual diminution of the large scale generation connected at EHV level and this will be further compounded by this generation having much reduced running hours compared to today's levels particularly at times of favourable RES generation conditions

The main answer to this is to increase the controllability and the flexibility of all power system elements, including RES, to deliver a power system which can react and cope better with the volatility of RES.

Technical challenges ahead related to stable operation of the power systems

The three main new or expanded technical challenges ahead related to stable operation of the power systems are:

- **Frequency management**
- **Voltage management**
- **Fault level (system strength) management**

Frequency Stability

Frequency Stability is significantly impacted by the rapid increase of RES generation both through the variability of generation patterns (driven by wind speed and solar irradiation) and reduced system inertia as large conventional synchronous generation is replaced by non-synchronous convertor based RES generators.

To compensate new response and reserve strategies are required with more particularly RES generation having to be resilient to wider frequency ranges and provide new capabilities (fast frequency response and system inertia, frequency sensitive mode for large parks…).

Voltage stability

At transmission voltages, voltage management needs to be ensured in areas remote from main centres of RES installations during times of high RES production when conventional generation, which has traditionally provided this service, being displaced;

Voltage stability would be compromised if the increasing levels of generation connected at distribution voltages are unable to provide the necessary reactive power support. There are also economic benefits in providing voltage support at a distribution level (close to the demand) rather than from centralized sources connected to the transmission system.

Fault Ride Through (FRT)

Small levels of RES generation (geographically dispersed) are unlikely to significantly impact the secure operation of the system should they shut down simultaneously. However, as the levels of RES increase it is of increasing importance that a single system event should not result in the large scale shut down generation. RES generation needs to be resilient to system faults staying connected (and generating) during the initial voltage transients (as conventional generation does today).

Fault level (system strength) management shall be possible in context of rapid changes from high system strength during low RES production to extreme low system strength during high RES production, when synchronous generation is displaced (not operating).

Remote Control of distributed generation units

Remote Control of distributed generation units is a highly relevant requirement in the modern electrical network. In this sense, there already exists a very successful experience in Europe with the Spanish CECRE.

The control capability is foreseen to include active as well as reactive power regulation in order to support grid stability as well as online reconfiguration. Functionality like on the fly reconfiguration is foreseen to be essential for implementation of Smart Grid solutions in the near future, an added enabler for further RES integration.

TECHNICAL REQUIREMENTS

FOR RES CONNECTION TO THE GRID

(Onshore connection)

ENTSO-E Network code – Requirements for generators

The RfG code :

- sets requirements for connections to the grid for Power Generating Facilities, including Synchronous Power Generating Modules, Power Park Modules and Offshore Generation Facilities (AC connected).
- defines the operational notification procedure for connection to the grid.
- defines compliance criteria & derogation processes.

What does RfG NC cover?

The network code sets out the technical requirements that all new electricity generators must adhere to. The requirements depend on the size of the generator – with the smallest facing only a minimum set of requirements and obligations, gradually building up as plant size increases. The requirements clearly set out the tasks and responsibilities for generation owners and network operators (TSO and DSOs).

They determine procedures to ensure non-discriminatory treatment of generators across Europe and are based on realistic future generation/demand scenarios based on the development of large volumes of renewable energy sources (RES) in Europe.

What does RfG NC cover?

The Network Code on Requirements for Generators (NC RfG) identifies four classes of generators to which the regulation will apply (type A, B, C, D). These are categorised by size, with type A covering the smallest generating units (anything above 800W) and including technologies such as solar panels installed on the roof of a house or a small wind turbine. Requirements increase as size increases, with type D applying to the largest plants connecting to electricity transmission systems.

Type A generators have to meet the most basic set of requirements, focused on frequency stability. The requirements increase progressively; for example, type D generators will have to meet most of the requirements met by a type A, B and C generators in addition to other specific requirements.

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What does RfG NC cover?

Two large categories of generation exist, rotating machine generation and power electronic interfaces.

For each category, specific requirements are set out (requirements for Synchronous Power Generating Modules and Power Park Modules).

In RfG NC, specific considerations for a given technology can be dealt with at the national implementation level.

Classification of Power Generating Modules

Type A	Type B	Type C	Type D
Conected below 110 kV			above 110 kV
maximum capacity threshold:			
0.8 kW or more	1 MW or more	50 MW or more	75 MW or more

General Requirements for Type A, B, C and D Power Geenrating Modules

Additional Requirements for Type B, C and D Synchronous Power Generating Modules or Power Park Modules

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Will the requirements for new generators apply to existing ones?

The requirements set out in the RfG NC will apply to new generators. They will not apply to existing generators unless the relevant network operator and corresponding regulatory authority request it. For this to happen, a clear process must be followed including extensive analysis and approval by regulatory authorities.

If there is a valid case for retrofitting existing generators, the RfG NC provide a transparent process to be followed. This involves a number of steps including; a quantified cost benefit analysis, public consultation and final decision by the national regulatory authorities.

Example

- For several countries in Europe, development of the Backfitting procedure for existing photovoltaic power plants
- – "50.2Hz Problem" to minimise the risk of splitting the network in sub-networks and of blackout

  Procedure is based on
  - Public consultation
  - Cost-Benefit Analysis
  - Detailed procedure for transmission and distribution network operators and power generation facility owners
- In Germany, new Procedure is starting in May 2015 – "Backfitting of RES related to 49.5 Hz Problem"
  - 21000 Power Generating Facilities with an installed capacity of 26 GW

REQUIREMENTS RELATED TO FREQUENCY STABILITY

Frequency Ranges

[Article 8 – Applicable for Power Generating Modules Type A, B, C and D]

A Power Generating Module shall be capable of staying connected to the network and operating within the Frequency ranges and time periods as defined in the NC

Comments and examples : in continental Europe

Frequency ranges	Time period for operation
51.5 Hz ≤ f ≤ 52.5 Hz	*10 minutes*
51 Hz ≤ f < 51.5 Hz	*1 hour*
49 Hz ≤ f < 51 Hz	*Unlimited*
48.5 Hz ≤ f < 49 Hz	*1 hour*
47,5 Hz ≤ f < 48.5 Hz	*>30 minutes*

Rate of Change of Frequency Withstand Capability

[Article 8 – Applicable for Power Generating Modules Type A, B, C and D]

With regard to the rate of change of Frequency withstand capability, a Power Generating Module shall be capable of staying connected to the Network and operating at rates of change of Frequency up to a value defined by the Relevant TSO.

Comments and examples :

In Eire, ROCOF up to a value of -0.5 and +0.5 Hz/ sec

Limited Frequency Sensitive Mode (Overfrequency)

[Article 8 – Applicable for Power Generating Modules Type A, B, C and D]

With regard to the Limited Frequency Sensitive Mode - Overfrequency (LFSM-O) :

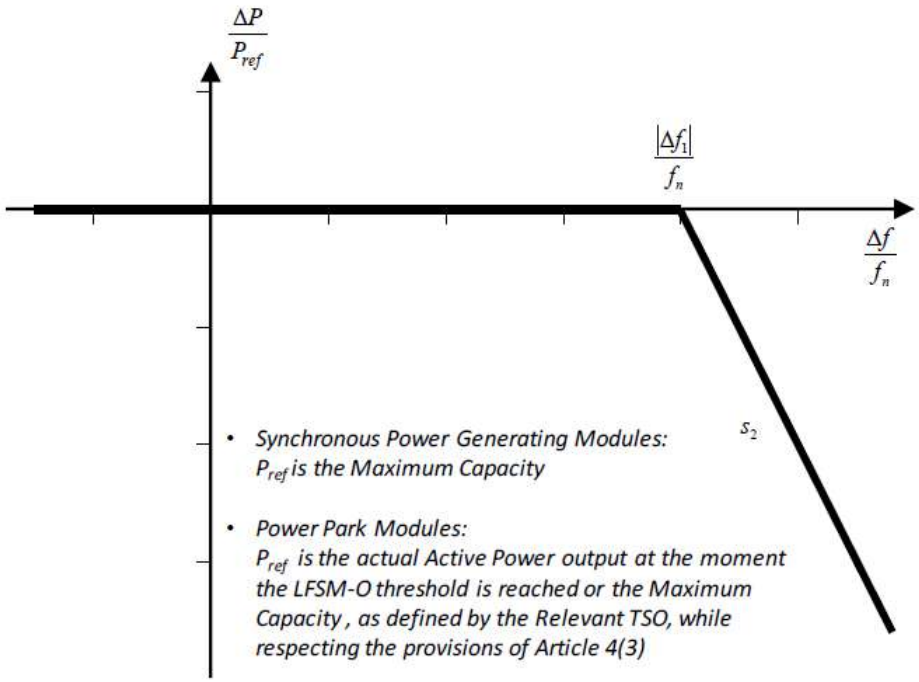


Figure 1: Source: Requirements for Grid Connection Applicable to all Generators

The Power Generating Module shall be capable of activating the provision of Active Power Frequency Response according to figure at a Frequency threshold, adjustable between and including 50.2 Hz and 50.5 Hz with a Droop in a range of 2 - 12 %.

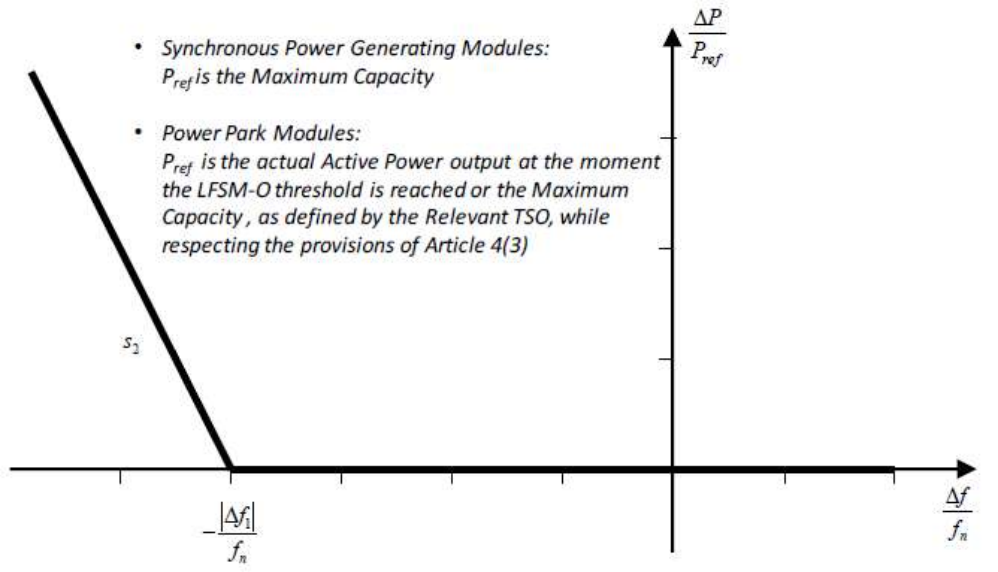
In proposals for Turkish Grid Code, the Frequency threshold is 50.2 Hz and the Droop is 4% unless stated otherwise by TEIAS.

Additional requirement in Turkey : Type A PGM shall stop to provide electric power to the network, when the Frequency is above 51.5 Hz.

Limited Frequency Sensitive Mode (Underfrequency)

[Article 10 - Applicable for Power Generating Modules Type C and D]

The Power Generating Module shall be capable of activating the provision of Active Power Frequency Response according to figure at a Frequency threshold between and including 49.8 Hz and 49.5 Hz with a Droop in a range of 2 – 12 %.

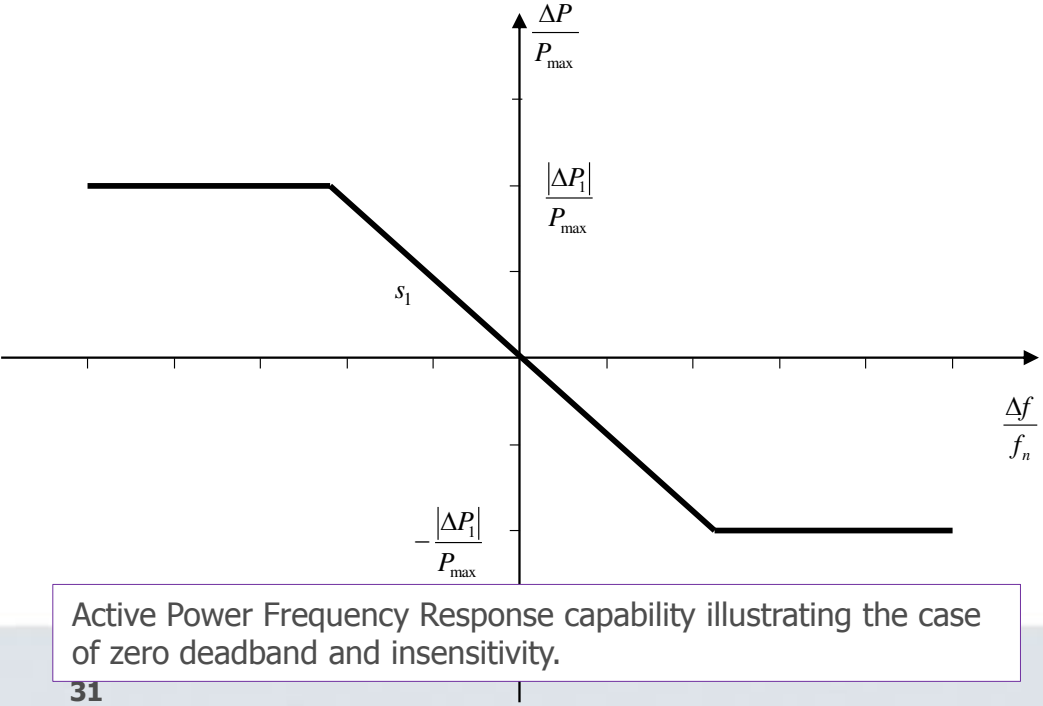


In proposals for Turkish Grid Code, the Frequency threshold is 49.8 Hz and the Droop is 4% unless stated otherwise by TEIAS.

Frequency Sensitive Mode (1/2)

[Article 10 - Applicable for Power Generating Modules Type C and D]

The Power Generating Module shall be capable of providing Active Power Frequency Response with respect to following figure and in accordance with the parameters specified by the TSO within the following ranges (see table)



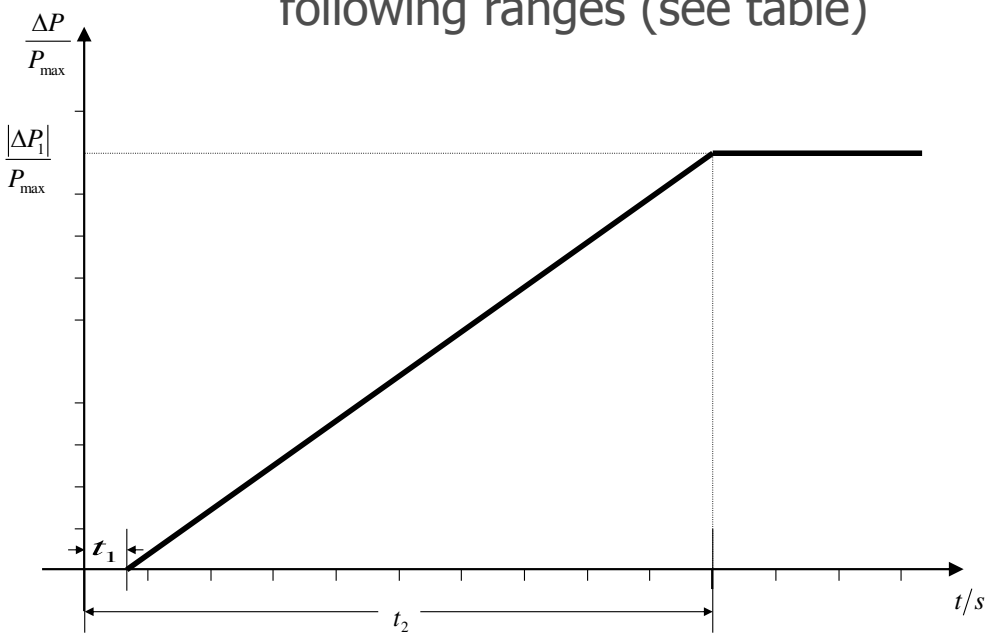
Active Power Frequency Response capability illustrating the case of zero deadband and insensitivity.

Parameters		Ranges
Active Power range related to Maximum Capacity		1.5 – 10 %
Frequency Response Insensitivity		10 – 30 mHz
		0.02 – 0.06 %
Frequency Response Deadband		0 – 500 mHz
Droop		2 – 12 %

Frequency Sensitive Mode (2/2)

[Article 10 - Applicable for Power Generating Modules Type C and D]

As a result of a frequency step change, the Power Generating Module shall be capable of activating full Active Power Frequency Response, at or above the full line according to following figure in accordance with the parameters specified by each TSO within the following ranges (see table)



Parameters	Ranges or values
Active Power range related to Maximum Capacity (Frequency response range)	**1.5 – 10 %**
Maximum admissible initial delay unless justified otherwise f**or generation technologies with Inertia**	**2 seconds**
Maximum admissible initial delay unless justified otherwise for generation technologies without Inertia	as specified by the Relevant TSO
Maximum full activation time	**30 seconds**

Synthetic Inertia to a low frequency event

[Article 16 – Applicable for Power Park Modules Type C and D]

The Relevant TSO has the right to require a Power Park Module, which is not inherently capable of supplying additional Active Power to the Network by its Inertia and which is greater than a MW size specified by the Relevant TSO, to install a feature in the control system which operates the Power Park Module so as to supply additional Active Power to the Network in order to limit the rate of change of Frequency following a sudden loss of infeed.

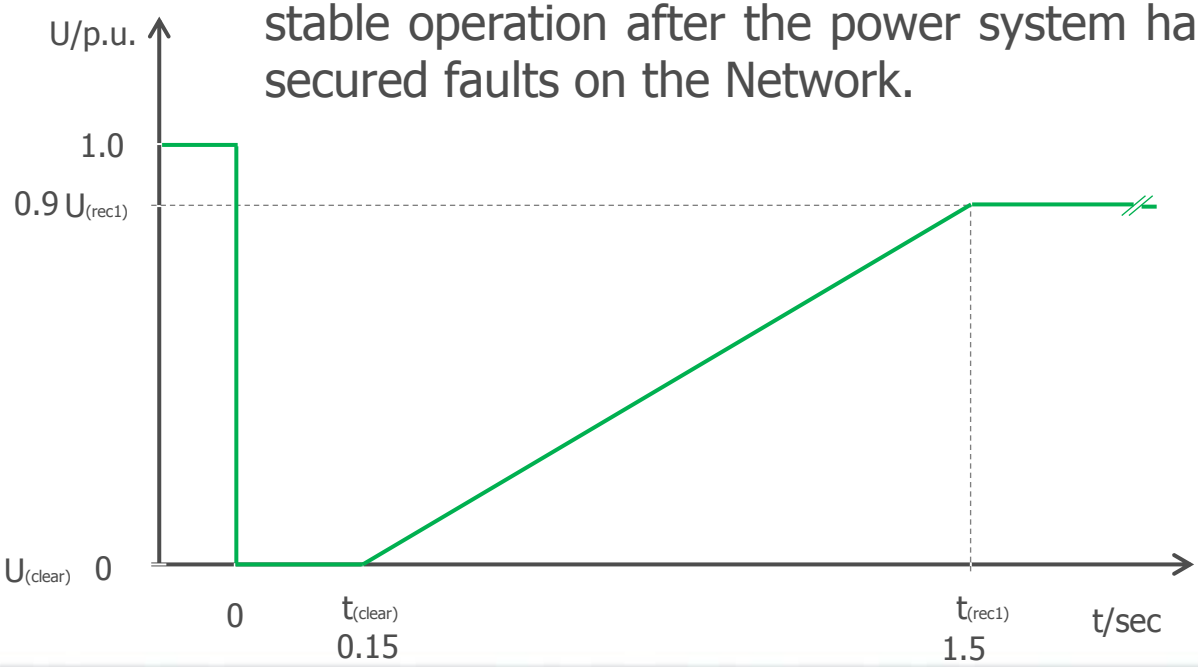
The operating principle of this control system and the associated performance parameters is defined by the Relevant TSO.

FAULT RIDE THROUGH (FRT)

Fault ride through capability

[Article 8 – Applicable for Power Generating Modules Type B, C and D]

Each TSO defines at national level a voltage-against-time-profile at the Connection Point for fault conditions which describes the conditions in which the Power Generating Module shall be capable of staying connected to the Network and continuing stable operation after the power system has been disturbed by secured faults on the Network.



proposals for Turkish Grid Code:

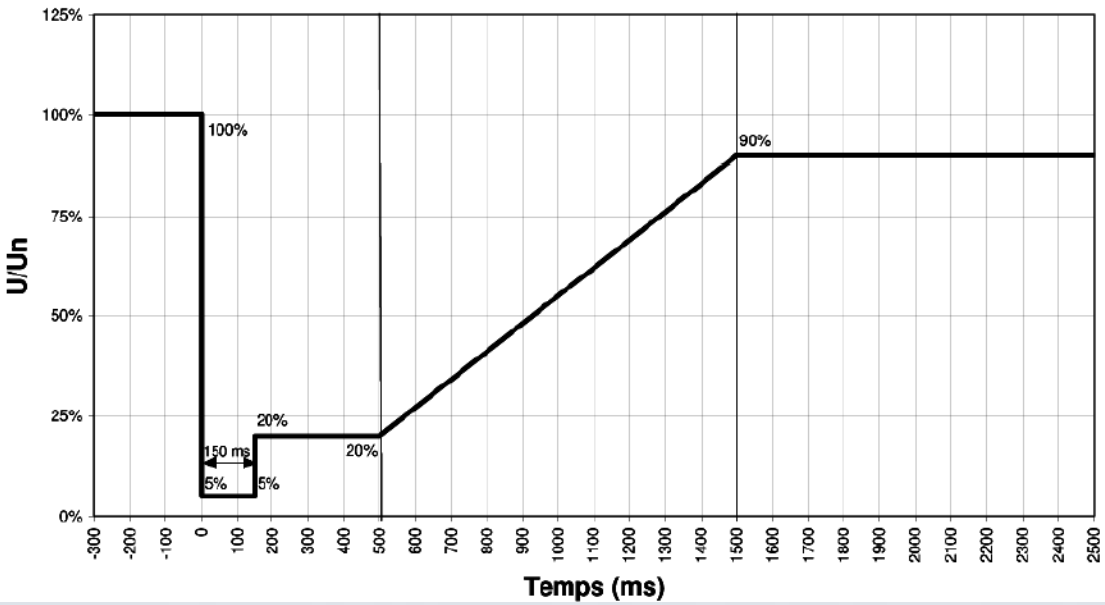
Voltage-against-time-profile (symmetrical and asymmetrical faults)

In particular cases, TEIAS can extend the time (trec1) up to 3 sec

Fault ride through capability

[Article 8 – Applicable for Power Generating Modules Type B, C and D]

Each TSO defines at national level a voltage-against-time-profile at the Connection Point for fault conditions which describes the conditions in which the Power Generating Module shall be capable of staying connected to the Network and continuing stable operation after the power system has been disturbed by secured faults on the Network.



Existing French Distribution Grid Code:

Voltage-against-time-profile for facilities connected to MV networks (>5 MW)

Fault ride through capability

[Article 15 – Applicable for Power Park Modules Type B, C and D]

The Relevant Network Operator in coordination with the Relevant TSO has the right to require fast acting additional reactive Current injection at the Connection Point to the pre-fault reactive Current injection in case of symmetrical (3-phase) faults.

The Power Park Module shall be capable of activating this additional reactive Current injection during the period of faults. The Power Park Module shall be capable of either:

- ensuring the supply of the additional reactive Current at the Connection Point (which magnitude depends on the deviation of the Voltage at the Connection point from its nominal value); or
- alternatively, measuring Voltage deviations at the terminals of the individual units of the Power Park Module and providing an additional reactive Current at the terminals of these units which magnitude depends on the deviation of the Voltage at units' terminals from its nominal value.

Fault ride through capability

[Article 16 – Applicable for Power Park Modules Type C and D]

The Relevant TSO defines whether Active Power contribution or Reactive Power contribution has priority during faults for which fault-ride-through capability is required.

If priority is given to Active Power contribution, its provision shall be established no later than 150 ms from the fault inception.

VOLTAGE STABILITY

Voltages stability

[Article 15 – Applicable for Power Park Modules Type B]

The Relevant Network Operator has the right to define the capability of a Power Park Module to provide Reactive Power.

Example (*proposals for Turkish Grid Code*):

1. The U-Q/Pmax-profile within the boundary of which the Type B Power Park Modules is capable of providing Reactive Power at its Maximum Capacity is a rectangular shape defined by the coordinates in the following table.

Q/P_{max} [pu]	Voltage at the Connection Point
x_1=0.33pu(lag) y_1=	0.95 pu
x_2=0.33pu(lag) y_2=	1.05 pu
x_3=-0.33 (lead) y_3=	1.05 pu
x_4=-0.33 (lead) y_4=	0.95 pu

Voltages stability

[Article 15 – Applicable for Power Park Modules Type B]

The Relevant Network Operator has the right to define the capability of a Power Park Module to provide Reactive Power.

Example (*proposals for Turkish Grid Code*):

2. The P-Q/Pmax-profile at the connection point, within the boundary of which the Type B Power Park Modules is capable of providing Reactive Power below Maximum Capacity is a rectangular shape defined by the following coordinates:

Q/P_{max}	P/P_{max} at the Connection Point [pu]
x_1=0.33pu (lag)	y_1=1pu
x_2=0.33pu (lag)	y_2=0.1pu
x_3=-0.33 (lead)	y_3=0.1pu
x_4=-0.33 (lead)	y_4=1pu

Below 0.1pu Active Power, Reactive Power Capability is not required.

Voltages stability

[Article 16 – Applicable for Power Park Modules Type C and D]

The Relevant Network Operator in coordination with the Relevant TSO defines the Reactive Power provision capability requirements in the context of varying Voltage. For doing so, it defines:

- a U-Q/Pmax-profile within the boundaries of which the Power Park Module is capable of providing Reactive Power at its Maximum Capacity.
- define a P-Q/Pmax-profile within the boundaries of which the Power Park Module is capable of providing Reactive Power below Maximum Capacity.

The Power Park Module shall be capable of providing Reactive Power automatically by either Voltage Control mode, Reactive Power Control mode or Power Factor Control mode.

Voltages ranges

[Article 11 – Applicable for Power Generating Modules Type D]

A Power Generating Module shall be capable of staying connected to the network and operating within the ranges of voltage at the Connection Point (in per unit), and the time periods specified by following tables.

Voltage ranges	Time period for operation	Voltage Level
0.85 pu – 0.90 pu	60 minutes	from 66 kV to 300 kV (excluding)
0.90 pu – 1.118 pu	Unlimited	
1.118 pu – 1.15 pu	20 minutes	

Voltage ranges	Time period for operation	Voltage Level
0.85 pu – 0.90 pu	60 minutes	from 300 kV to 400 kV
0.90 pu – 1.05 pu	Unlimited	
1.05 pu – 1.0875 pu *)	60 minutes	
1.0875 pu -1.10 pu *)	60 minutes	

*) 400kV excluded

Rte International

REMOTE CONTROL OF DISTRIBUTED GENERATION UNITS

Active power controllability

The Power Generating Module shall be equipped with a logic interface (input port) in order to:

- Type A&B) cease Active Power output within less than 5 seconds following an Instruction from the Relevant Network Operator
- Type B) to be able to reduce Active Power output as instructed by the Relevant Network Operator and/or the Relevant TSO.

Could be operable remotely if requested by the Network Operator

For Type C & D, the control system shall be capable of adjusting an Active Power Setpoint as instructed by the Relevant Network Operator / TSO to the Power Generating Facility Owner.

Automatic connection

For Type A,B & C Power Generating Modules, automatic connection is allowed unless determined otherwise by the Relevant Network Operator in coordination with the Relevant TSO. Conditions are defined by the Relevant TSO (frequency ranges, within which an automatic connection is admissible, and a corresponding delay time; maximum admissible gradient of increase of Active Power output).

When starting a Type D Power Generating Module, synchronization shall be performed by the Power Generating Facility Owner after authorization by the Relevant Network Operator.

CONNECTION PROCEDURES COMPLIANCE MONITORING

OPERATIONAL NOTIFICATION PROCEDURE

Operational notification Procedure

for type A generators

for type B and C generators

for type D generators, HVDC systems, transmission connected distribution networks and demand facilities

Operational notification procedure for type A generators

The operational notification procedure for connection consists of an Installation Document.

Installation Document is obtained from the Relevant Network Operator and filled in by the Power Generating Facility Owner.

The content of the Installation Document is defined by the Relevant Network Operator, with at least :

the location at which the connection is made;
the date of the connection;
the Maximum Capacity of the installation in kW;
the type of primary energy source;
reference to Equipment Certificates used in the site installation;
for equipment used, which has not received an Equipment Certificate, information shall be provided as directed by the Relevant Network Operator; and
the contact details of the Power Generating Facility Owner and the installer and their signatures.

Permanent decommissioning shall be notified to the Relevant Network Operator in writing.

Operational notification procedure for type B and C generators

The operational notification procedure for connection comprises at least two steps:

1. The Power Generating Facility Owner send a Power Generating Module Document (PGMD) to the Relevant Network Operator.
2. The Relevant Network Operator on acceptance of a complete and adequate PGMD issues a Final Operational Notification to the Power Generating Facility Owner.

The PGMD contains information as defined by the Relevant Network Operator and the relevant TSO, including a Statement of Compliance.

Equipment certificates can be used as validated information about components of a power generating module.

Permanent decommissioning shall be notified to the Relevant Network Operator in writing.

Operational notification Procedure for type D generators

Also applies to HVDC systems, transmission connected distribution networks and demand facilities

The operational notification procedure for connection comprises at least three steps:

1. Energisation Operational Notification (EON);
2. Interim Operational Notification (ION); and
3. Final Operational Notification (FON).

Energisation Operational Notification (EON)

1. The Energisation Operational Notification (EON) is issued by the TSO after agreement with the owner of the facility on the protection and control settings relevant to the Connection Point.
2. The owner of the facility is entitled to energies its internal Network and auxiliaries for the facility by using the grid connection that is defined by the Connection Point

Interim Operational Notification (ION)

The Interim Operational Notification (ION) is issued by the TSO subject to the completion of data and study review process related to:

- itemized Statement of Compliance (can be partly based on Equipment Certificates);
- detailed technical data of the facility with relevance to the grid connection;
- simulation models required by the TSO;
- studies demonstrating expected steady-state and dynamic performance
- details of intended compliance tests

The owner of the facility is entitled to operate its facility (inject or extract power) by using the grid connection for a limited period of time (max 24 months)

Final Operational Notification (FON)

- The Final Operational Notification (FON) is issued by the TSO subject to the completion of data and study review process related to:
  - itemized Statement of Compliance
  - update of applicable technical data, simulation models and studies including use of actual measured values during testing.
  - Test results

- The owner of the facility is entitled to operate its facility (inject or extract power) by using the grid connection.

COMPLIANCE MONITORING

Compliance monitoring

- The Facility Owner shall ensure that its facility is compliant with the requirements under the Network Code. This compliance shall be maintained throughout the lifetime of the facility.
  - Planned modifications of the technical capabilities of the facility with possible impact on its compliance are notified to the Relevant Network Operator by the Facility Owner before initiating such modification.
  - Any operational incidents or failures of a facility that have impact on its compliance is notified to the Relevant Network Operator by the Facility Owner.
  - Any foreseen test schedules and procedures to verify compliance of a facility shall be notified to the Relevant Network Operator by the Power Generating Facility Owner in due time and prior to their launch and shall be approved by the Relevant Network Operator.
  - The Relevant Network Operator shall be facilitated to participate in such tests and may record the performance of the Power Generating Modules.

Example : Reactive Power Capability test for Type C Power Park Module

- The Network Code includes a detailed list of tests and simulations that shall be carried out in order to demonstrate the technical capability of the facility regarding requirements under the regulation.

The Power Park Module shall demonstrate its technical capability to provide leading and lagging Reactive Power capability according to Article 16(3) (b) and (c).

The Reactive Power Capability test shall be carried out at maximum Reactive Power, both leading and lagging, and concerning the verification of the following parameters:

- operation in excess of 60 % of Maximum Capacity for 30 min;
- operation within the range of 30 – 50 % of Maximum Capacity for 30 min; and
- operation within the range of 10 – 20 % of Maximum Capacity for 60 min.

The test is deemed passed, provided that the following criteria are cumulatively fulfilled:

- the Power Park Module has been operating no shorter than requested duration at maximum Reactive Power, both leading and lagging, in each parameter as referred to in Article 42(6) (b);
- the Power Park Module has demonstrated its capability to change to any Reactive Power target value within the agreed or decided Reactive Power range within the specified performance targets of the relevant Reactive Power control scheme; and
- no action of any protection within the operation limits defined by Reactive Power capacity diagram occurs.

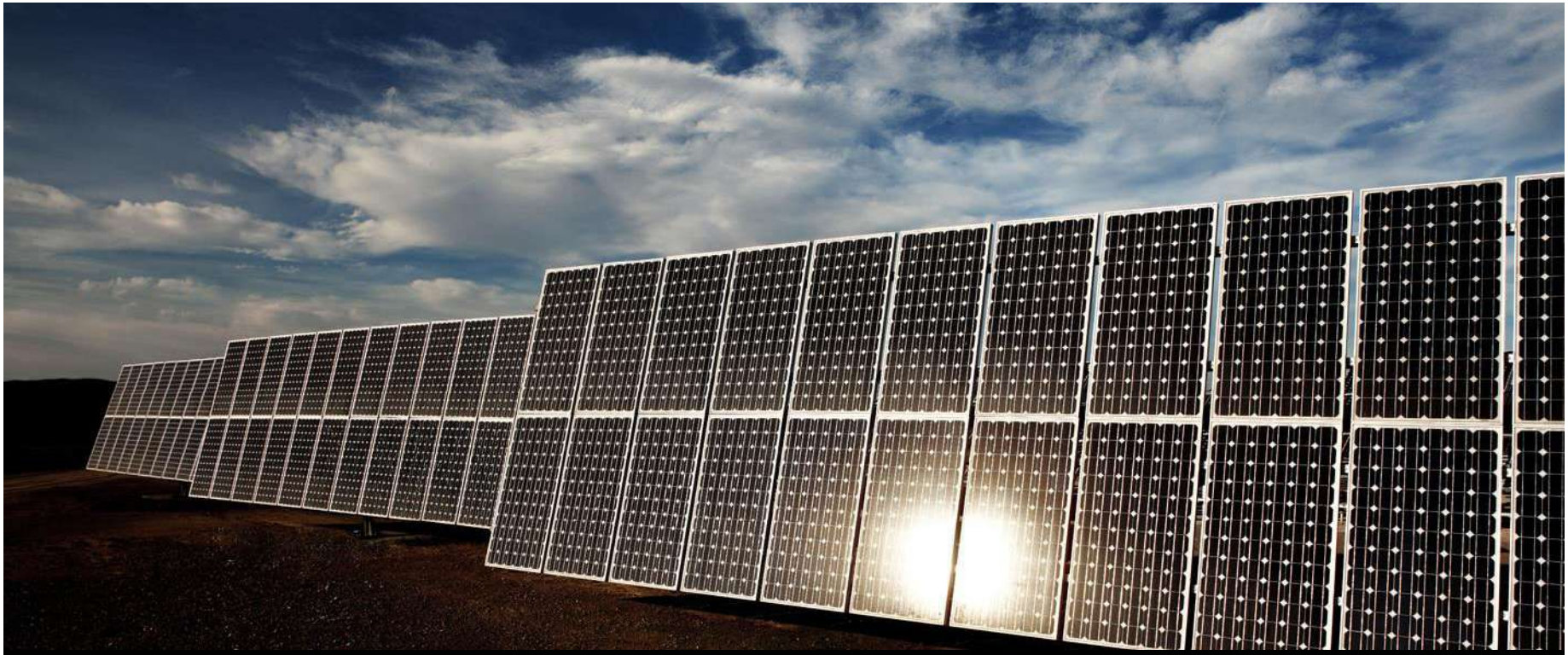
Compliance monitoring

- The Relevant Network Operator regularly assesses the compliance of a facility with the requirements under the Regulation throughout the lifetime of the Power Generating Facility.
- The Relevant Network Operator has the right to request that the Facility Owner carries out compliance tests and simulations not only during the operational notification procedures but repeatedly throughout the lifetime of the Facility (according to a pre-defined plan or after any failure, modification or replacement of any equipment that may have impact on the facility's compliance).
- The Facility Owner shall be informed of the outcome of these assessments, compliance tests and simulations.
- The Relevant Network Operator shall make publicly available the procedure related to compliance monitoring including information and documents to be provided as well as requirements to be fulfilled

CONCLUSIONS

Conclusions

- It is recommended to establish a grid code with clear and transparent requirements for RES
- Requirements need to be anticipated for future operation conditions
- Requirements included in the draft European grid code RfG (Requirements for Generators) are a valuable basis for developing grid code in Arabic countries. Standardisation => lower investment costs for RES integration



Pietro Raboni, R&D engineer, BU DMPC PG Solar

Integration of PhotoVoltaic Plants, the ABB experience
Lessons learned and case studies

ESCWA Workshop, Amman, 2nd-3rd September 2015

Power and productivity for a better world™

List of the contents

- Introduction to ABB
- An R&D Forward-Thinking approach:
  - Grid code compliance and customer satisfaction
  - PVIs model portfolio
- Our Utility Scale PV Plant Engineering experience:
  - Services
  - Plant capability fulfilment: Q sources and related issues
  - Step-up transformer choice
  - Short circuit current limitation and our skid
  - Energization and Harmonic studies
  - Centralized Vs Decentralized solutions
- Conclusions

A global leader in power and automation technologies
Leading market positions in main businesses

~150,000 employees

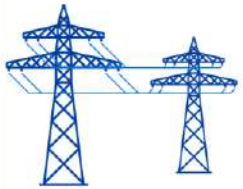
$42 billion
In revenue (2013)

Present in +100 countries

Formed in 1988
merger of Swiss (BBC, 1891) and Swedish (ASEA, 1883) engineering companies

How ABB is organized
Five global divisions

Power Products



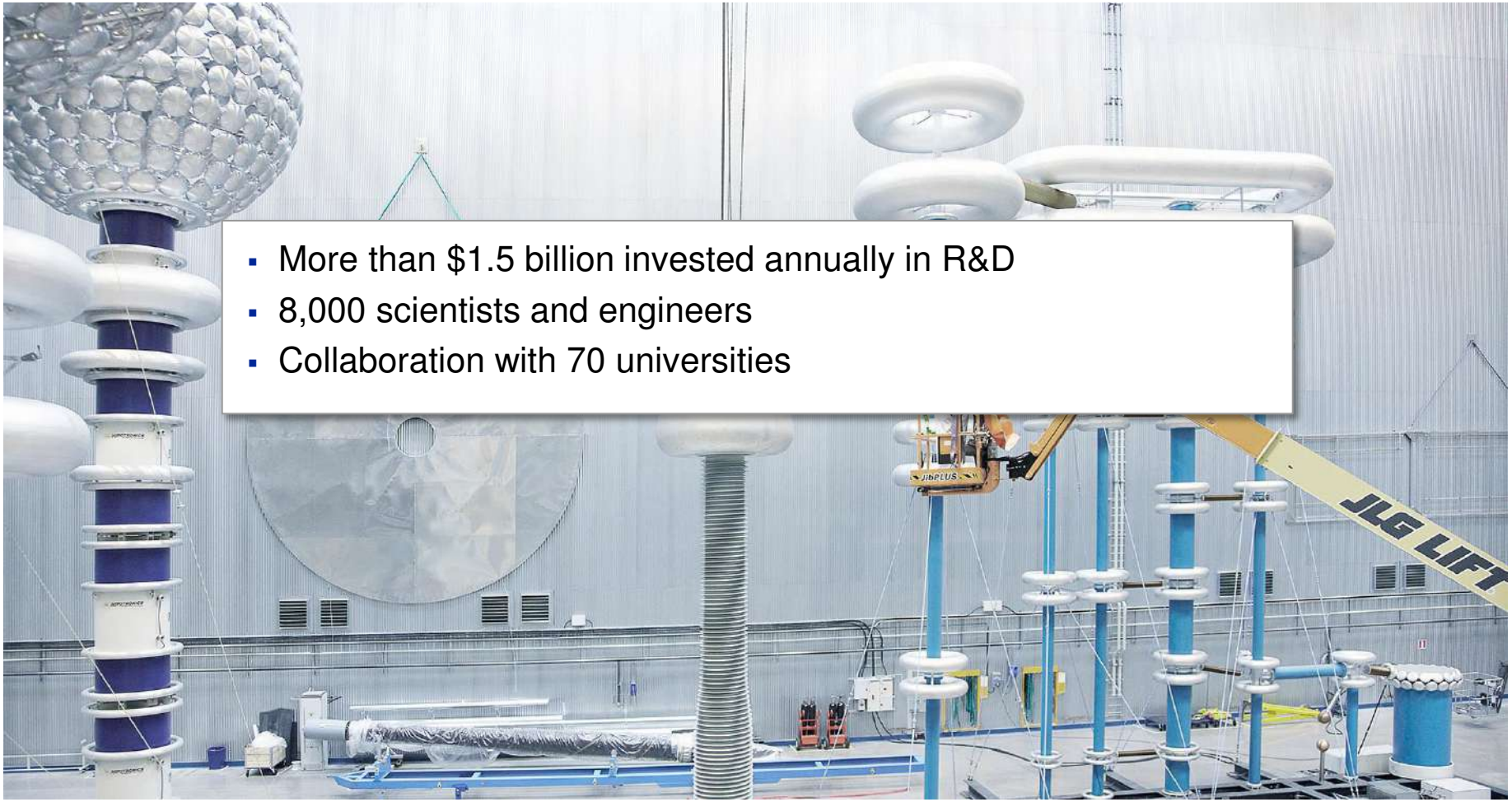
Power Systems

Discrete Automation and Motion

Low Voltage Products

Process Automation

Innovation is key to ABB's competitive advantage
Leadership built on consistent R&D investment



- More than $1.5 billion invested annually in R&D
- 8,000 scientists and engineers
- Collaboration with 70 universities

ABB reinforces its commitment to solar
Power-One Renewable: a strategic acquisition

The largest and more capillary presence

Over 100 countries covered

The widest inverter portfolio

From 250W up to 2MW

A complete offer for renewables

Switchgears

Transformers

Protection devices

SCADA

PLCs and meterings

ABB DMPC PG Solar
Central PV Inverters

- CORE 1000
- PVS 800
- ULTRA 1400

Almost 1.6 GW of ULTRA installed

Wide V_{DC} range

Technical Data	ULTRA-1400-TL-OUTD
MPP Input Voltage Range	470-900 Vdc
Rated Power MPP Input Range	585-850 Vdc
Maximum Power MPP Input Range	645-850 Vdc
Max. Input Voltage	1000 Vdc
Number of Independent MPPT	4
Independent functional module	390 kVA
Output Voltage	690 Vac
Rated Power ($P_{ac,r}$)	1.400 kW
Maximum Power ($P_{ac,m}$ @ cosφ=1)	1.560 kW
Max. Eff. (η_{max}) / Euro Eff. (η_{EU}) / CEC Eff. (η_{CEC})	98.7%/98.2%/ 98.0%
User Interface	Touch Screen Graphical Display
Communication	RS 485
Ambient Temperature Range	-20/60°C (with derating above 50°C)
Environmental Protection Rating	IP 65 / NEMA 4X
Cooling	Liquid
Size (WxHxD in mm)	4420 x 2920 x 1520
Certification	CE
Safety Standards	EN50178, EN61000-6-2, EN61000-6-4, EN61000-3-11, EN61000-3-12
Grid Standard	Att. A70 Terna, CEI 0-16; BDEW, FERC661

Grid code compliance
A successful case of R&D proactiveness

R&D department overwhelmed by new grid code requirements consequent to market expansion

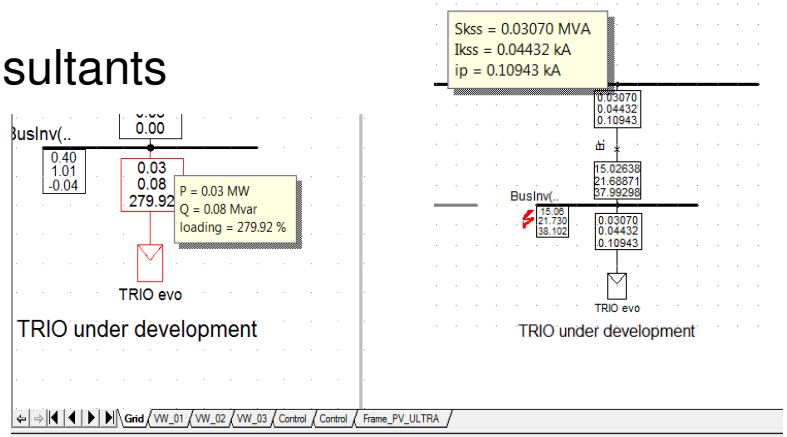
- Task force for Grid Code Monitoring
- Compliance to incoming most stringent grid codes and standards
  - CEI 0-16, CEI 0-17, BDEW, NEPCO, IEC, NERSA, Rule 21 phase 1, HECO, Chilean Grid code
- Fully parameterized PVIs to facilitate the compliance to further grid codes
- Eased by internal testing labs

Grid code compliance
State of the art functionalities

- Reactive power modes
  - PF_{PVI}=const (local / remote via PPC)
  - Q=const (local / remote via PPC)
  - Q(V) (local)
  - P=const=min{P_{av},P_{ref}} (local / remote via PPC)
- Control of positive and negative sequence currents
- Decentralized power ramp-up rate limitation
- *ULTRA:*
  - *Modular inverter: M&S or MultiMaster*
  - *Specifically designed for harsh environments (IP65, liquid cooled)*

PVI models portfolio
Certifications, g.c. compliance and customer needs

- Design and maintenance of PVI templates portfolio
  - In-House: DIgSILENT PowerFactory, SimPowerSystem
  - Coordination for PSS/E, PSCAD, DSA model designs
- FGW-TR4 certification
- Full models ready for the consultants
  - Fully parameterized
  - Capability
  - Harmonic load flow
  - Short circuit contribution
  - Dynamic VSC response




```
DIgSI/wrng - ' C':
DIgSI/wrng - Nominal voltage differs by 72.50 % from bus voltage!
DIgSI/wrng - ' L':
DIgSI/wrng - Nominal voltage differs by 72.50 % from bus voltage!
DIgSI/info - Element 'AC Voltage Source' is local reference in separated
DIgSI/info - Grid split into 3 isolated areas
DIgSI/info - Calculating load flow...
DIgSI/info - ----------------------------------------------------------------
DIgSI/info - Start Newton-Raphson Algorithm...
DIgSI/info - load flow iteration: 1
DIgSI/info - Newton-Raphson converged with 1 iterations.
DIgSI/wrng - 'Grid\TRIO evo.ElmGenstat':
DIgSI/wrng - Maximum Reactive Power Limit Exceeded (0.08 Mvar > 0.01 Mvar)
DIgSI/info - Load flow calculation successful.
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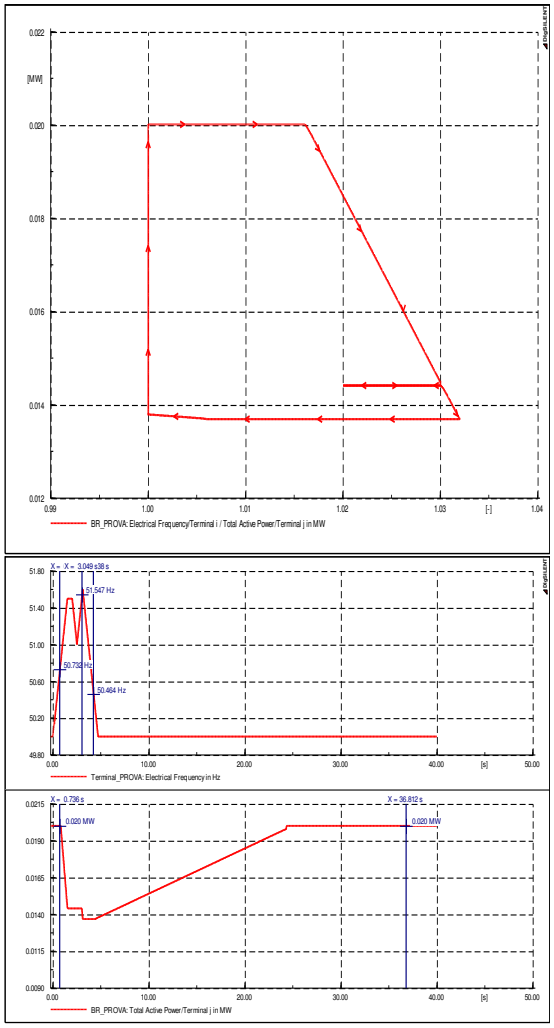
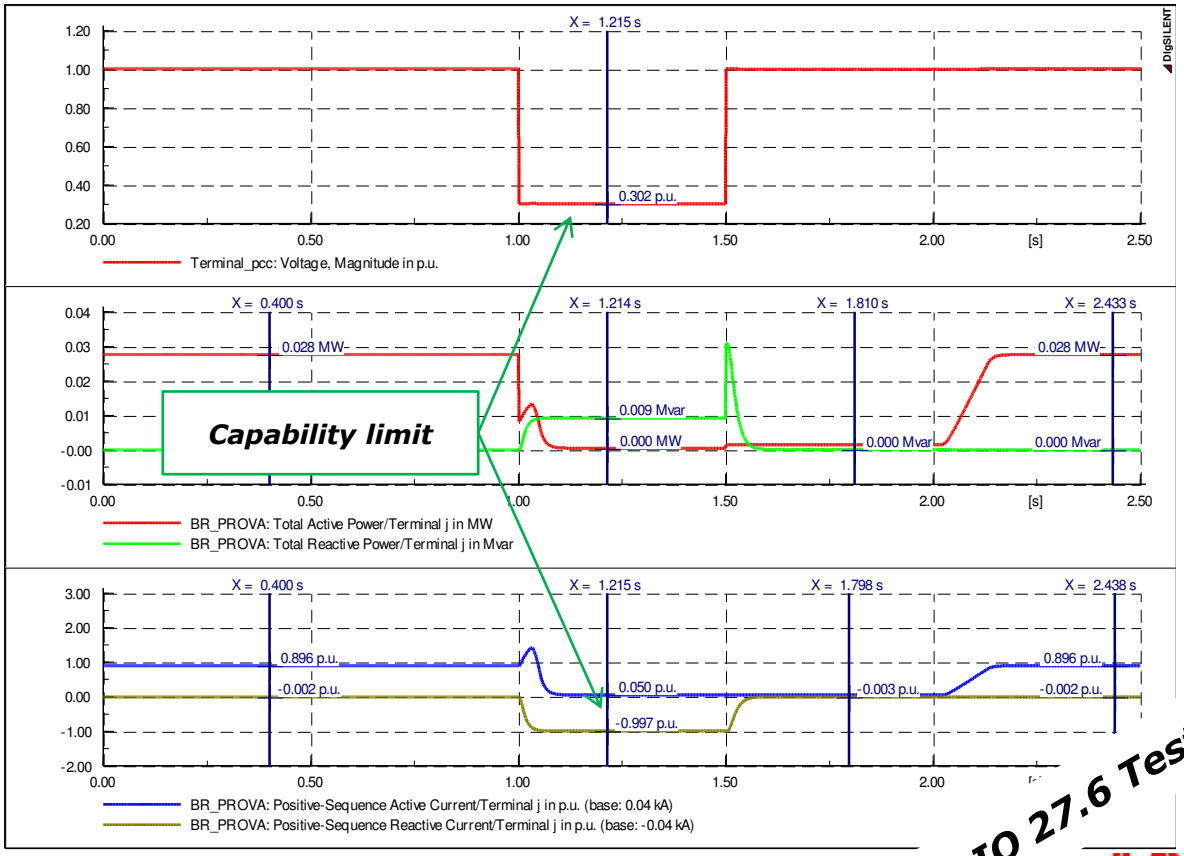
TRIO 27.6 Tests

PVI models portfolio
Examples of dynamic studies



- HFRT
- DRCS



TRIO 27.6 Tests

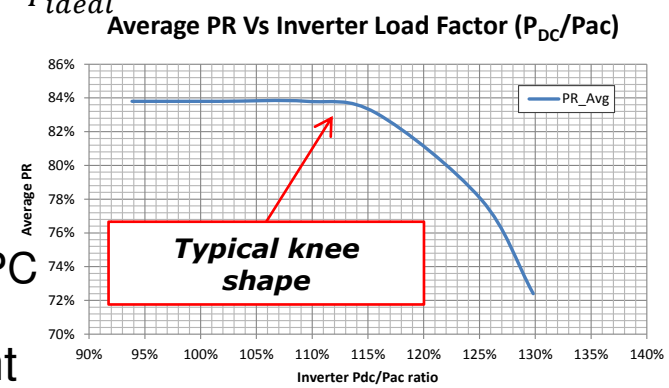
PVI models portfolio
The proper model

- GIS ⇨ Detailed plant model with PVI templates designed for RMS sims, Load Flows, Short Circuit calculations
- Network integration studies ⇨ An equivalent PVI for the overall plant
- R&D PVI debugging or control testing ⇨ An equivalent network-plant connected to a detailed PVI model

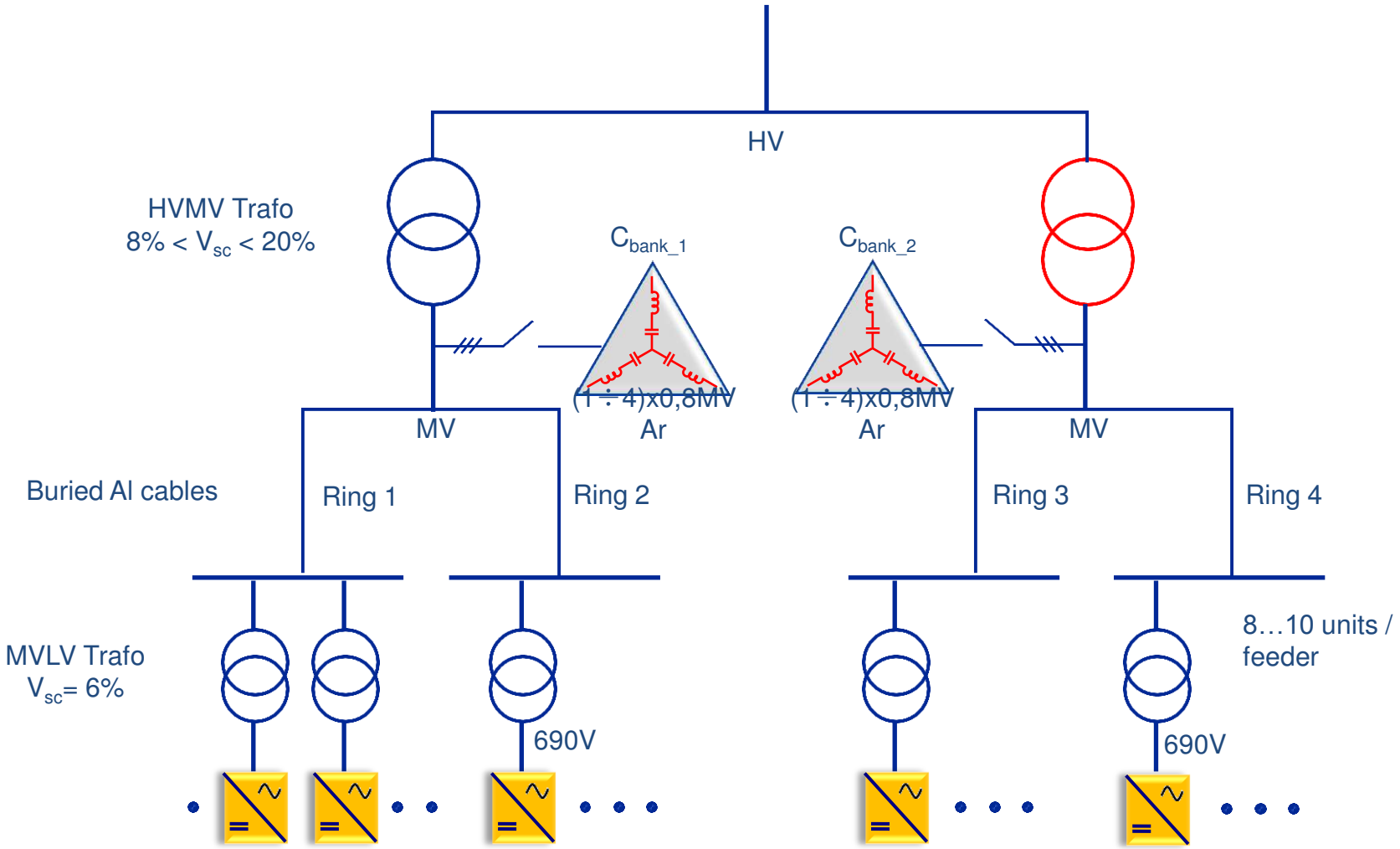
Engineering Support
Beyond a Power Electronics manufacturer

A successful project relies on a solid plant design

- ABB DMPC PG Solar doesn't take over the role of EPC
- Offered services:
  - Preliminary studies
    - Estimations of Performance Ratio $PR = \frac{Y_{real}}{Y_{ideal}}$
    - Plant capacity assessment (P,Q)
  - Grid Impact Studies
    - In-house preparation OR support to EPC
  - Component selection and procurement
    - ABB and trusted suppliers



Engineering Support
Typical utility scale plant layout



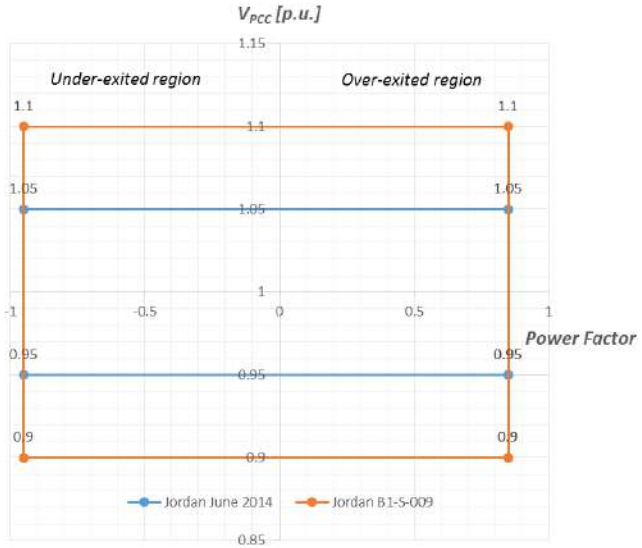
Fulfillment of contractual powers at the PCC
The problem and grid codes capability requirements

An optimized design

- Objective Function
  - $k_c \cdot \min\{\Sigma c_{PVI} + \Sigma c_{Qcomp.\ devices}\} + k_{PR} \cdot (1\text{-}PR)$
    - ⇨ define n_{PVI} and Q compensation issue
    - ⇨ Maintain acceptable PR
    - Further OF terms: min losses and equalize plant layout
  - Comply with the requirements
    - NEPCO (HKJ) ⇨$P_{AC\text{-}PCC}^{max}$ + capability

      ⇨ceiling to $P_{AC\text{-}PCC}$⇨ P_{DC}^{n}
    - Israel ⇨capability (PF)

      ⇨plant design starts from P_{DC}^{n}

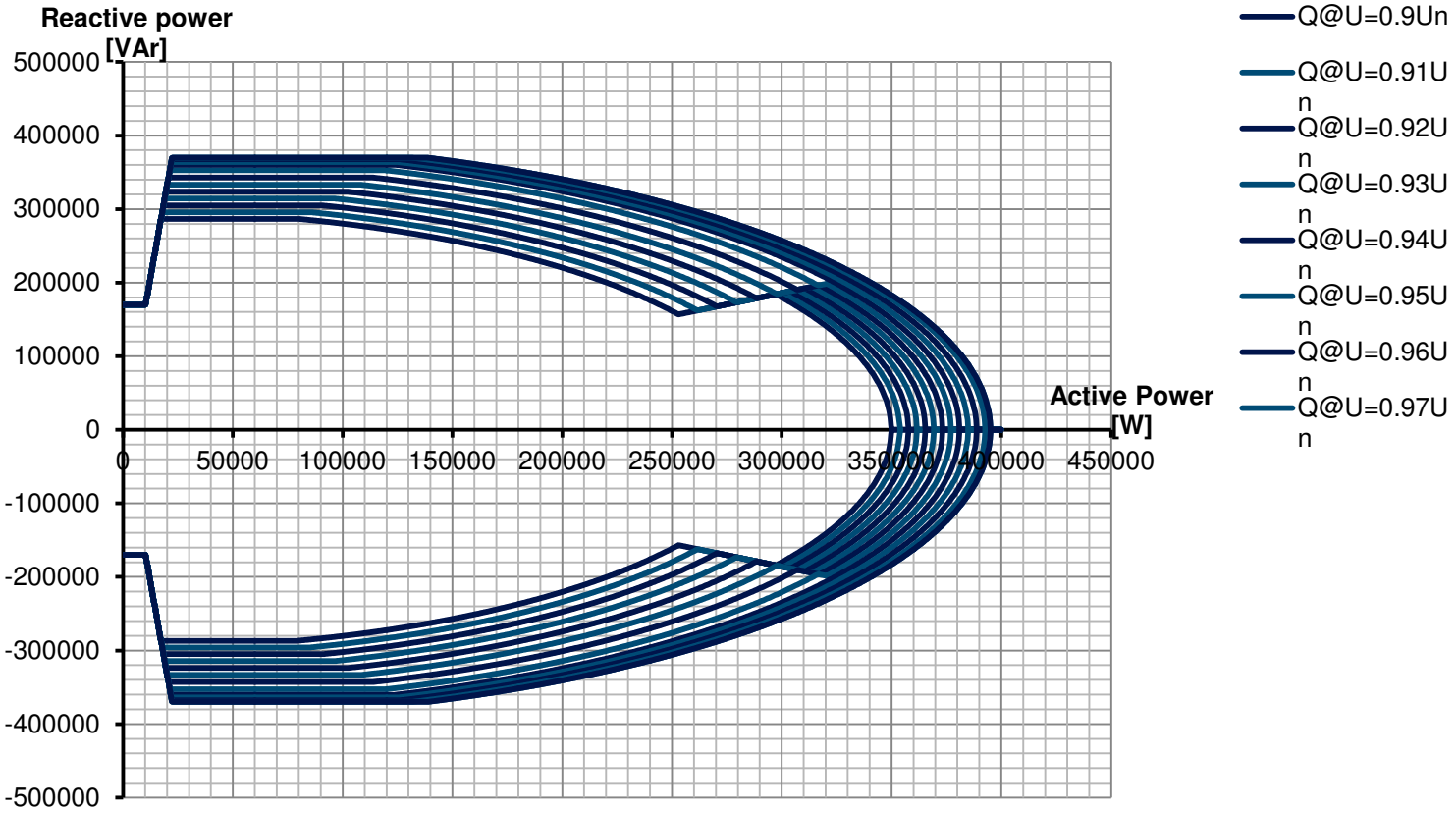


Fulfillment of contractual powers at the PCC
Constraints and possible degrees of freedom

- Constraints
  - PVIs and STATCOM capabilities are V and ϑ_{amb} dependent
    - dependency is lin. vs quadratic of SVC and cap banks
  - V rating of plant devices
    - Typical problem with MV devices when V_{cc}^{HVMV}>>
  - Tap changer position ranges for:
    - HVMV Trafo On-Load-Tap- Changer
    - MVLV Trafo Off-Load-Tap- Changer
- In case of small capability violations the designer could demand modifying transformer ratings:
  - Nominal V
  - Special designs leading to reduced leakage impedance

Fulfillment of contractual powers at the PCC
Reactive power sources: Caps and PVIs

- Capacitor banks normally split in stages
- PVI inverters



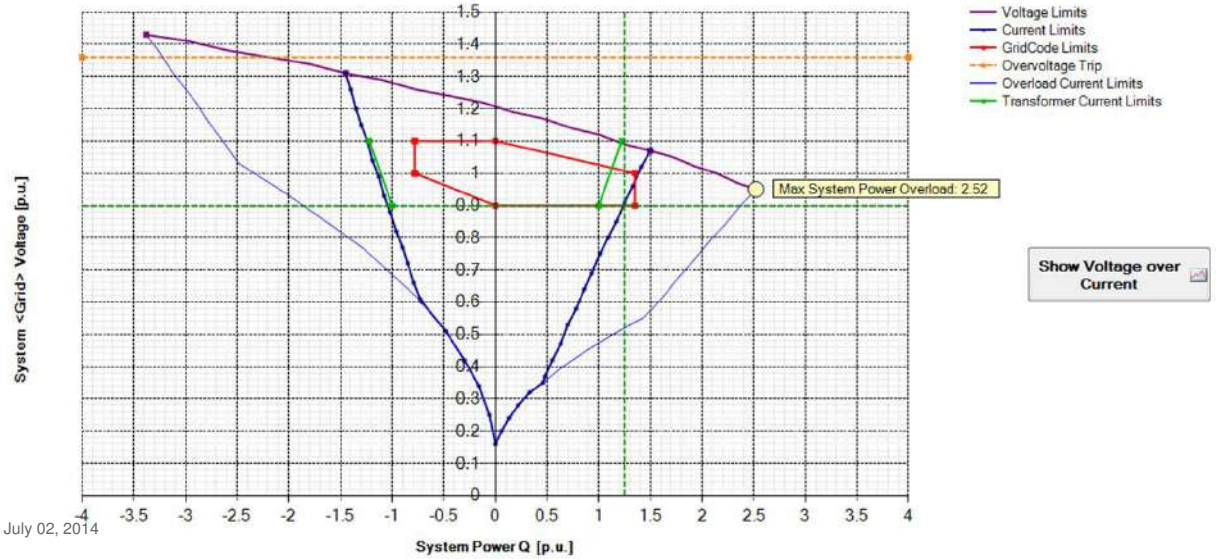
Fulfillment of contractual powers at the PCC
Reactive power sources: STATCOM (ABB PCS 100)

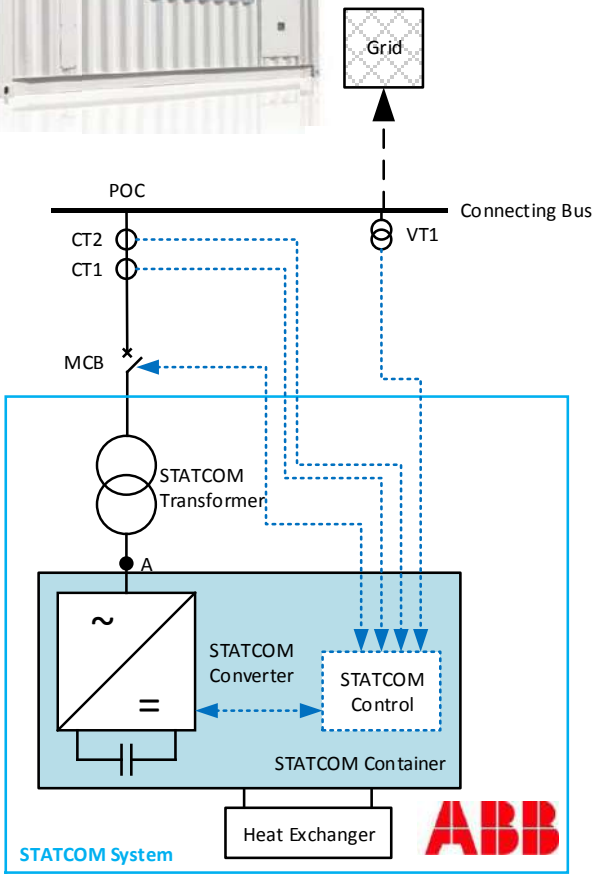
Rack mountable module

2.0 MVAr STATCOM line-up with all 24 modules

Containerized solution

ABB tool for preliminary design (STATCOM and plant capability at the MV PCC)



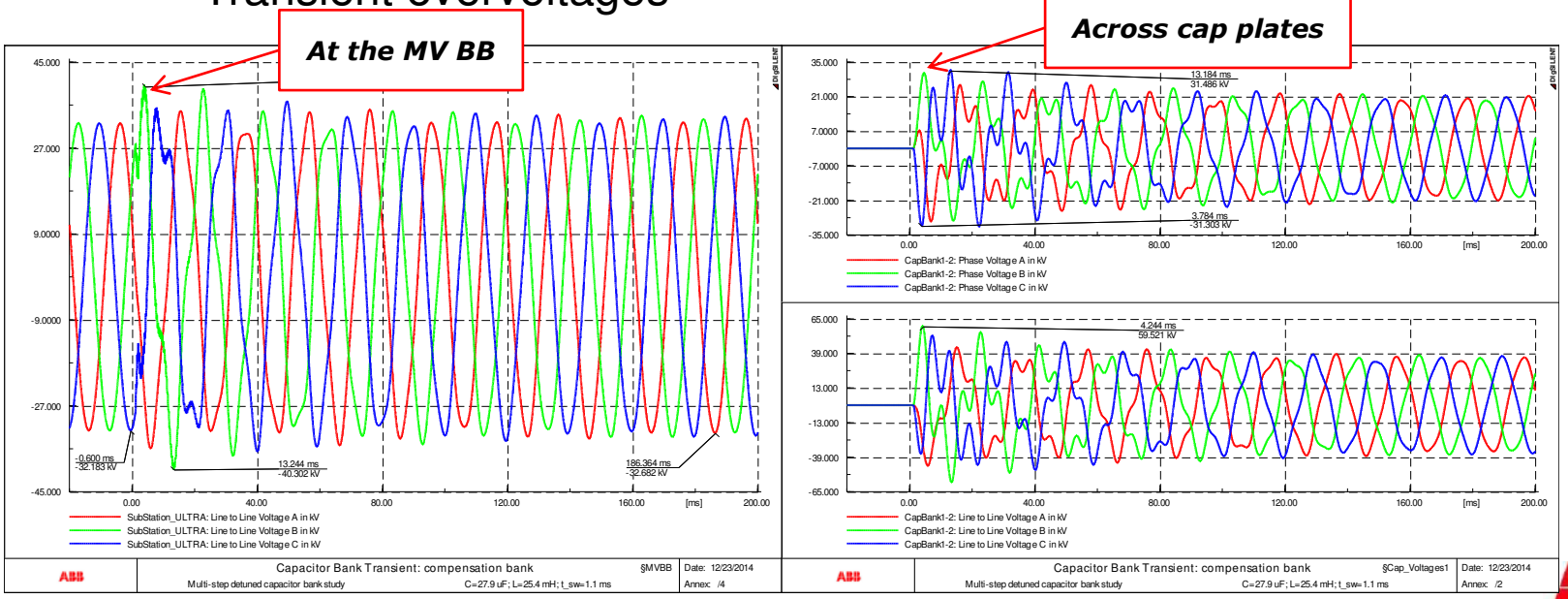


Fulfillment of contractual powers at the PCC
Comparison between Q sources

	Pros	***Cons***	***Design challenges***
Caps	Low cost Simplicity	Prone to harmonic and energization issues	Granularity definition Insertion strategy definition Design of inrush bank impedance Carefully evaluation of: Harmonics and eventual harmonic traps, inrush and energization scenarios
PVIs	High Q granularity Limited cost Expected lower loading of the inverter for most of the time (extended lifetime)	V dependent capability Efficiency reduction (<0.2%)	Possibility to find optimal solution taking into account plant PR
STATCOM	High Q granularity Harmonic compensation Enhanced fault support	High cost Large footprint on the plant substation	Damping harmonics capability must be properly verified Coordination with PVIs control in case Q capability is shared with the same

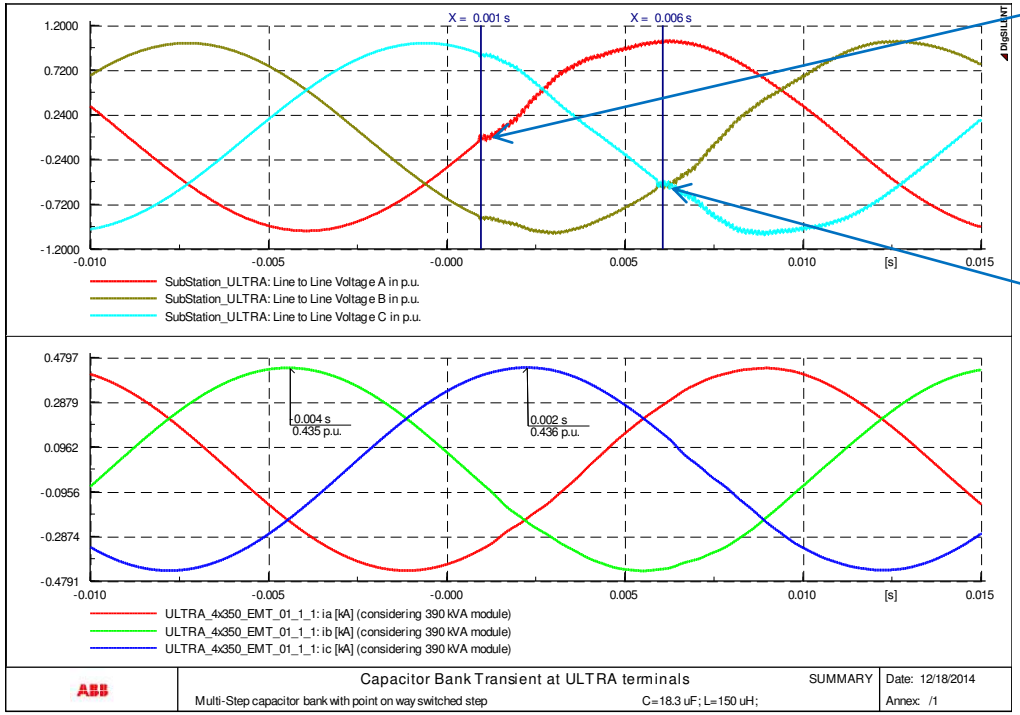
Cap compensation bank design
The objective function

- ULTRA is a 4 level inverter
  - Smaller output filter ⇨ Prone to inrush current phenomenon during capacitor insertions in case of weak networks
- Harmonics
- Transient overvoltages



Cap compensation bank design
Possible solutions

- Increase number of stages
- Inrush resistor (US Solution)
- Point-On-Wave reclosure



v_{k-l}=0 V
⇨ closure of phases k and l

⇩ After ¼ period

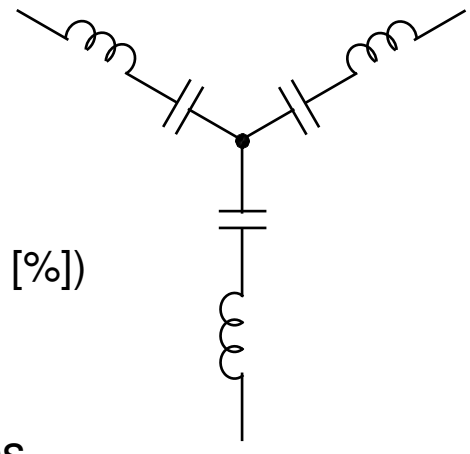
⇨ closure of phase m

Seamless insertion

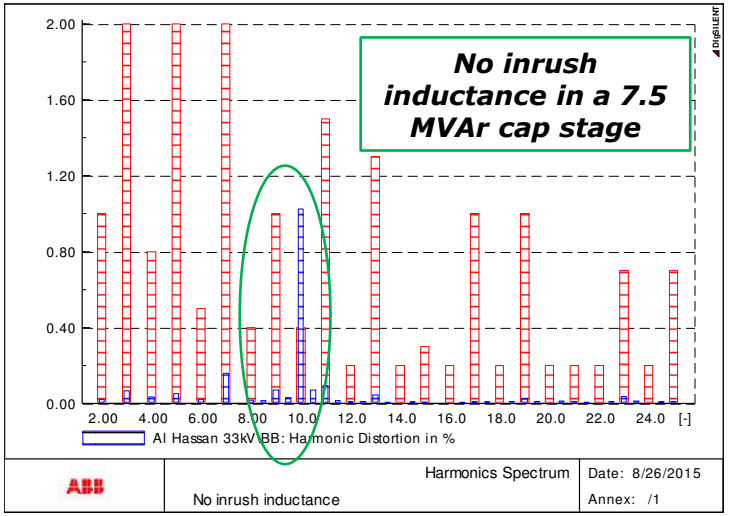
- No contribution to harmonics damping

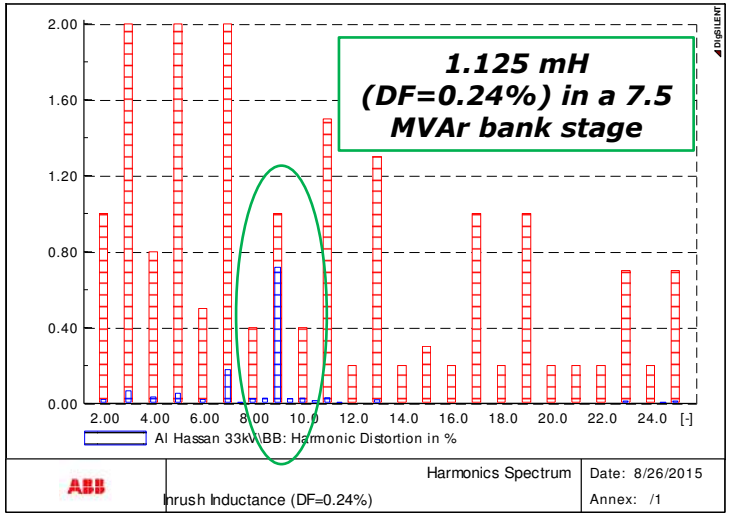
Cap compensation bank design
Possible solutions: inrush inductors and detuned filters

- Detuned filter design guidelines
  - Detuning factor DF = x_L/x_C
  - Given Q_{stage}:
    - DF ↑ ⇨ C↓ and L↑ (typical DF= 5-6-7-14 [%])
    - Tuned at an interharmonic
- Outstanding benefits on the harmonics studies



The case of an external bank connected at the plant PCC node





Insertion strategies of compensation bank stages

Ensure an hysteretical mechanism

Method	***Insert a stage if …***	***Disconnect a stage if …***
A	$\Sigma Q_{PVI} > \%_{insert}\ Q_n^{stage}$	$\Sigma Q_{PVI} > \%_{disc}\ Q_n^{stage}$
B	$PF_{PVI} < PF_{PVI}(p_{PVI})$	$PFeq = \frac{\sum P_{inv}}{\sqrt{\sum P_{inv}^2 + \left(\sum Q_{inv} + Q_{stage}\right)^2}}$ $PFeq < PF_{PVI}(p_{PVI}) - 0.1$
C	$\Sigma Q_{PVI} > 0$ (no over-ex if possible)	$PFeq = \frac{\sum P_{inv}}{\sqrt{\sum P_{inv}^2 + \left(\sum Q_{inv} + Q_{stage}\right)^2}}$ $PFeq < 0.99$

Risk of overvoltages at PVI terminals

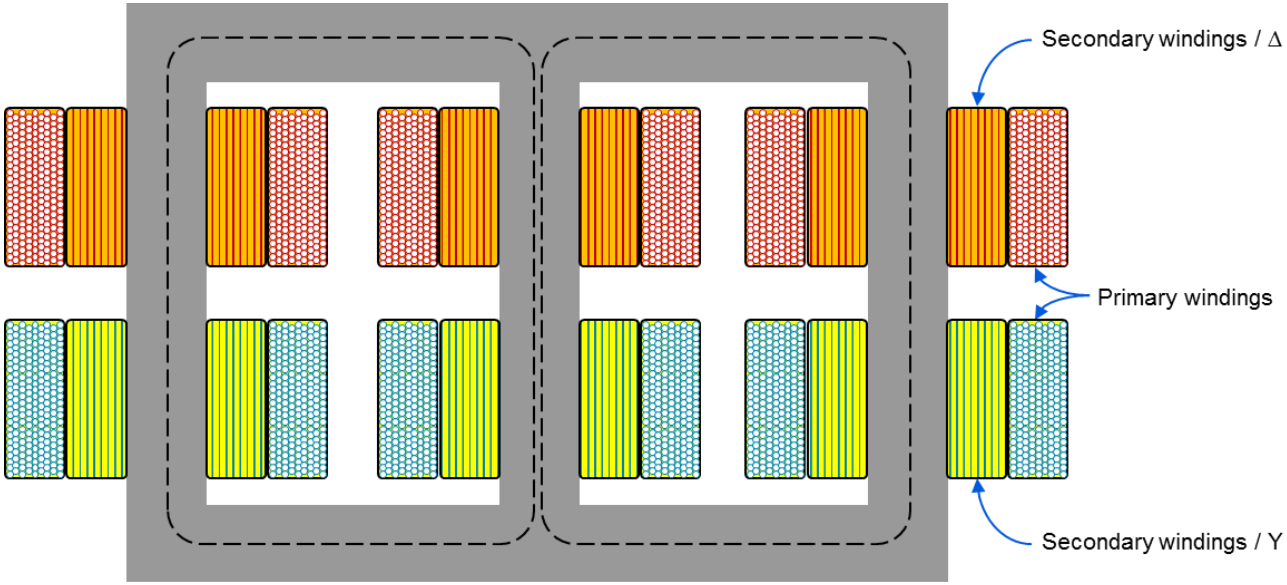
Linked to a predefined $PF_{PVI} < PF_{PVI}(p_{PVI})$ ***curve***

Applied algorithm

Multiwindings MVLV tranformers
Plant cost reduction

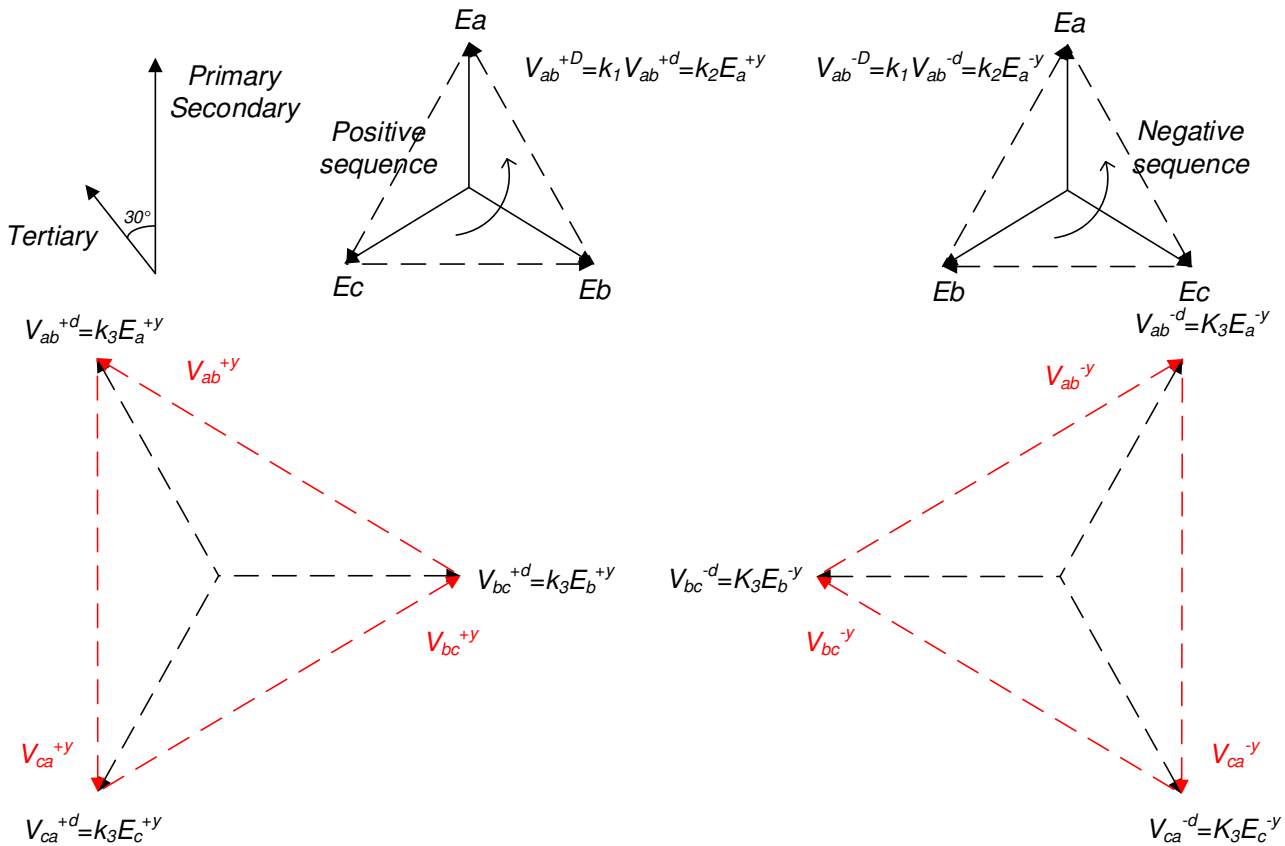
Transformer cost is almost proportional to the weight

- ULTRA doesn't inject common mode currents -> no shielded transformer
- Typical ABB proposal: Dd0y11 connection
  - Stacked construction
  - $z_{cc}^{23}=0.9(z_{cc}^{12}+z_{cc}^{13})$



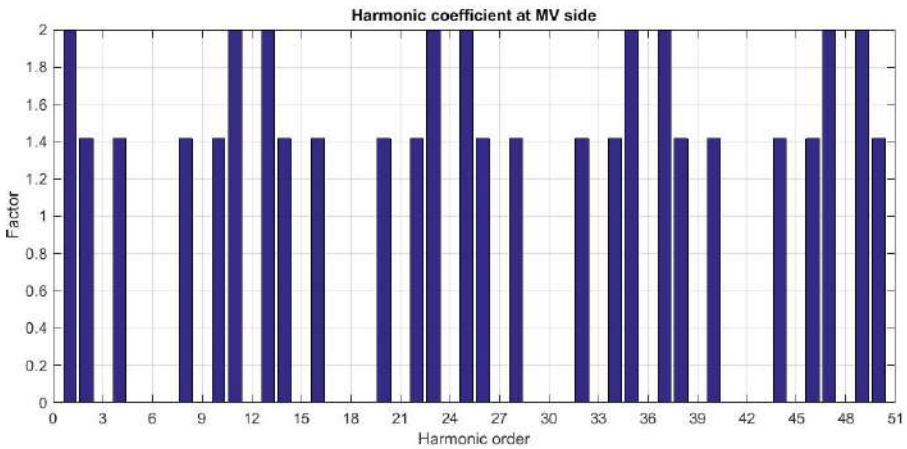
Multiwindings MVLV tranformers
Windings connection choice Dd0y11

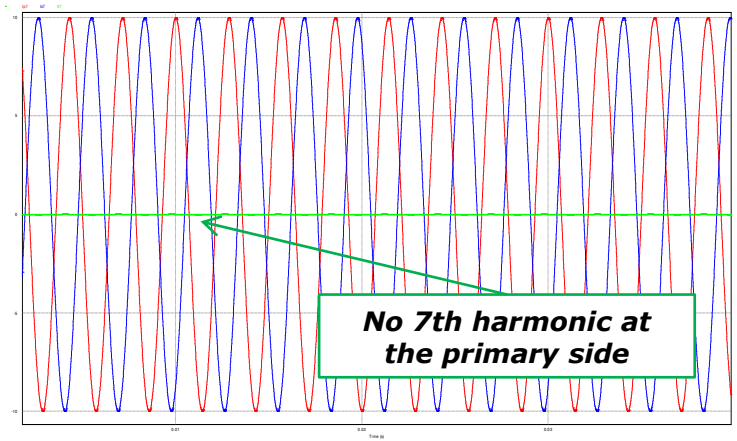
- No homopolar sequence from the secondaries to the primary (recommended ungrounded star conn. secs)
- Sequence circuits of Dd0y11



Multiwindings MVLV tranformers
Windings connection Dd0y11 (contd) OLTC choices

- Dd0y11 effects
  - Harmonic cancellation under the assumption of homogeneous PVI spectrums (3n and 6+12k±1)



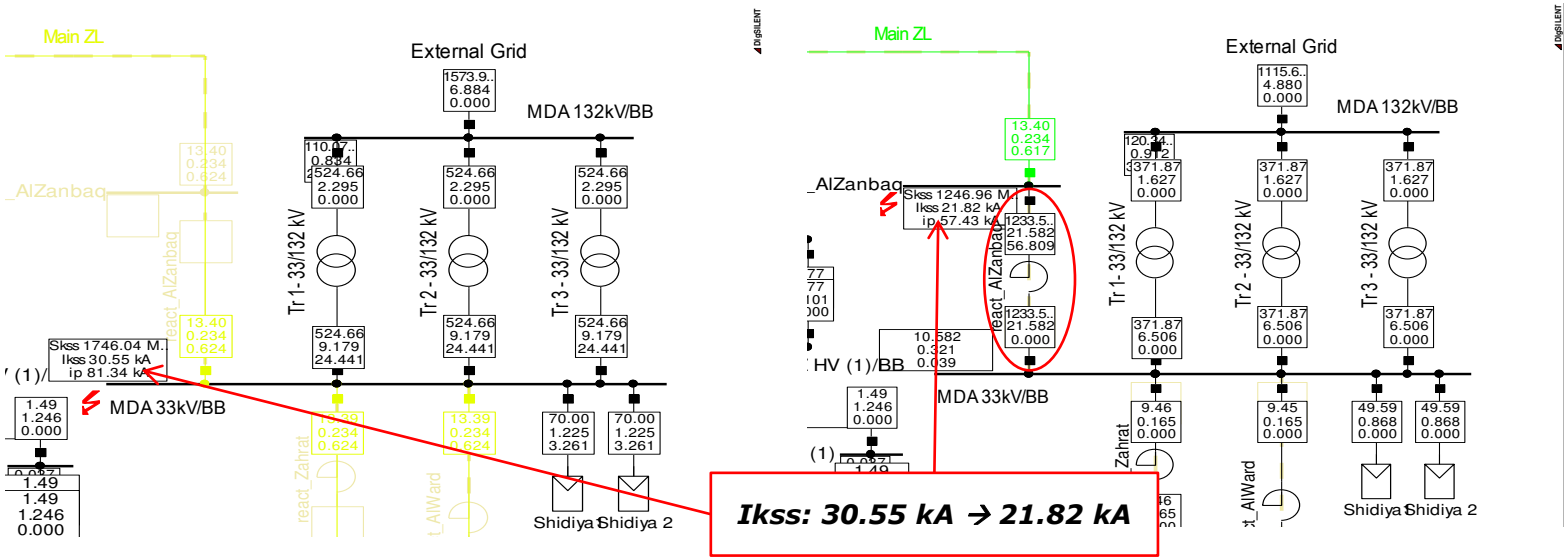


  - Awareness about the effect of asymmetrical faults on the inverters connected at the same transformer

- Off Load Tap changer
  - Typically ±2·2.5%

Short circuit current limitation
Limiting reactors

I_{SC}^{PCC}>> ⇨ $I_n^{plant\ switchgears}$>> ⇨ Costly solutions

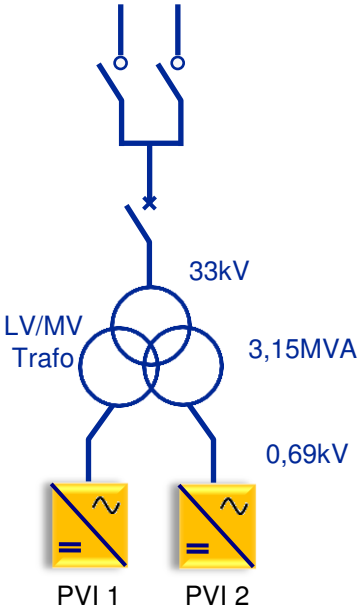


- Limiting reactors
  - Installed at the substation side of the plant feeder
  - Side effect:
    - parasitic power consumption

Complete skid
ULTRA outdoor station

- Our turn key solution
  - MV Switchger with RMU
  - 3w transformer
    - ONAN
  - AUX services
  - PLC for PPC, monitoring and Plant Automation

ABB SafePlus	
Un [kV]	33
Isc, 1s [kA]	25
Isc, 3s [kA]	20
Uimp [kV]	170 / 70



Centralized Vs Decentralized functions
Time decoupling

Fast control must be performed from the PVI

Decentralized Functions PVI

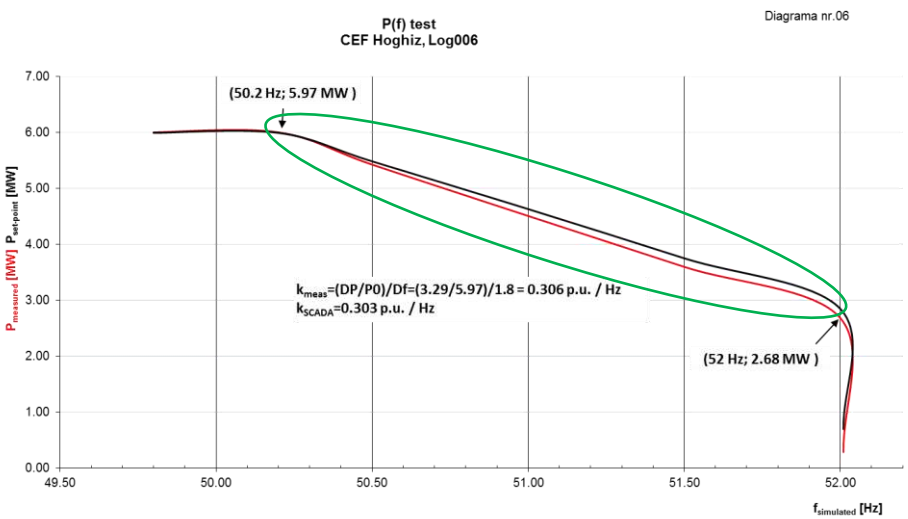
- Dynamic Reactive Current Support
- Anti-Islanding
- Local PQ control (PF=const, Q(V), P(V))
- Over Frequency Power Curtailment
- PCC PQ control (PF=const, Q(V), Qext, Pext)
- Damping clouding effects
- Data storage

Centralized Functions SCADA

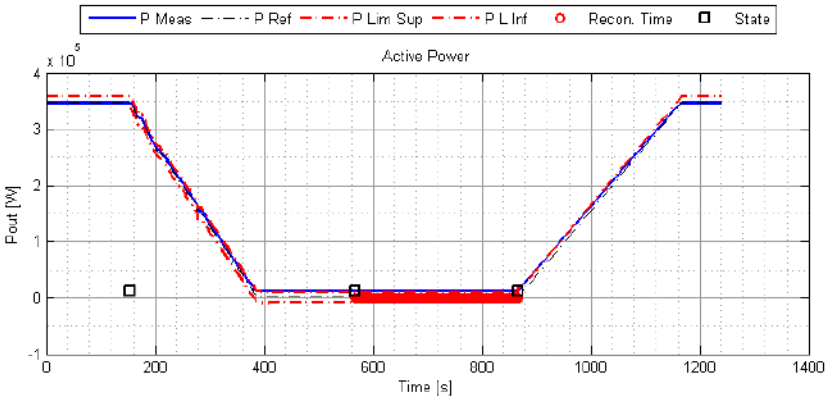
- Closed Loop schemes are recommended for decentralized controls

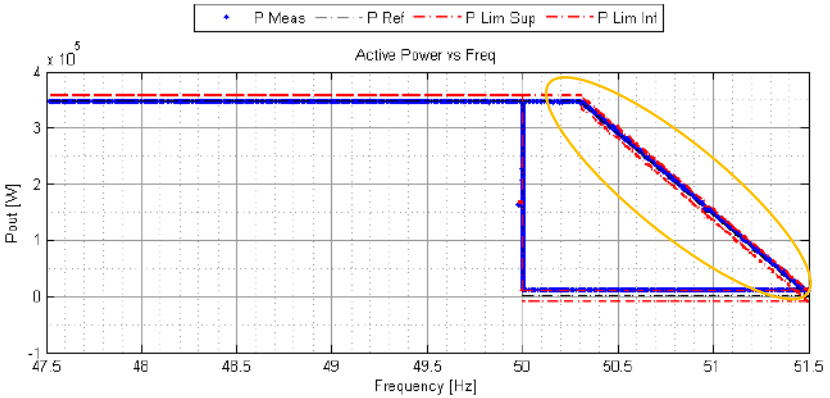
Centralized Vs Decentralized functions
The case of Over Frequency Power Curtailment

Central OFPC
Plant commissioning test through variation of the frequency signal at the SCADA

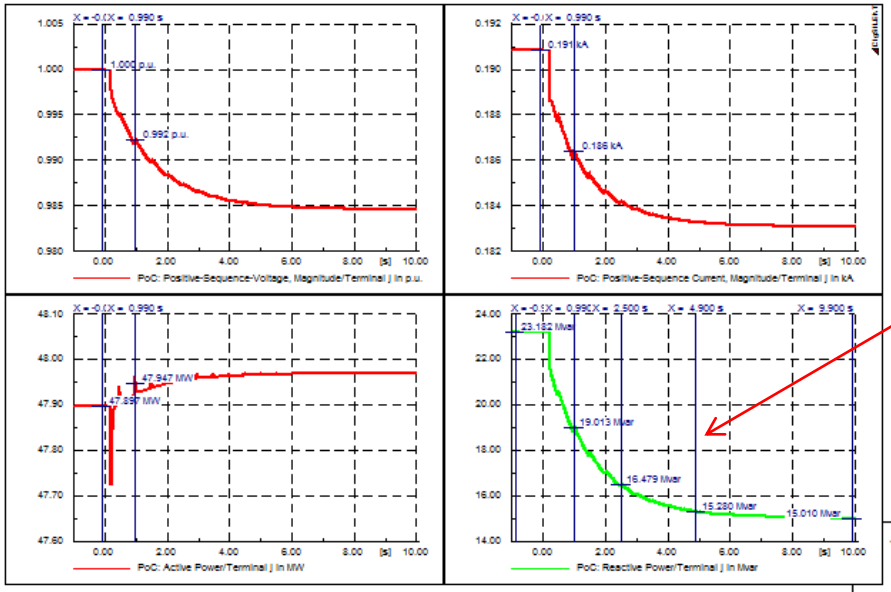


Decentralized OFPC
Lab test using a variable f grid simulator



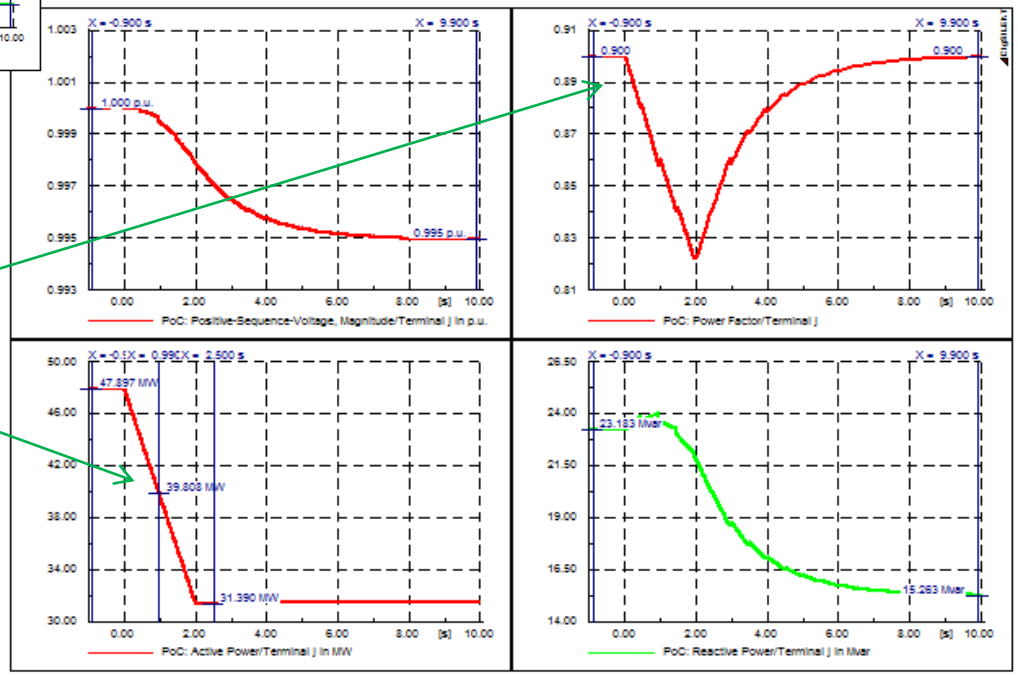


Centralized Vs Decentralized
Centralized Q control



Step ΔQ_{PCC}^{ref}=-8.2 Mvar

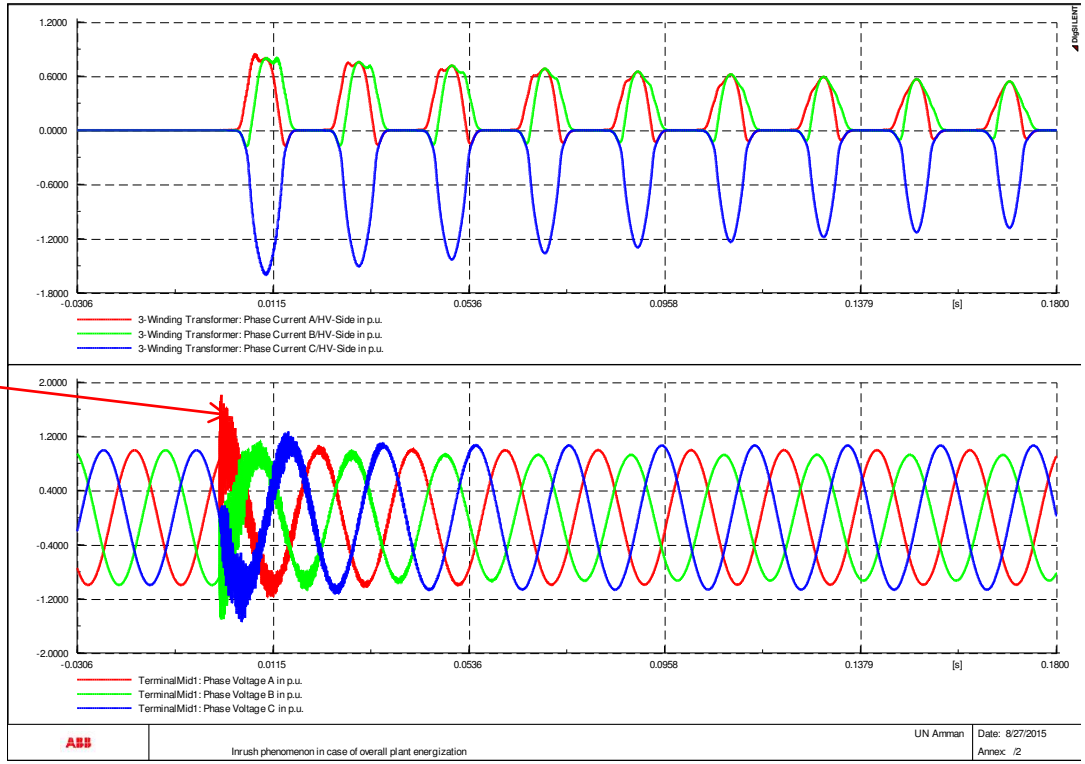
P_{PVI} ramp-down with centralized PF_{PCC} control (constant)



Energization
Mitigation methods

- Energizing transformers or lines (OHL>10 km or shorter cable lines) implies inrush phenomenon

Example case of overall plant energization (long OHL and step-up trafos)
⇨ Δv_{MV}=70% !



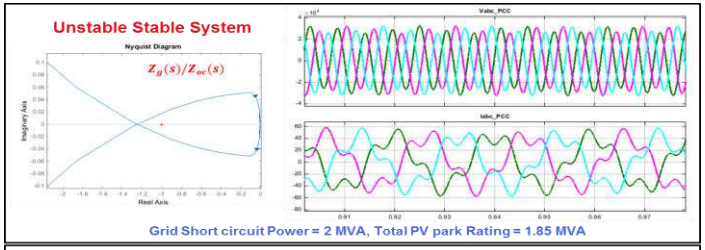
- Sequencing of plant trafos
- Adoption of inrush resistance mainstream to the line

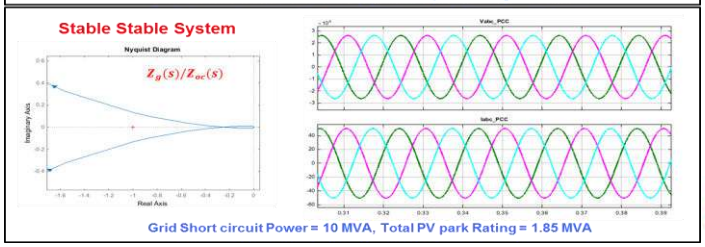
Inter/Harmonics studies
Risks and recommendations

- Need of detailed network data
- Harmonic load flows
  - PVI ⇨ Indipendent current sources
  - IEC 61000-3-6 $I_\mu = \sqrt[\alpha]{\sum_{i=1}^{\alpha} I_{\mu-i}^{\alpha}}$ ⇨ $I_\mu = \sqrt[\alpha]{\alpha} I_{\mu-i}$
  - BDEW $I_\mu = \sqrt{\sum_{i=1}^{n} I_{\mu-i}^{2}}$ where n is the number of PVI ⇨ $I_\mu = \sqrt{n} I_{\mu-i}$

IEC 61000-3-6	
Harmonic order h	α
<5	1
5≤h≤10	1.4
10<h	2

- Stability concerns if S_{PCC}<5S_{plant}
  - Detailed EMT studies
  - s-domain analyses





Conclusions

- Important factors for the successful integration of utility scale PV plants in the modern power systems are:
  - Grid Codes study, PVI and plant compliances
  - Accuracy of PVI templates and overall plant model
  - Professional Grid Impact Study
  - Awareness about pros and cons of alternative plant solutions

In this sense ABB offers one of the broadest solar inverter portfolio combined with a proved integration experience

Thank you for your attention

pietro.raboni@it.abb.com

Power and productivity
for a better world™

Renewable Energy in Jordan

AlShaima Rajai

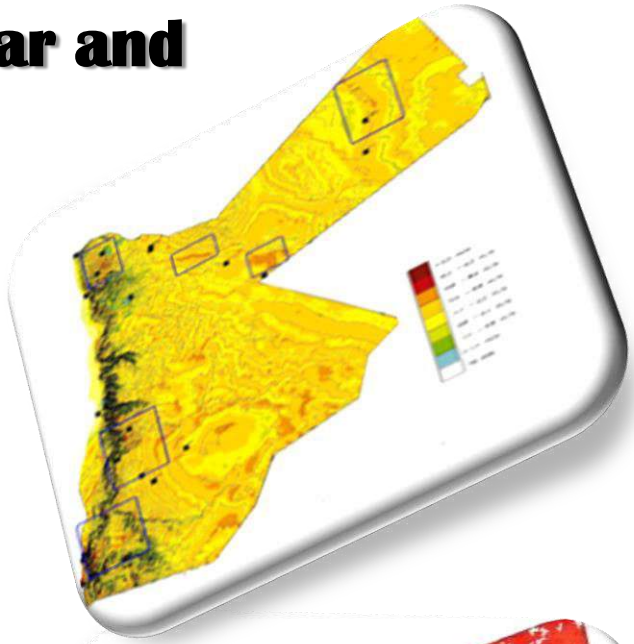
Transmission Planning Engineer , NEPCO

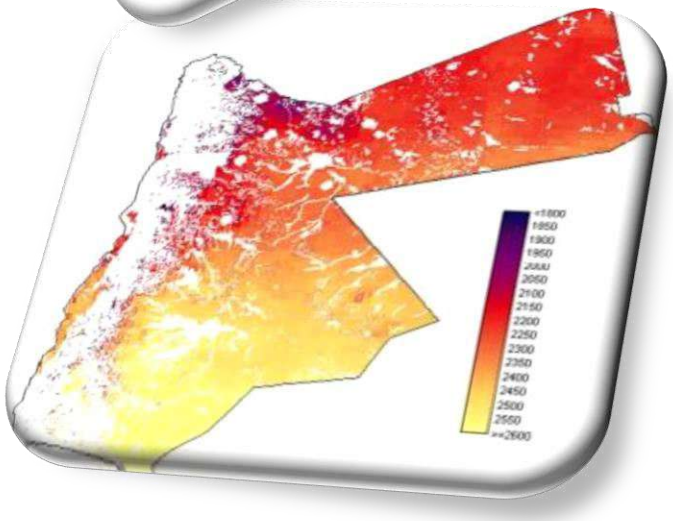
ejaber@nepco.com.jo

Sep. 2nd ,2015

Jordan enjoys world class quality Solar and Wind Energy

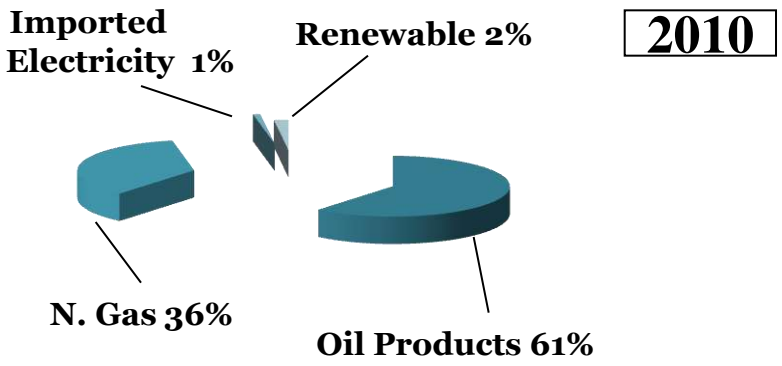
- Wind speed reaching between 7.5 to 10.0 m/s in some places.
- Wind projects are now feasible and competitive without further concessional support
- High solar radiation figures of 5 – 7 kWh/m2 per day with about 300 sunny days per year.
- Jordan future Renewable Energy source is Solar Energy.



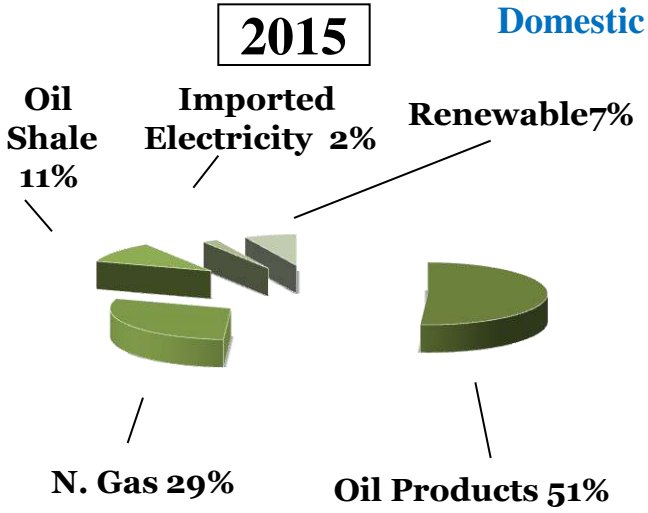


Jordan Energy Strategy

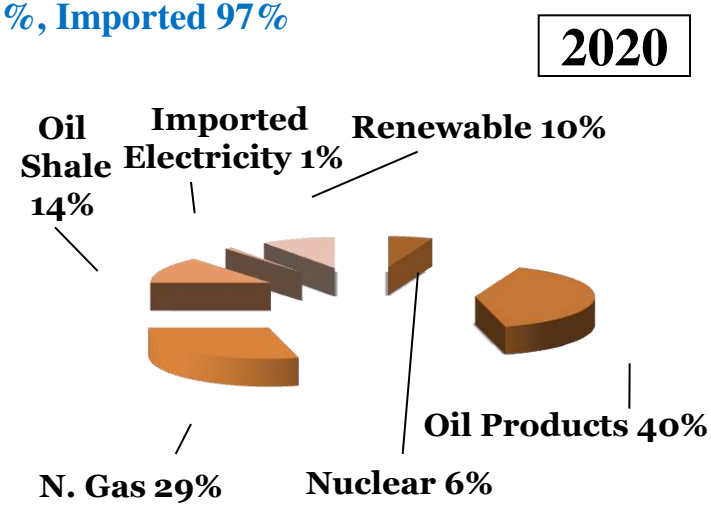
The Energy Mix in Jordan (2010 – 2020)



Domestic Resources 3%, Imported 97%



Domestic Resources 25%, Imported 75%



Domestic Resources 39%, Imported 61%

Regulatory Framework

- The Renewable Energy and Energy Efficiency Law was passed as a permanent Law in 2012 and amended in 2014.

- This law, the first in the region, allows investors to identify and develop grid-connected electricity production projects through the so called unsolicited or direct proposal submission.

- the Jordan Renewable Energy and Energy Efficiency Fund has been established, which aims to channel financial resources to that end.

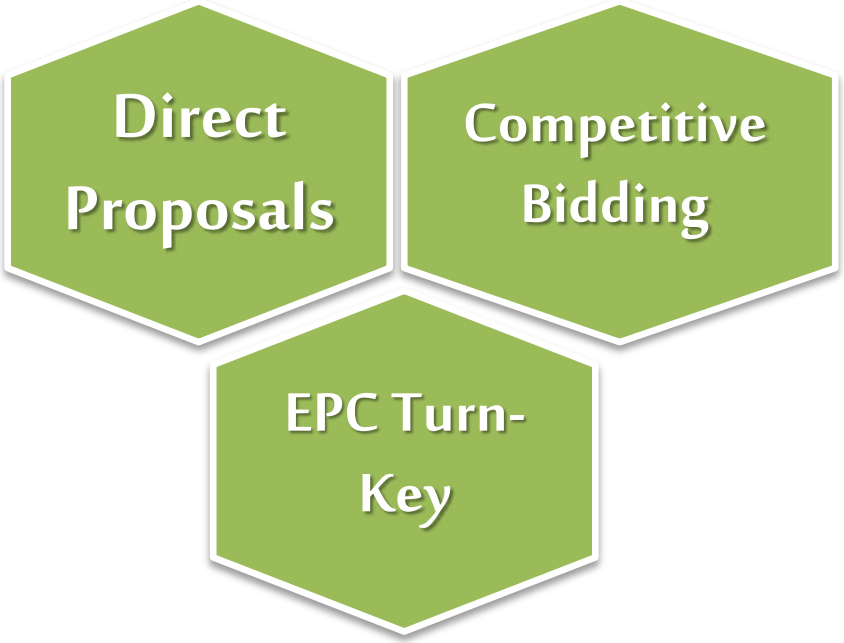
- A well-founded reference price list (ceiling prices) for different Renewable technologies was set by the EMRC .
- Net- Metering for small RE Systems (Roof Tops) with Fixed Purchase Prices for Excess Power.
- Tax Incentive regime, a By-Law was issued on Tax exemptions for RE and EE systems and Equipment.
- Grid Expansion and Reinforcement Plans are ongoing

Reference Price List

RE source	Tariff Fills/ kWh
Wind Energy	80
Solar Energy (CSP)	135
PV	100
Bio mass	90
Bio gas	60

Renewable Energy Development Schemes

The Government is currently engaged with the 3 tracks approach to develop RE Projects as follows:



Renewable Energy Projects 2016-2018

2016

- PV MDA 160 MW
- PV Qwera 100 MW
- PV Shamsuna 10 MW
- PV Scatec 10 MW
- PV JoSolar 20 MW
- Tafila Wind 117 MW
- King Hussein Wind 75 MW
- Fujaij Wind 100 MW

592 MW

2017

- PV MDC 150 MW
- PV Mwqr 50 MW
- PV Safawi 50 MW

842 MW

2018

- Wind KOSPO 50 MW
- Wind XENEL 50 MW
- Wind Rajif 83 MW

1025 MW

Net- Metering (Roof Top) Systems

- More than 4000 applications received by distribution companies, resulted in installations of about (20) MW of PV total capacity all over the country, it is expected to double this figure by the year end, or even more.

Power Wheeling

"Wheeling" refers to the transfer of electrical power through transmission and distribution lines from one utility's service area to another's.

Regulations for Power Wheeling

- **The Capacity allowed to be generated and transmitted through wheeling must be equal to or less than 10% of the firm capacity of the Transmission Line OR 20% of The firm capacity of the substation feeder for the load.**

- **The Generated Capacity = The Load**

-

Type Of Connection	Losses %	Wheeling Cost (Fills/KWH)
Connect to the **transmission** system to feed a **transmission** system connected consumer	2.3	4.5
Connect to the **distribution** system to feed a **distribution** system connected consumer	6	7
Connect to the **transmission** system to feed a **distribution** system connected consumer	2.3 (Transmission Sys.) + 6 (Distribution Sys.)	4.5 (Transmission Sys.) + 7 (Distribution Sys.)

NEPCO Technical Requirements for Grid Connected RE Projects

NEPCO has developed a document for all technical requirements which any grid connected RE project must comply with.

Intermittent Renewable Resources (IRR) Wind & PV Transmission Interconnection Code (TIC)

- Voltage Requirements
- Frequency Requirements
- Voltage Flicker
- Harmonics
- Ramp Rate

Thank You

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Session 1
Generals and EU experience

Impact of non-programmable RES (VRE) generation on the power system

Bruno Cova

Systems Planning Project Director

Division Consulting, Solutions & Services

Amman, September 2015

CESI Trust the Power of Experience

Testing • Consulting • Engineering • Environment

Session 1

Generals and EU experience

- System wide impact
  - Barriers to overcome
  - Additional reserve and balancing capability
  - Difficult transitions in the ramp up/down hours
  - Impact on power market mechanisms
  - Risk of overgeneration
- Network and local impacts
  - Network congestion
  - Critical behaviour of the system in dynamic conditions
  - Voltage profile and reactive power management
  - Coping with exceptional events

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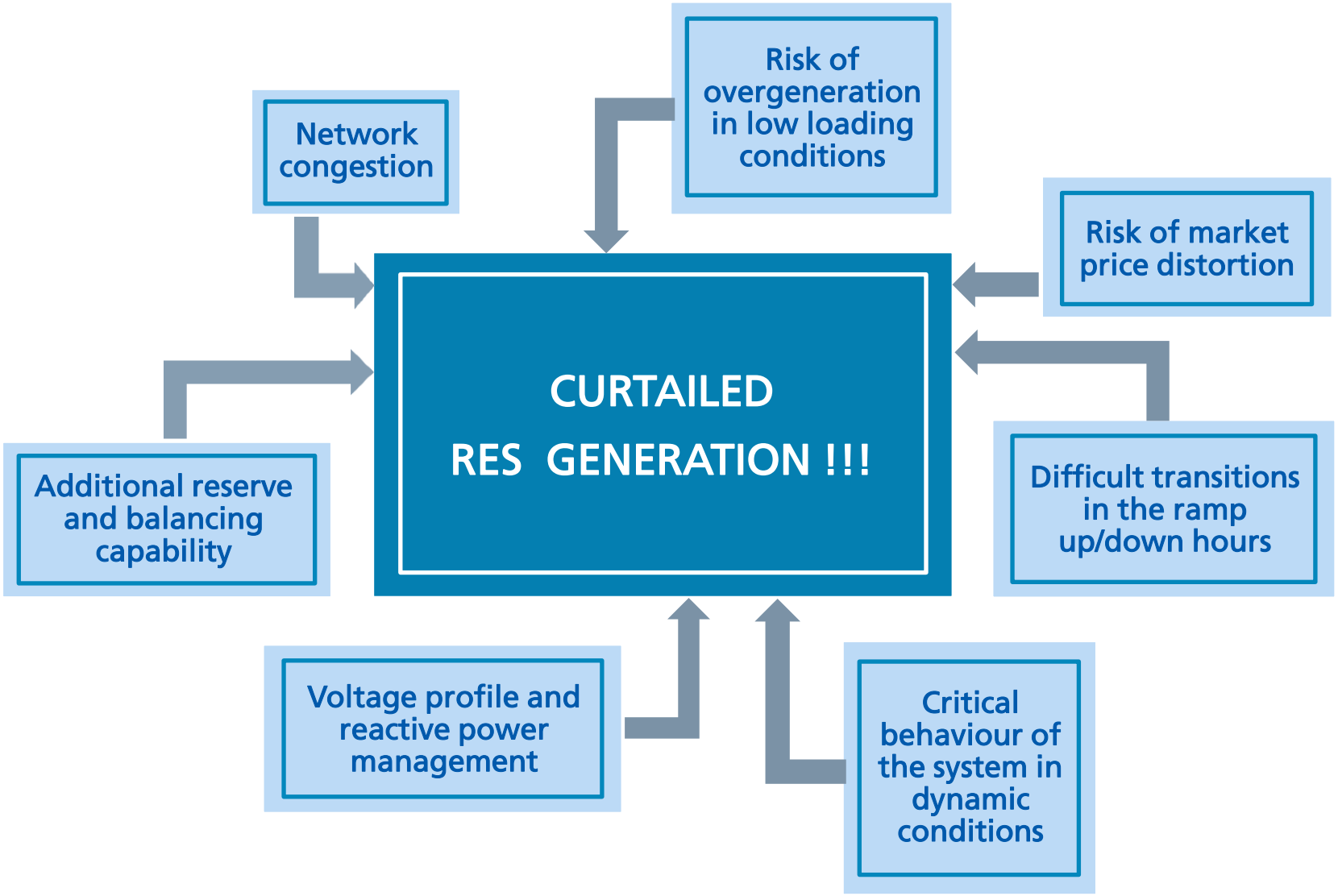
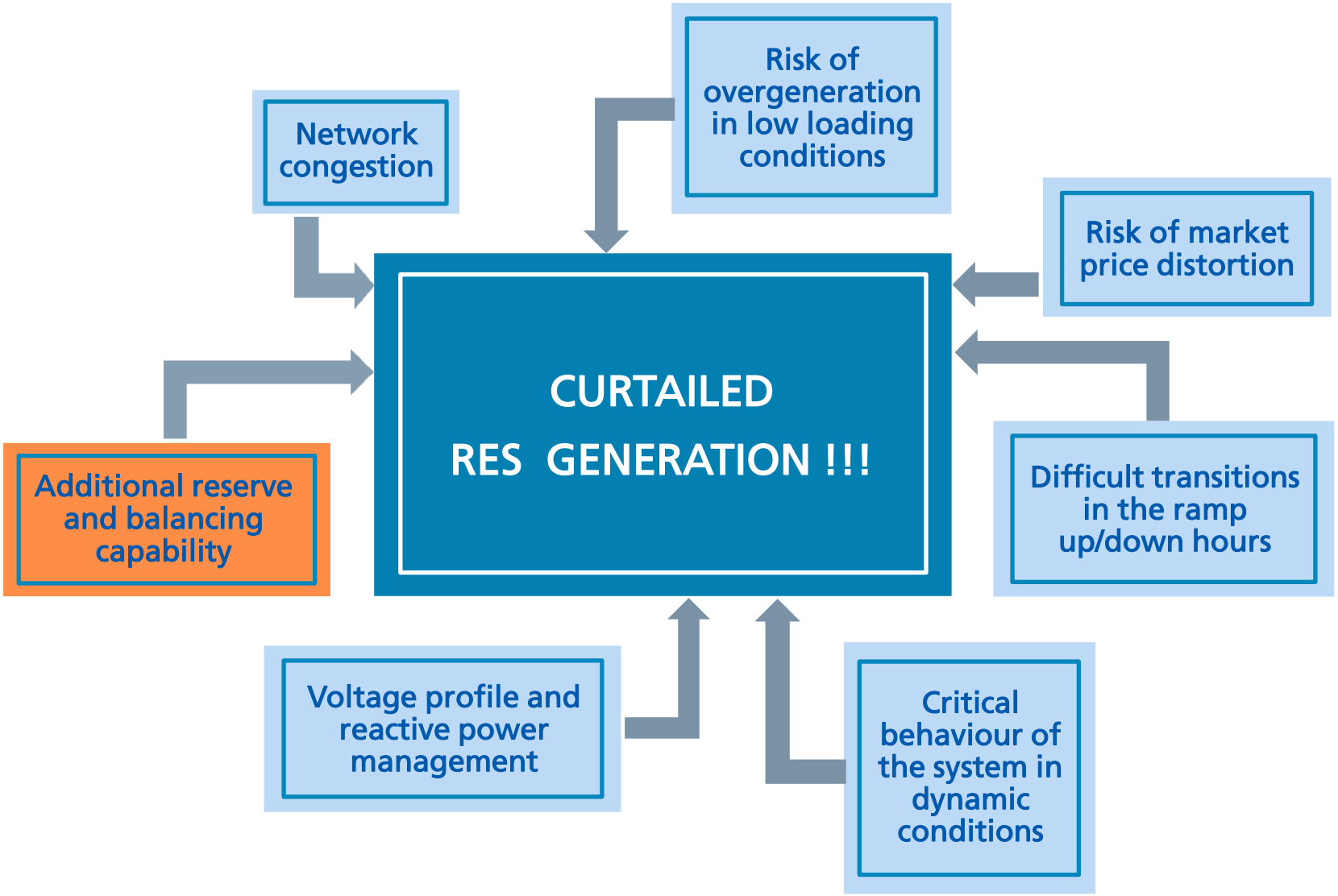
Barriers to overcome to enhance generation from non-programmable RES



Barriers to overcome to enhance generation from non-programmable RES

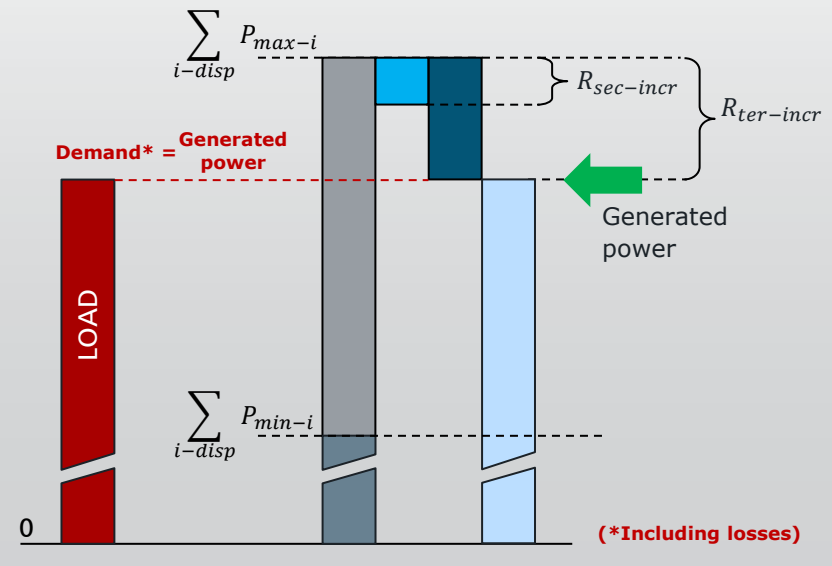


Additional Reserve and Balancing Capability

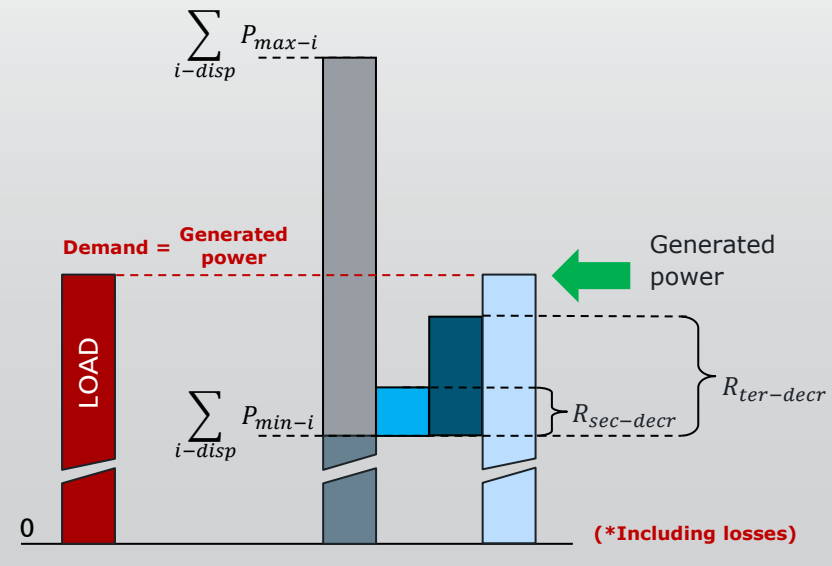
- **Secondary reserve*** $R_{sec} = \sqrt{10 \cdot L_{max} + 150^2} - 150$
- **Tertiary reserve*** $R_{ter-incr} = L_{max} \cdot 0.08$ **(daily)**

(Example of reserves according to ENTSO-E rules)*

➢ **In Peak Load condition these reserves define the maximum thermal generation**

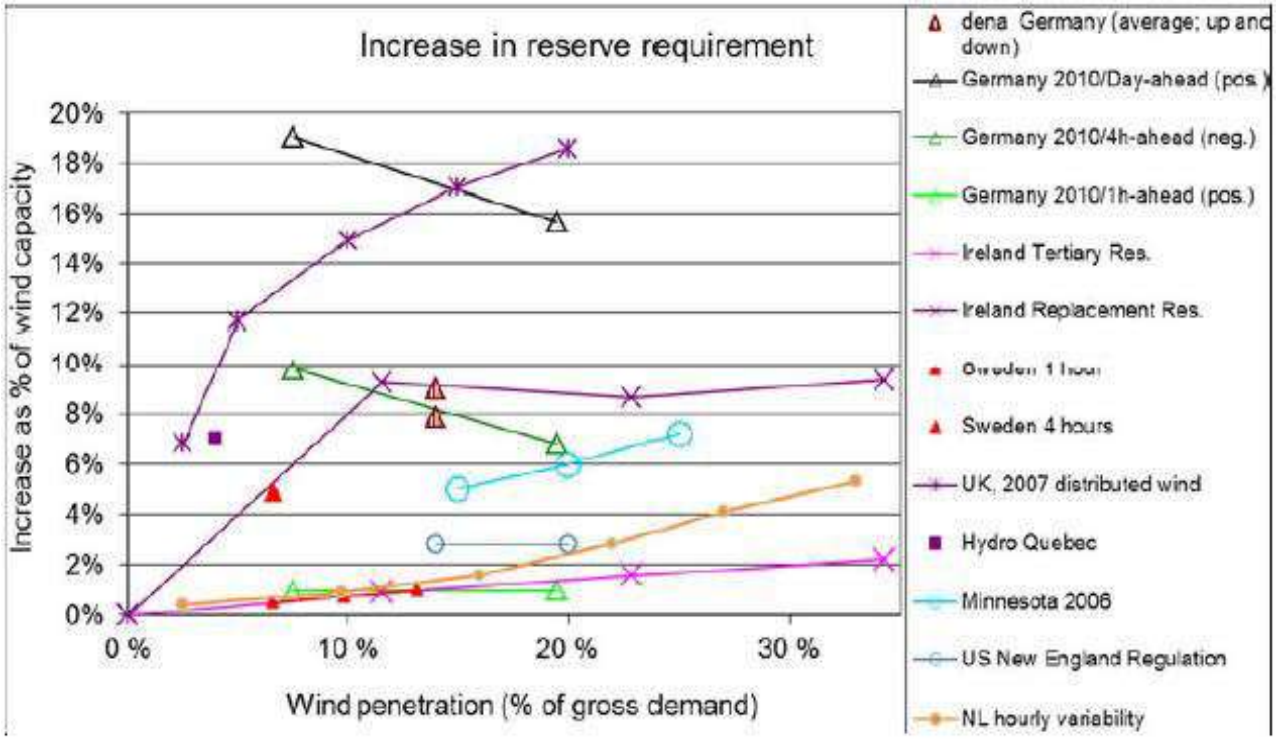


➢ **In Low Load condition these reserves define the minimum thermal generation**



Additional Reserve and Balancing Capability

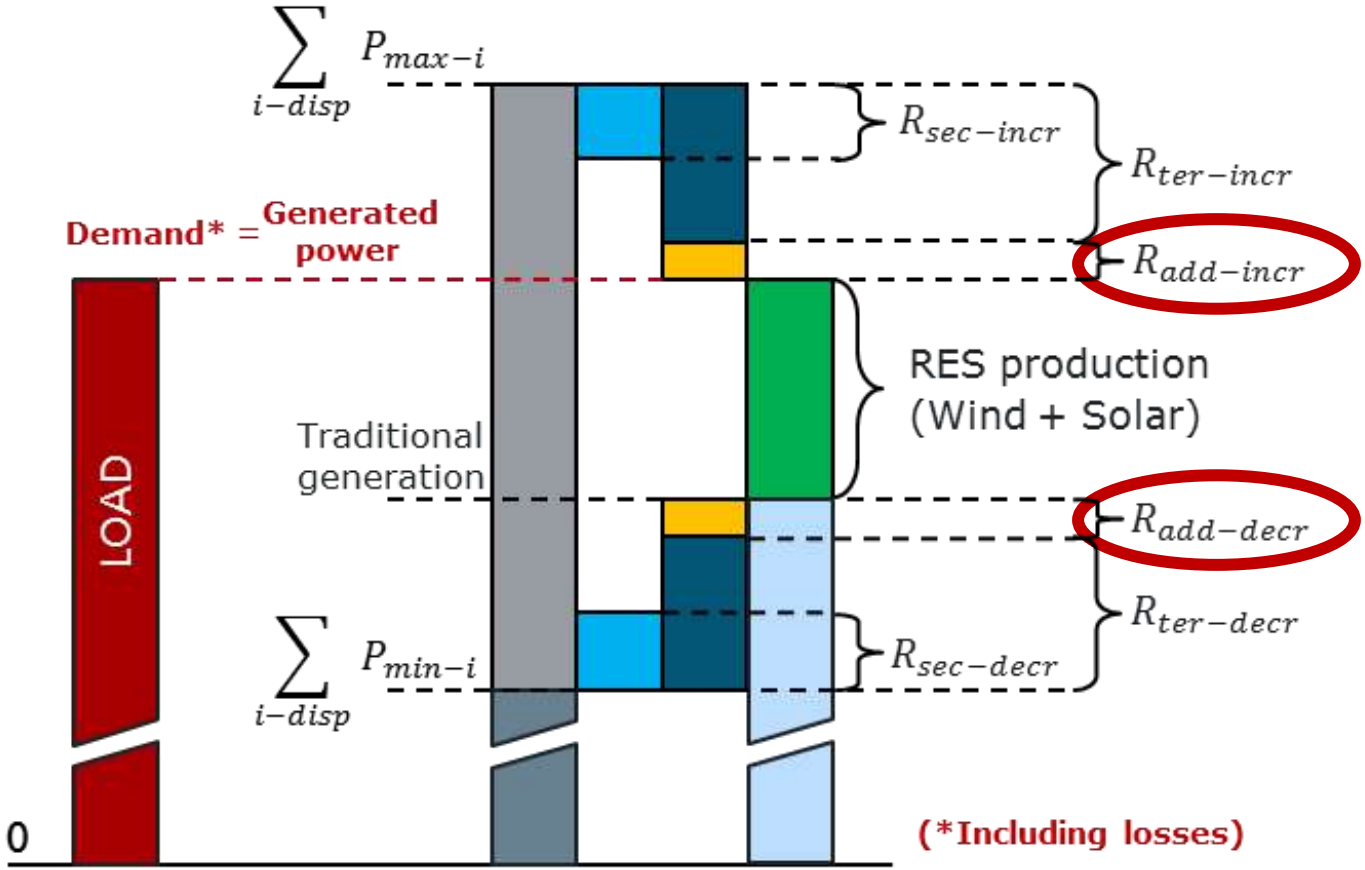
- **Need for Additional Reserve to cope with the intermittency of non-programmable RES generation**
  - Additional reserve [%]: percentage of wind generation
  - Penetration: wind production [MW] / demand



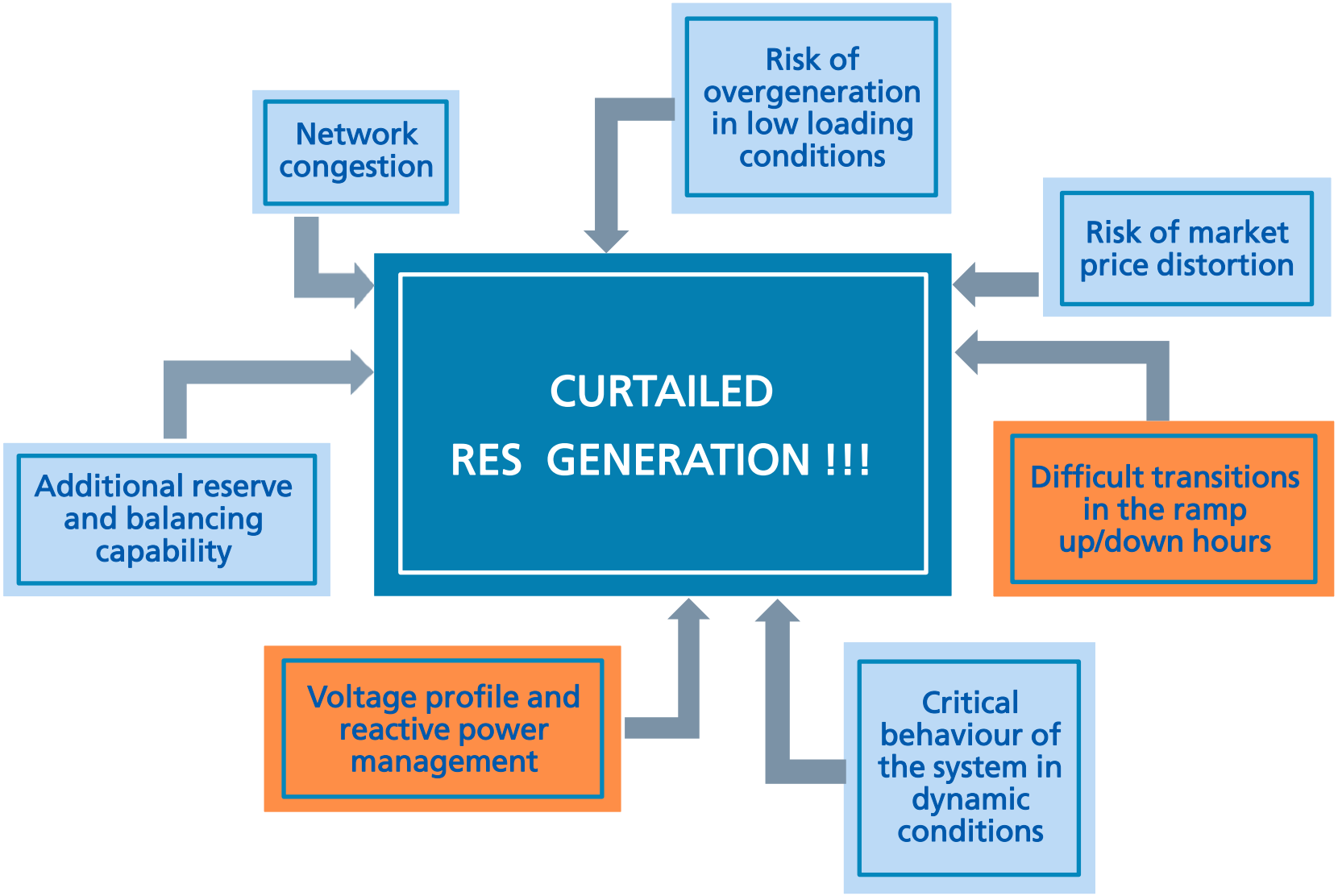
Source: IEA-Wind

Additional Reserve and Balancing Capability

- **Maximization of RES penetration considering also additional reserve**



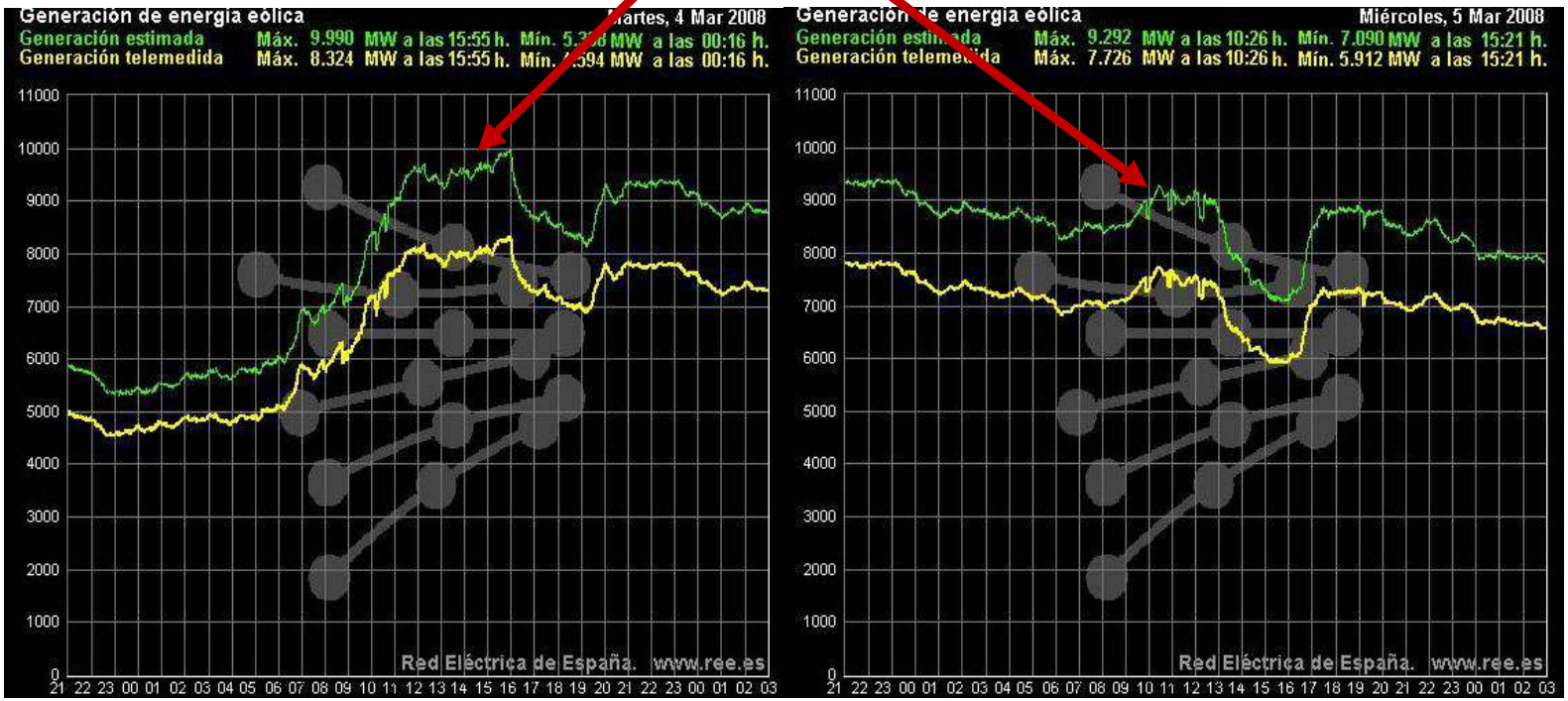
Barriers to overcome to enhance generation from non-programmable RES



Difficult upward/downward transitions

- **Possible Voltage problems**

Downward wind modulation

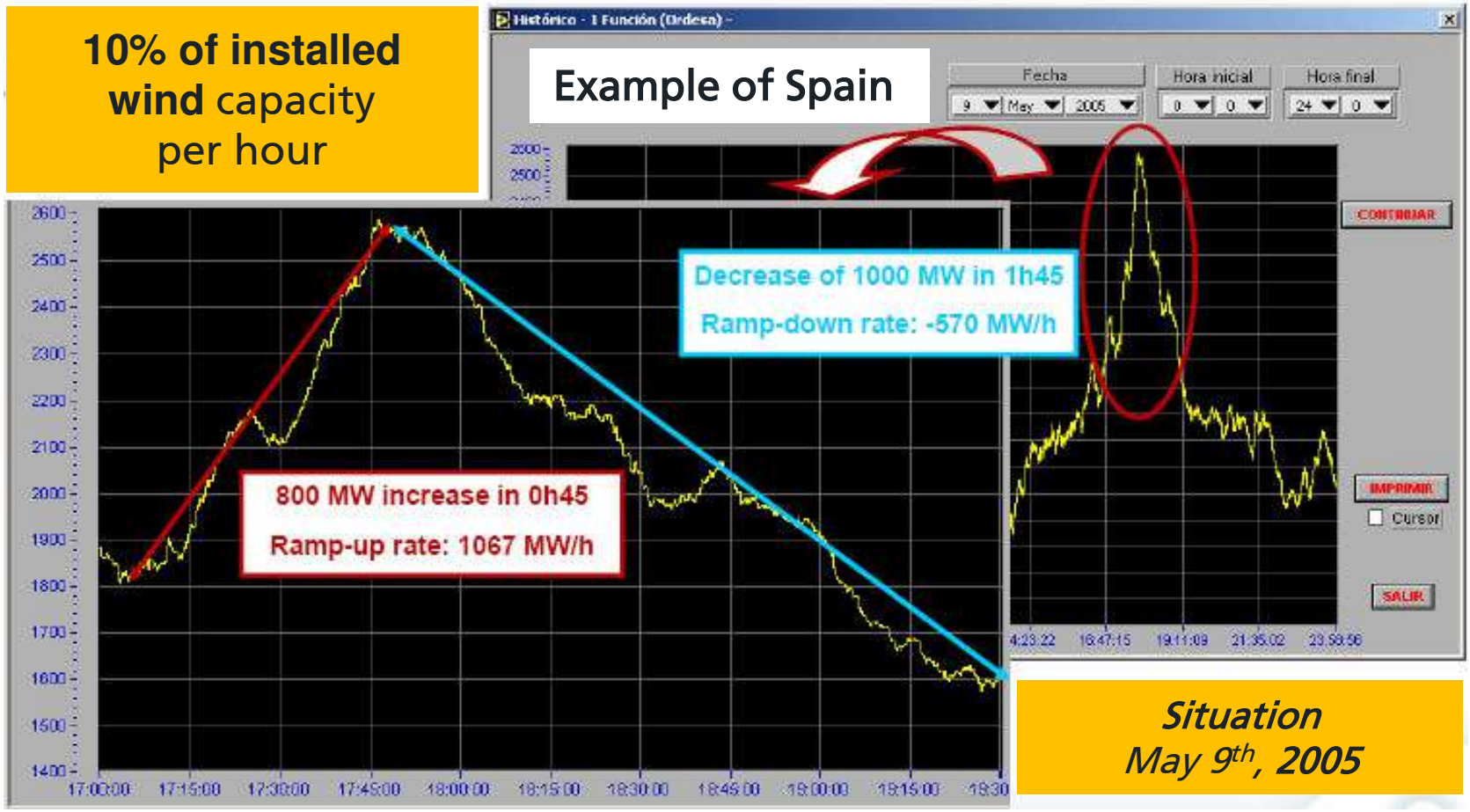


Wind generation in Spain on 4th and 5th March 2008 (source REE)

Difficult upward/downward transitions

- **Coping with sharp variations of RES generation**

10% of installed wind capacity per hour

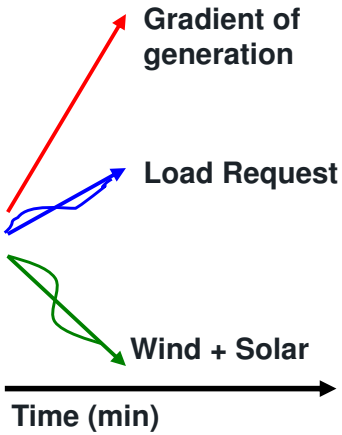


Situation
May 9th, 2005

Difficult upward/downward transitions

No correlation between Wind generation and demand!!!

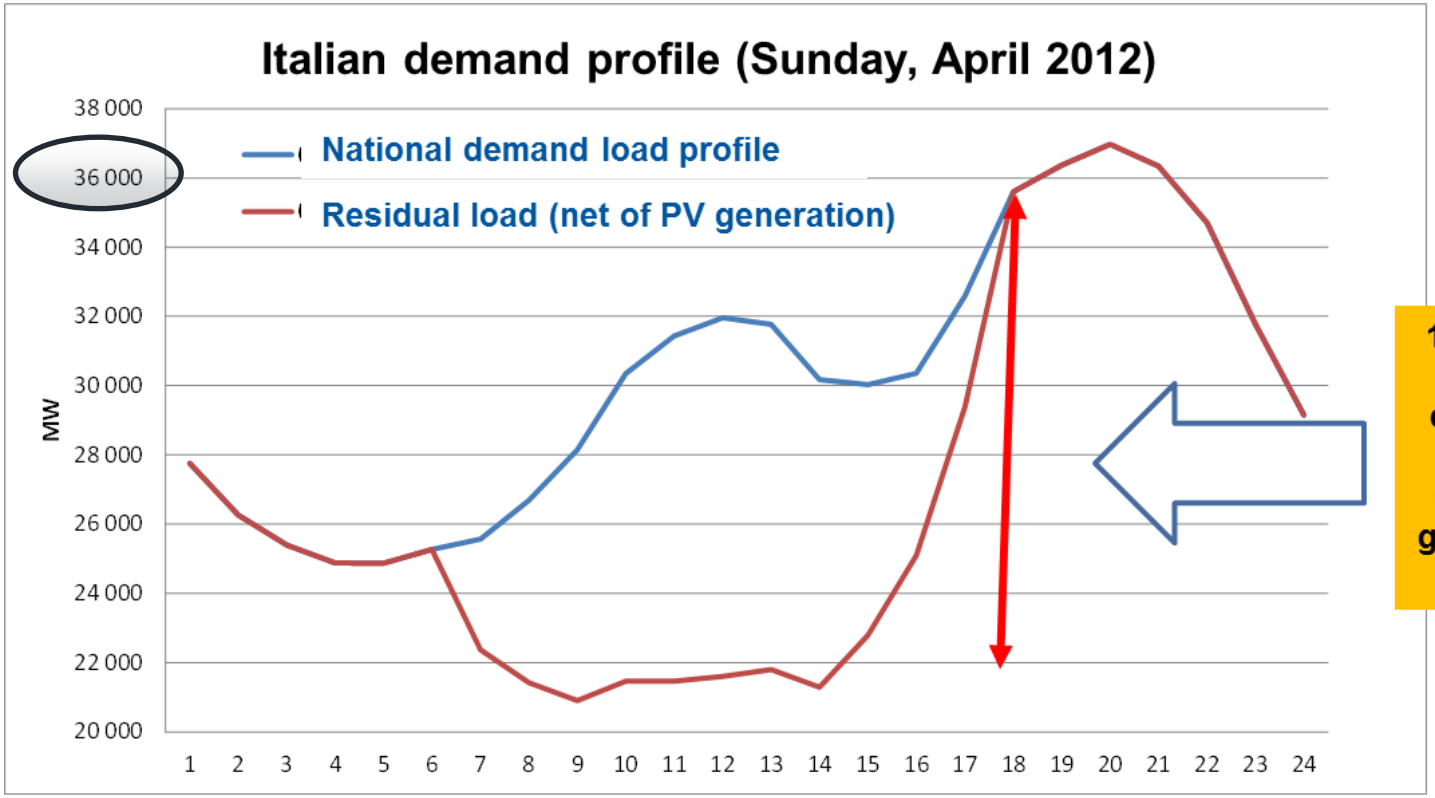
Difficult transitions during load ramp up/down



(Example of Spain)

Difficult upward/downward transitions

- **Load following in case of enhanced PV generation (1/2)**

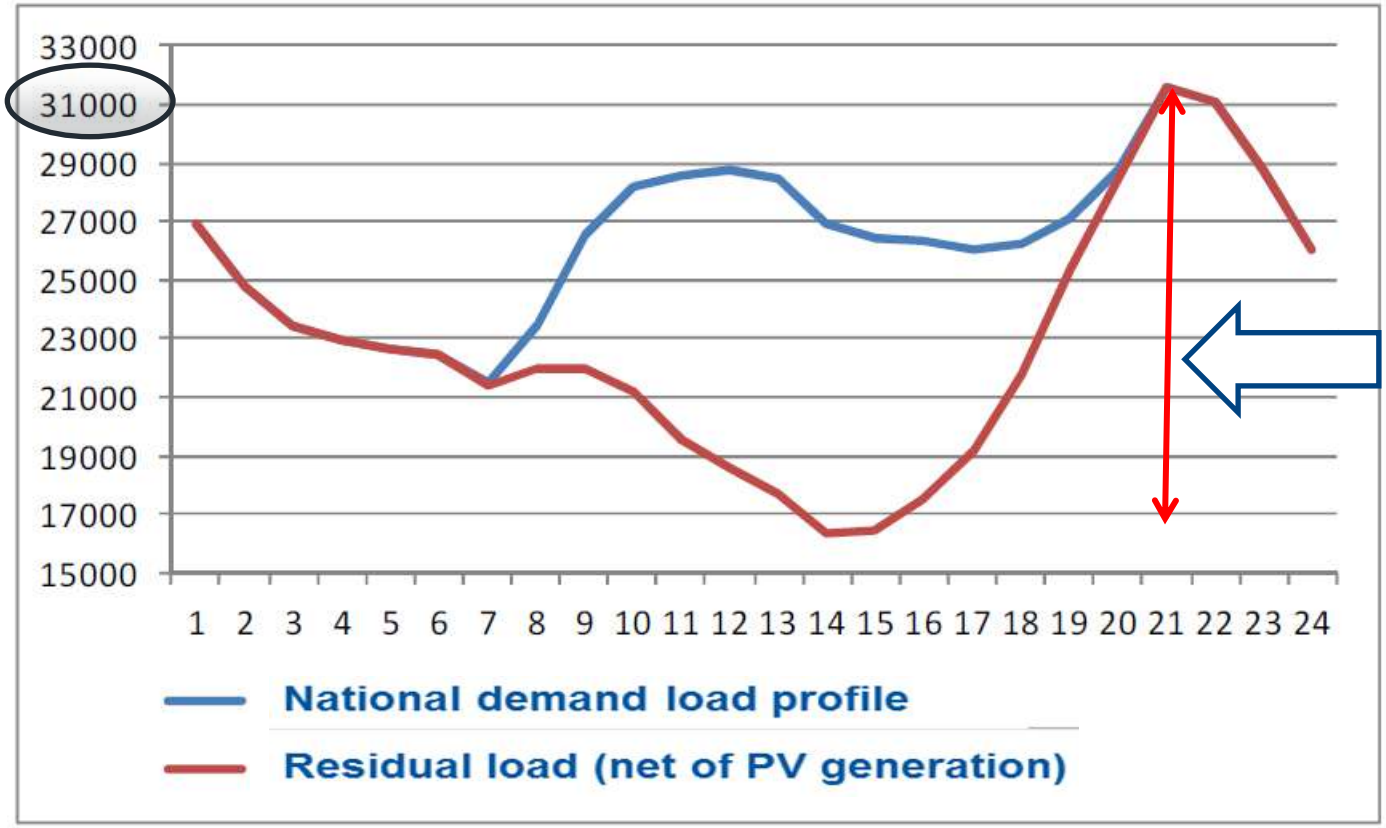


14 GW of load ramp in the evening to be covered by dispatchable generation and import

Difficult upward/downward transitions

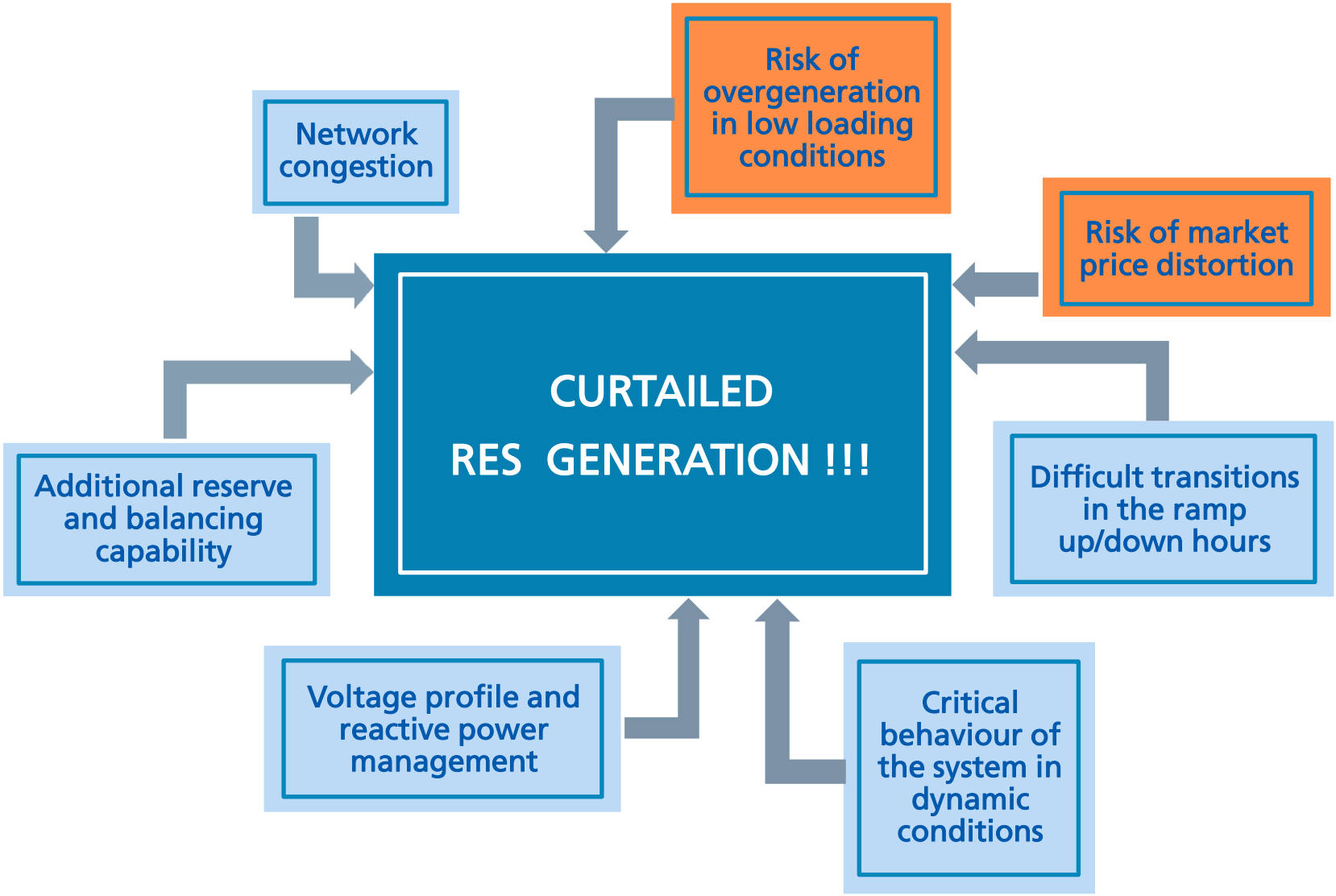
- **Load following in case of enhanced PV generation (2/2)**

Italian demand profile in a typical Summer Sunday in 2014

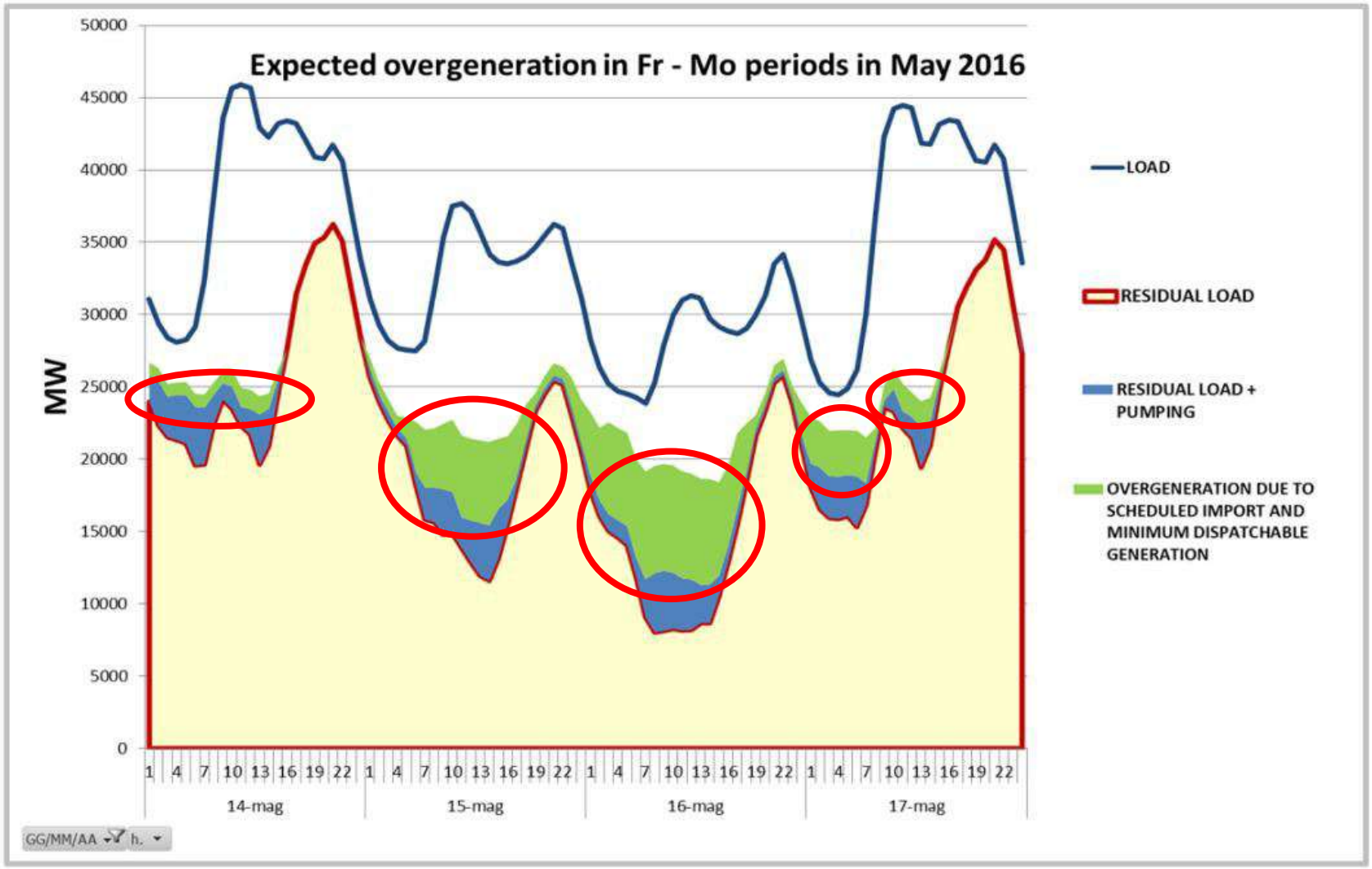


15 GW of ramp in the afternoon to be covered with a reduced set of dispatchable units (see reduced peak load)

Barriers to overcome to enhance generation from non-programmable RES

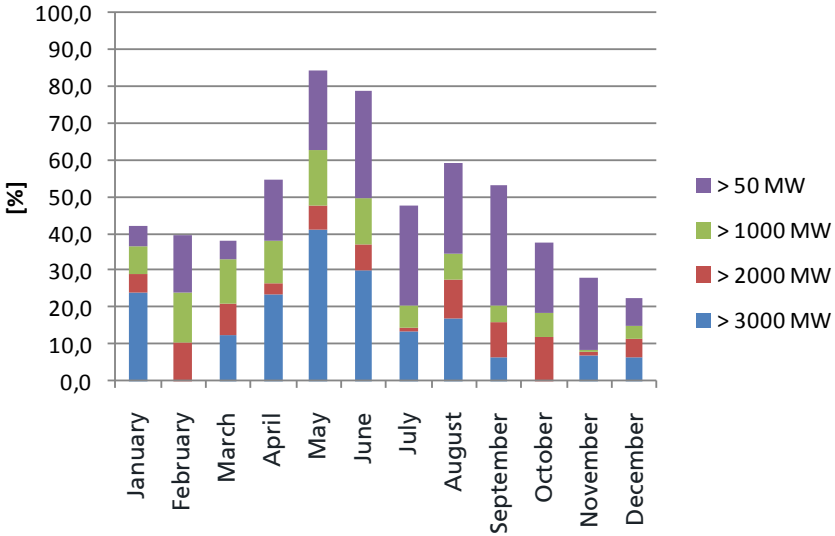


Risk of overgeneration



Risk of overgeneration
Example of Italian System

Overgeneration problems over weekends or public holidays



% of hours with overgeneration during weekends or public holydays

Countermeasures to reduce the risk of overgeneration:

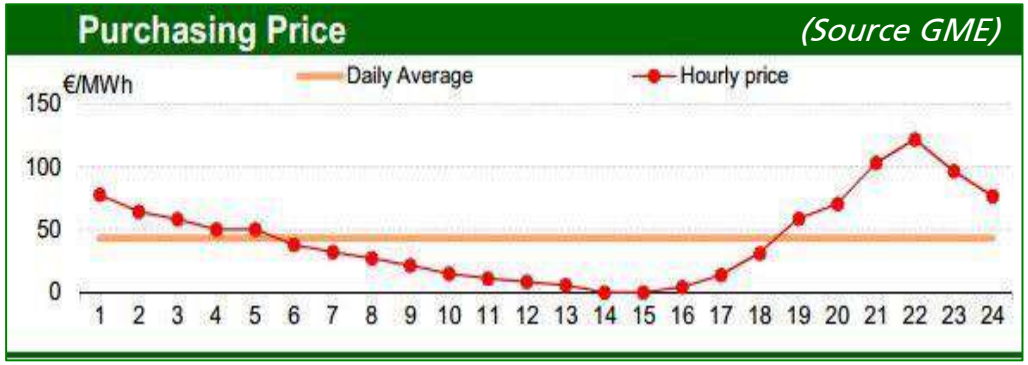
- Full exploitation of existing resources (maximizing existing pumping, reduction of power imported from neighbouring countries)
- Modulation of non-programmable RES generation
- Improve the forecast and management of distributed generation (on-site generation)
- Increase of energy storage capacity

Source: Terna

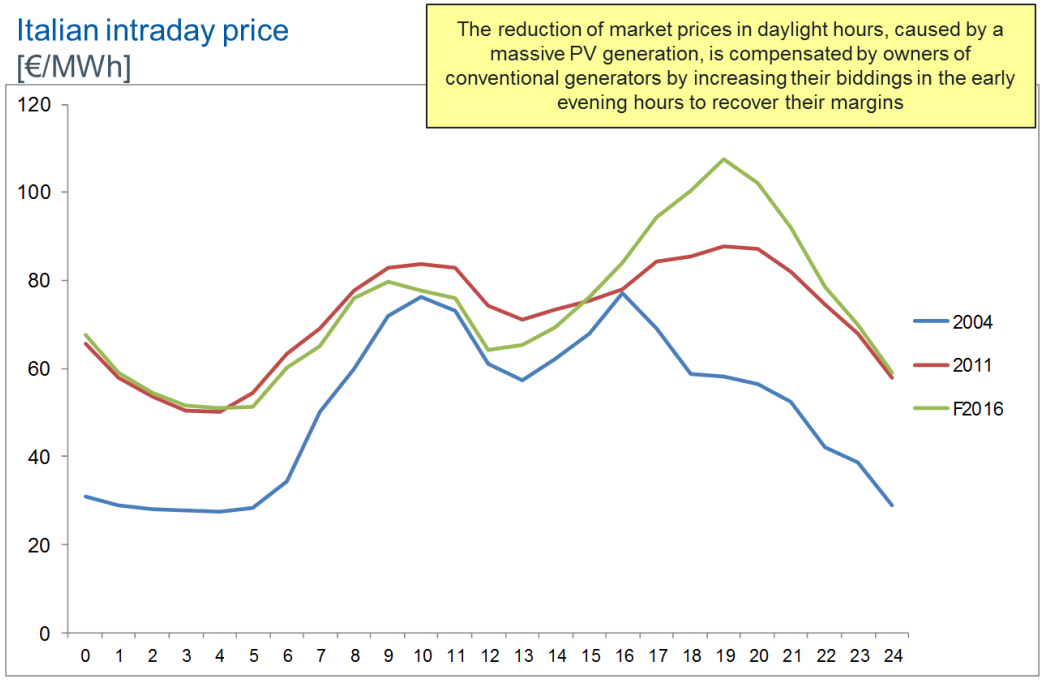
Impact on power market mechanisms
Example of Italian market

What happened in the **Italian day-ahead market** on June 16th, 2013:

- Minimum price: **0,00 €/MWh** (for 2 hours – 2:00 and 3:00 pm)
- Maximum price: 121,91 €/MWh (25.8% of offered energy supply by GSE)

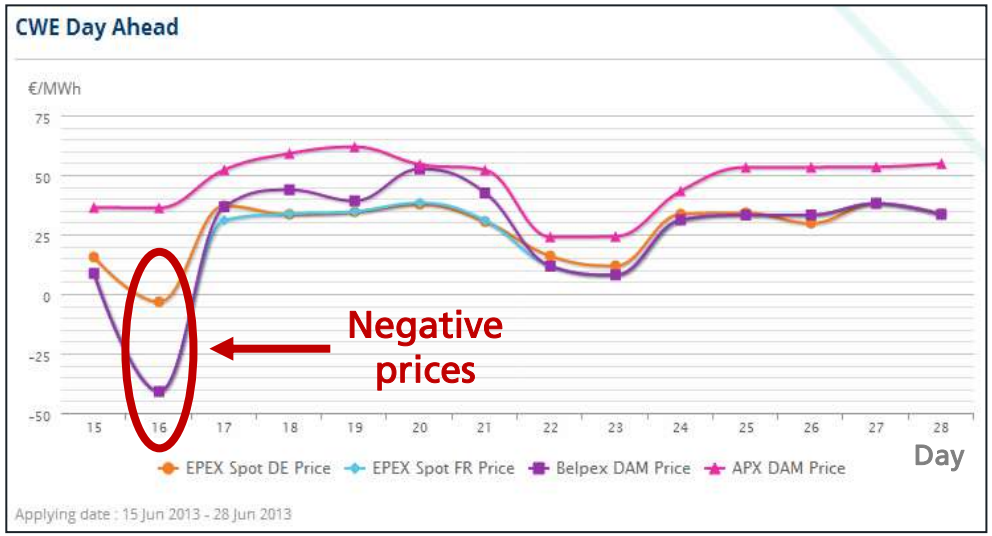


Italian intraday price [€/MWh]



Impact on power market mechanisms
Example of Central Western European (CWE) region

- **Negative baseload prices were observed in the Central Western European (CWE) region on June 16th, 2013:**
  - France -40,99 €/MWh
  - Belgium -40,99 €/MWh
  - Germany -3,33 €/MWh



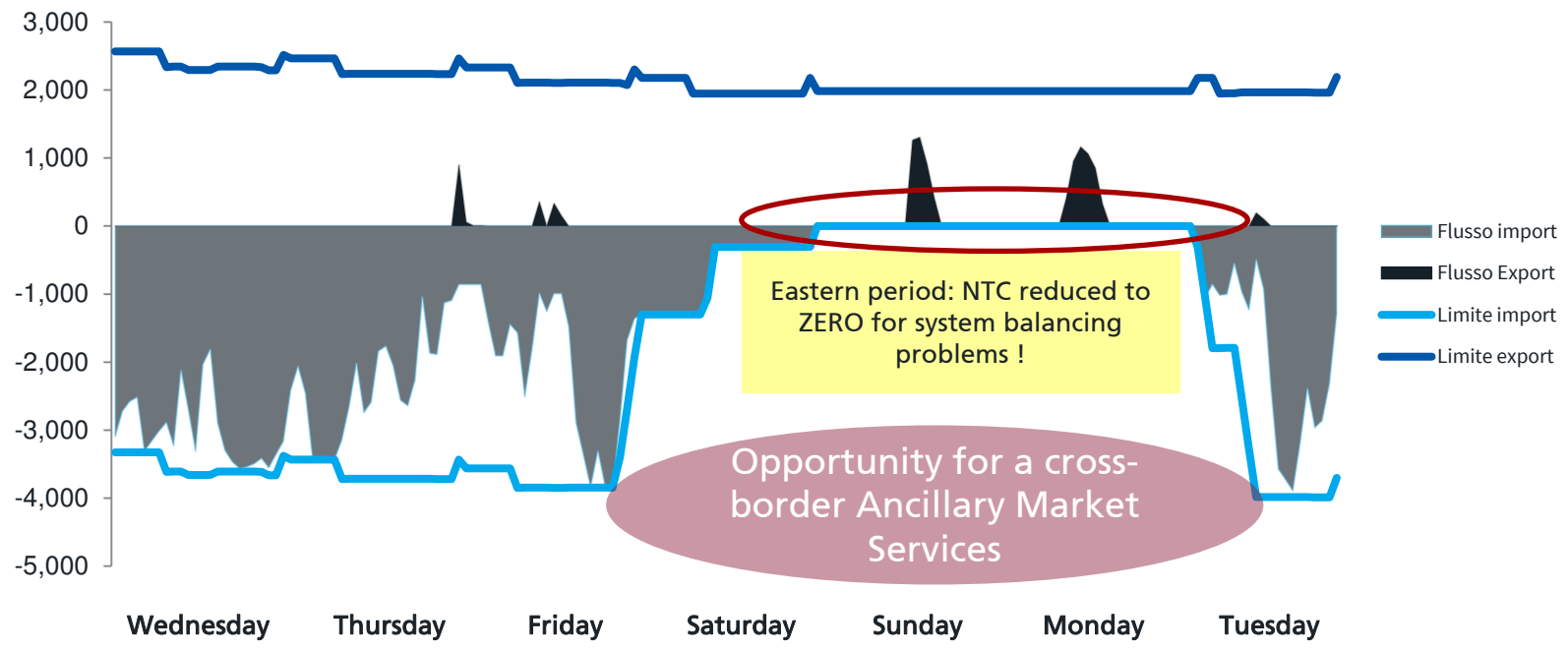
- **Low consumption and high levels of "non-flexible generation" (nuclear, hydro, wind, PV) in France, Germany and Belgium caused a generation surplus**

- **The Netherlands (price 36,16 €/MWh) did not face a surplus, but could not absorb more energy from the rest of CWE since the Netherlands imported the whole day at a level equal to its globally set import limit from Germany and Belgium.**

Source: APX, Belpex and EPEX Spot

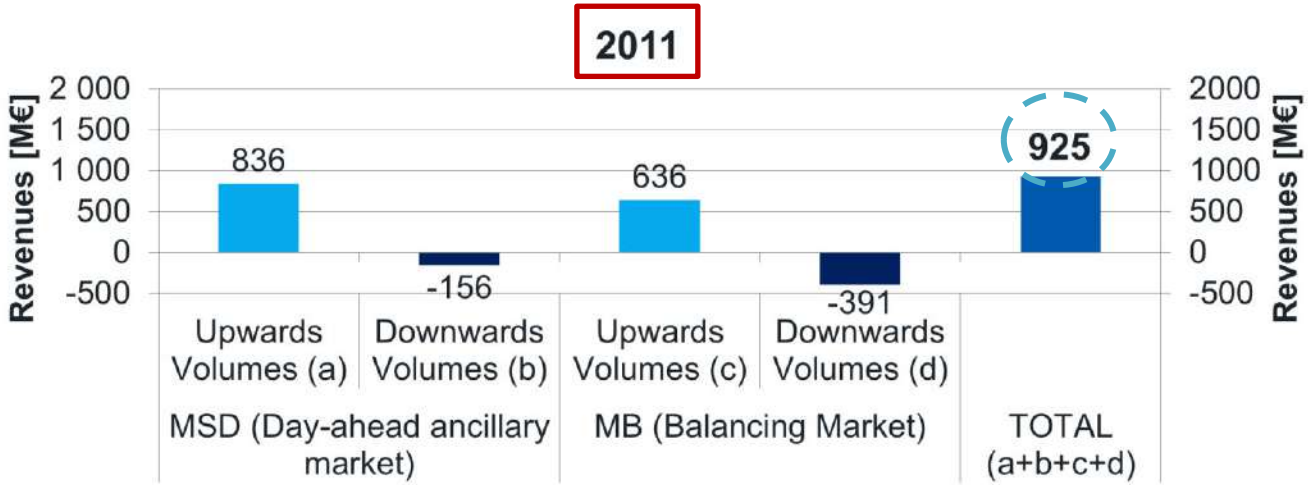
Impact on NTC arising from non-programmable RES (VRE) generation

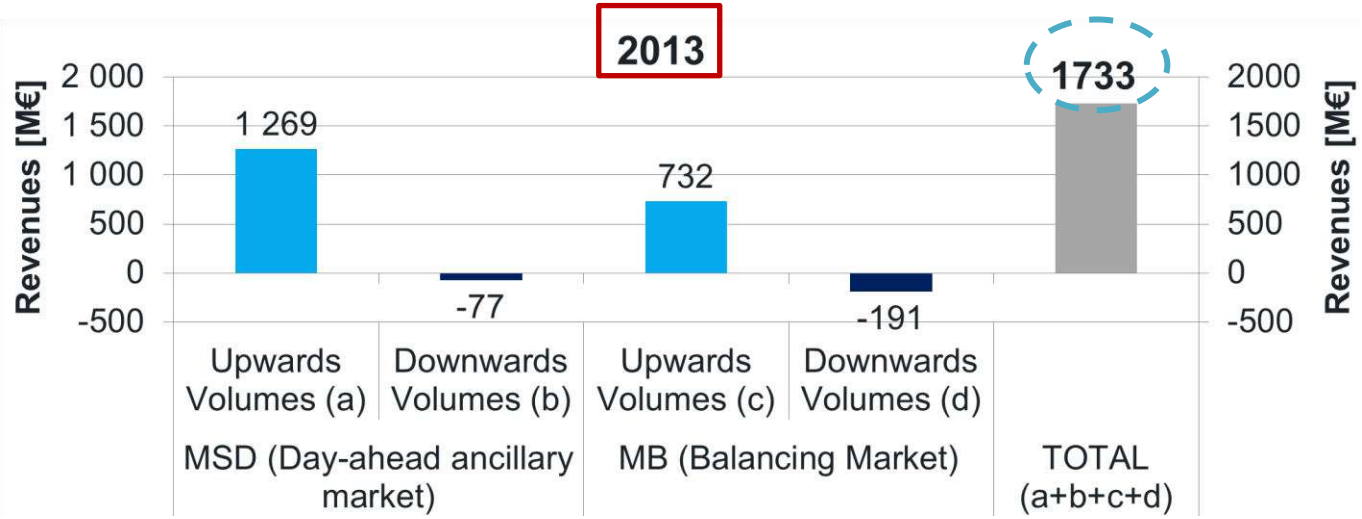
Net Transfer Capacity on the three borders (Slovenia, France, Austria) 01/04/2015-07/04/2015



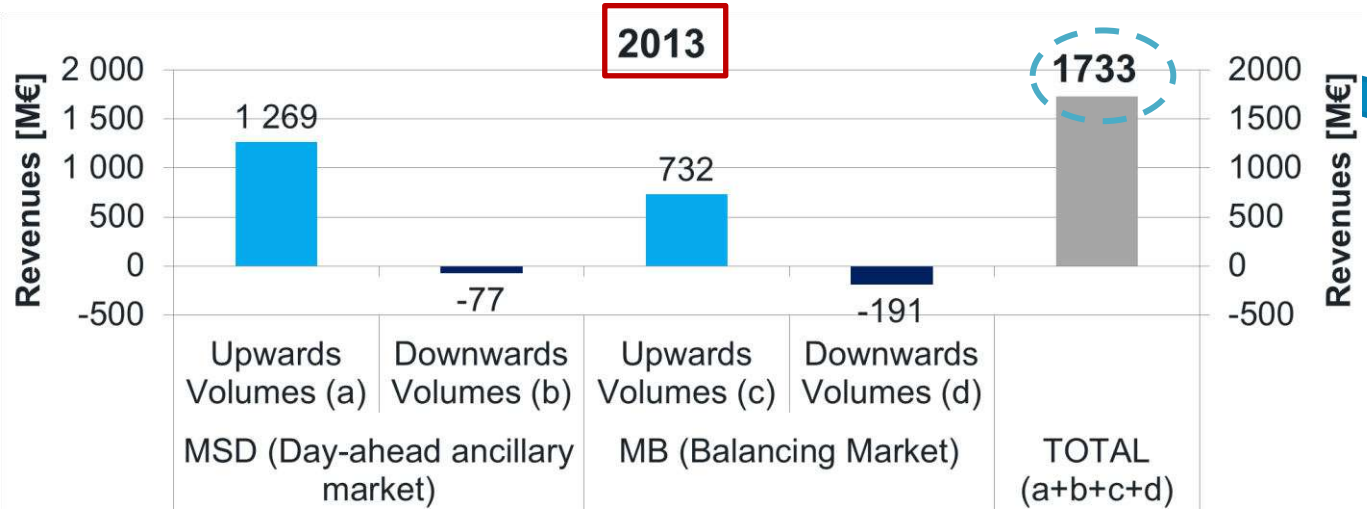
Over Generation in 2024 due to VRE 5.5 TWh/yr – possibility to reduce it to 700GWh/yr through modulation of the cross-border exchanges for balancing

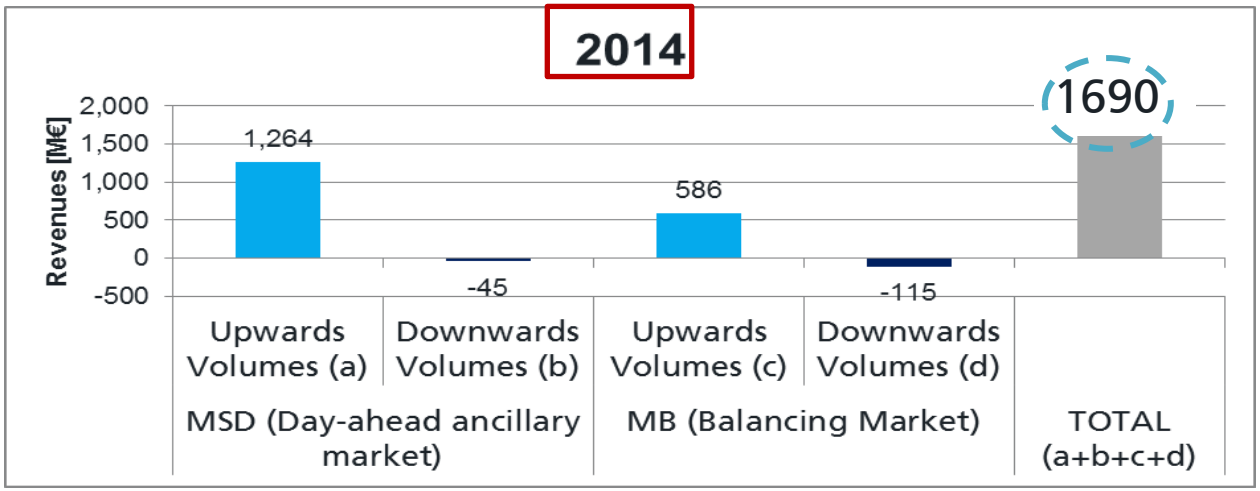
Impact of RES generation on the Ancillary Services Market





Impact of RES generation on the Ancillary Services Market

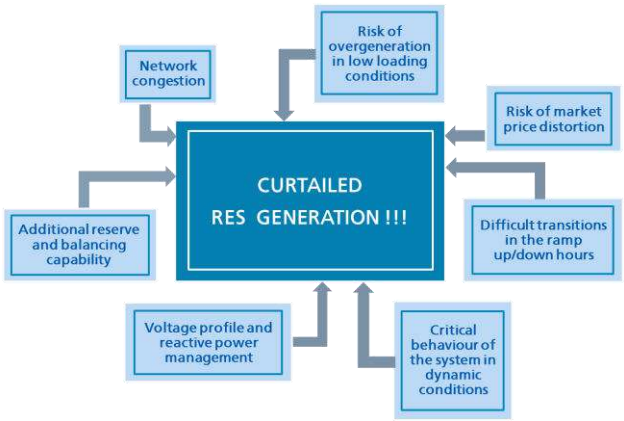




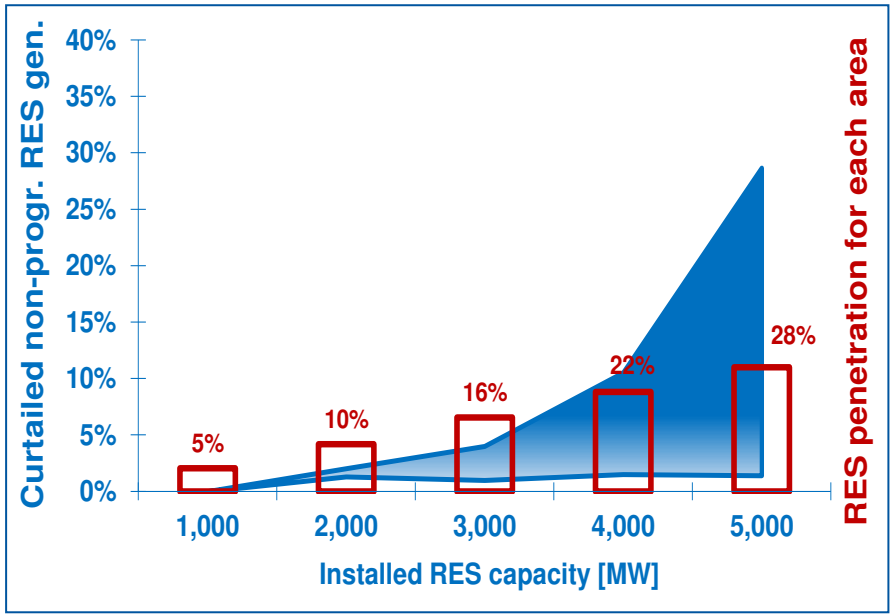
Disbursement in ASM stabilised in 2014 due to action taken by TSO and a slow down in RES generation installation.

Risks of RES generation curtailment

- **Risks of curtailment depending on:**
  - (In)flexibility of power plants
  - (in)adequacy of the transmission /distribution infrastructures (including cross-border lines)
  - Possibility of energy storage
  - Demand responsiveness



Different feasible penetration levels of non-programmable RES generation



Session 1

Generals and EU experience

- System wide impact
  - Barriers to overcome
  - Additional reserve and balancing capability
  - Difficult transitions in the ramp up/down hours
  - Impact on power market mechanisms
  - Risk of overgeneration
- Network and local impacts
  - Network congestion
  - Critical behaviour of the system in dynamic conditions
  - Voltage profile and reactive power management
  - Coping with exceptional events

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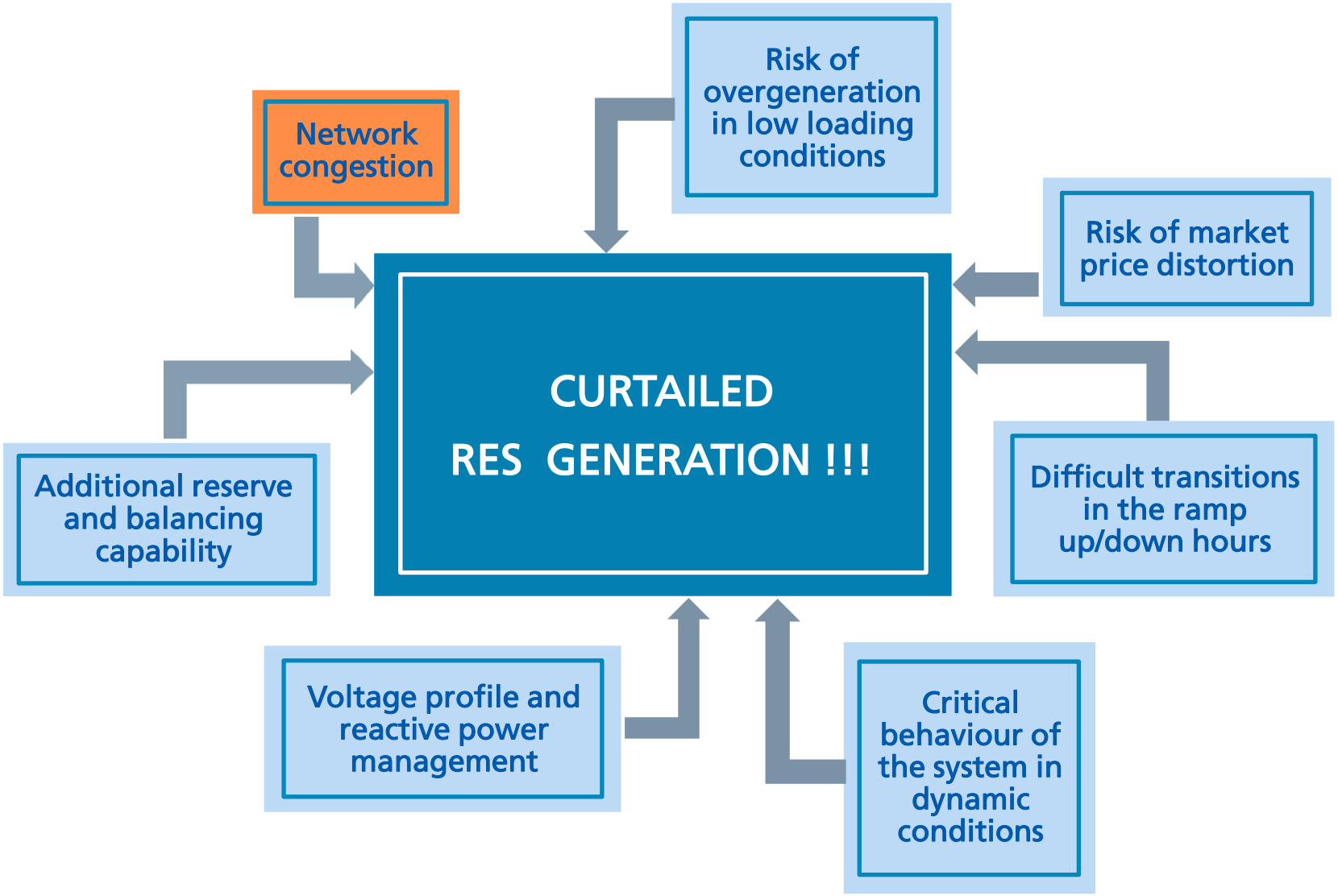
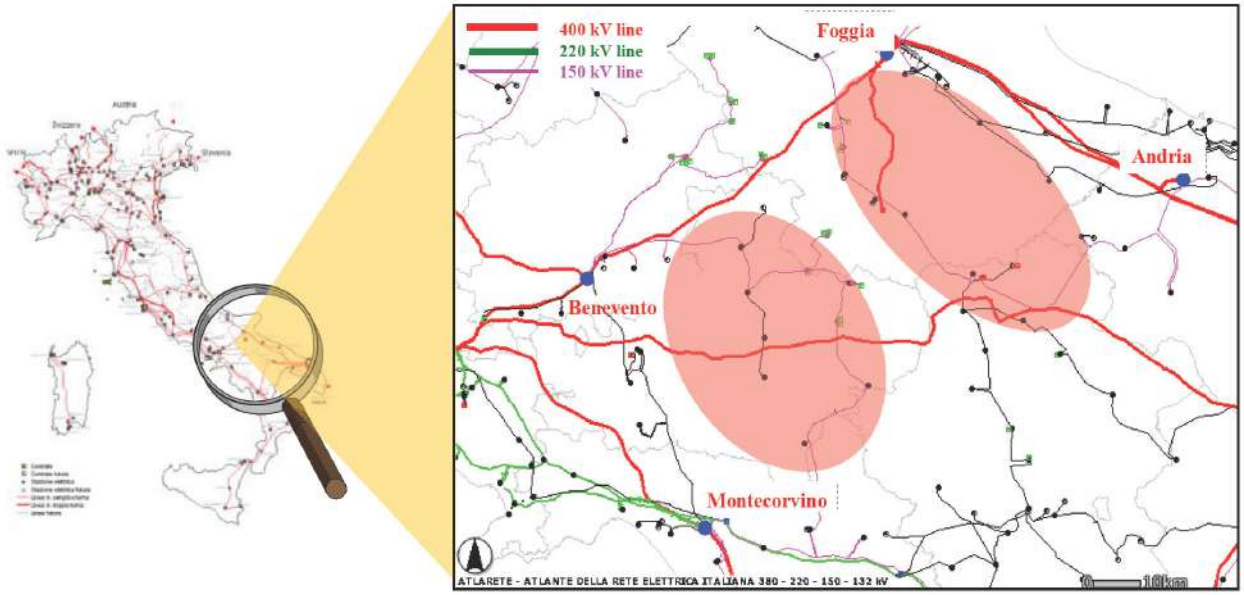
Barriers to overcome to enhance generation from non-programmable RES



Network congestion caused by RES generation

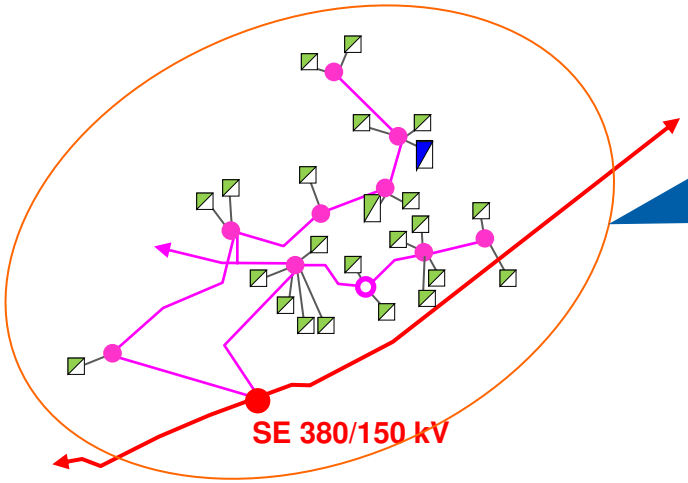
- **Wind location dependent – often remote locations w.r.t. the demand centres**
- **No correlation between demand and non-programmable RES generation location - power flowing on longer patterns through the network with risk of creating "scattered" congestion also relatively far away from RES generation areas**



Expected congestion in the 150 kV of the Italian peninsular regions due to WF (year 2009) – (source: CIGRE, CESI-Terna paper)

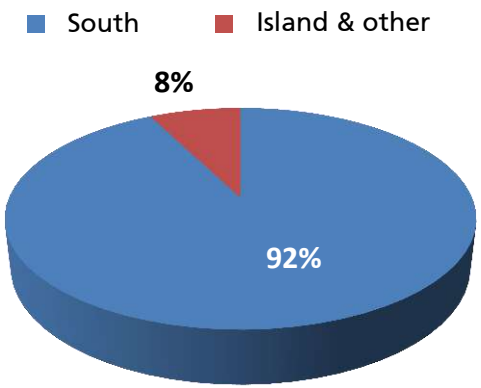
Network congestion caused by RES generation
Example of Italian system (1/2)

- **Overloads in the High Voltage network (150kV)**



Area with surplus of wind installed capacity and deficit in load and network infrastructures

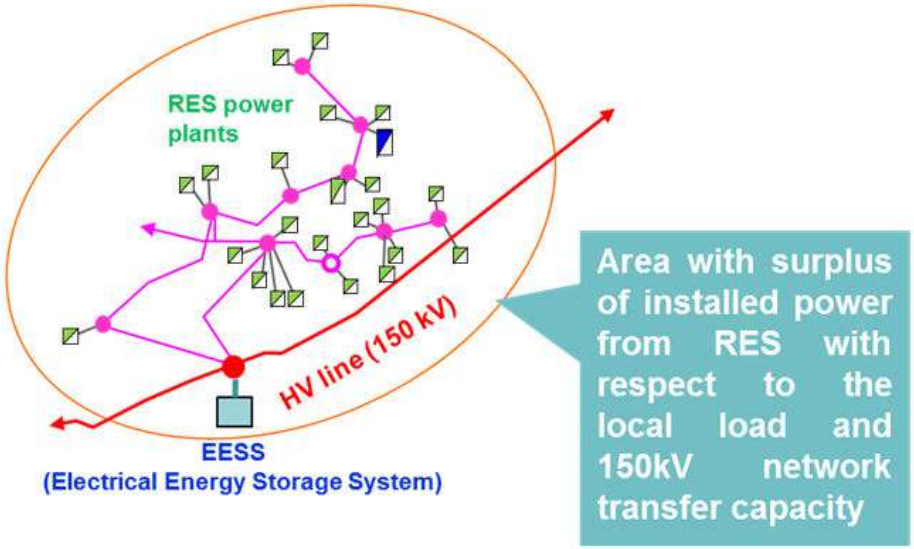
- **RES production constraints:**
  - The secure and reliable operation of the HV transmission network (150 kV)
  - Line overloads in the 150 kV network when high productions from RES occurred
  - Network developments needed to solve some critical conditions in the Extra High Voltage (EHV) network



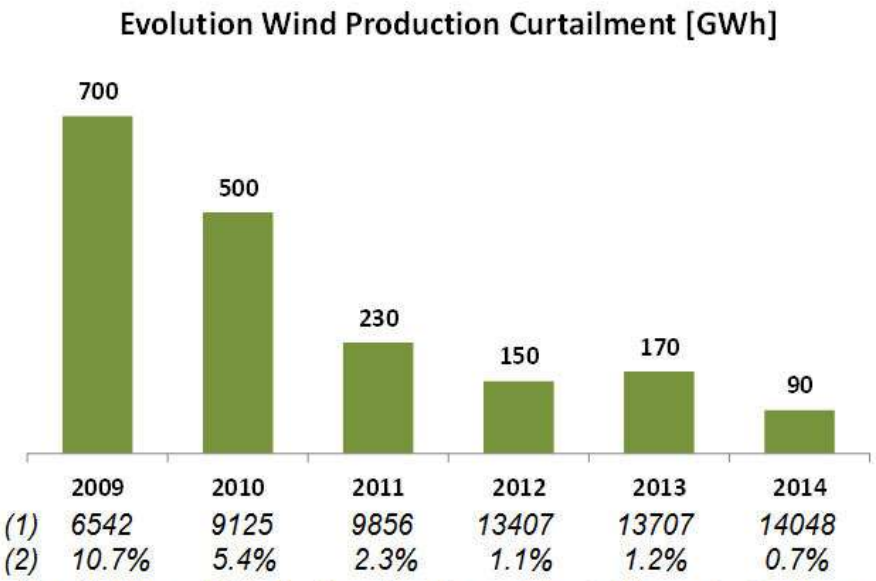
Source: Terna

Network congestion caused by RES generation
Example of Italian system

- **Effect on wind generation curtailments due to actions on transmission grid and local energy storage**



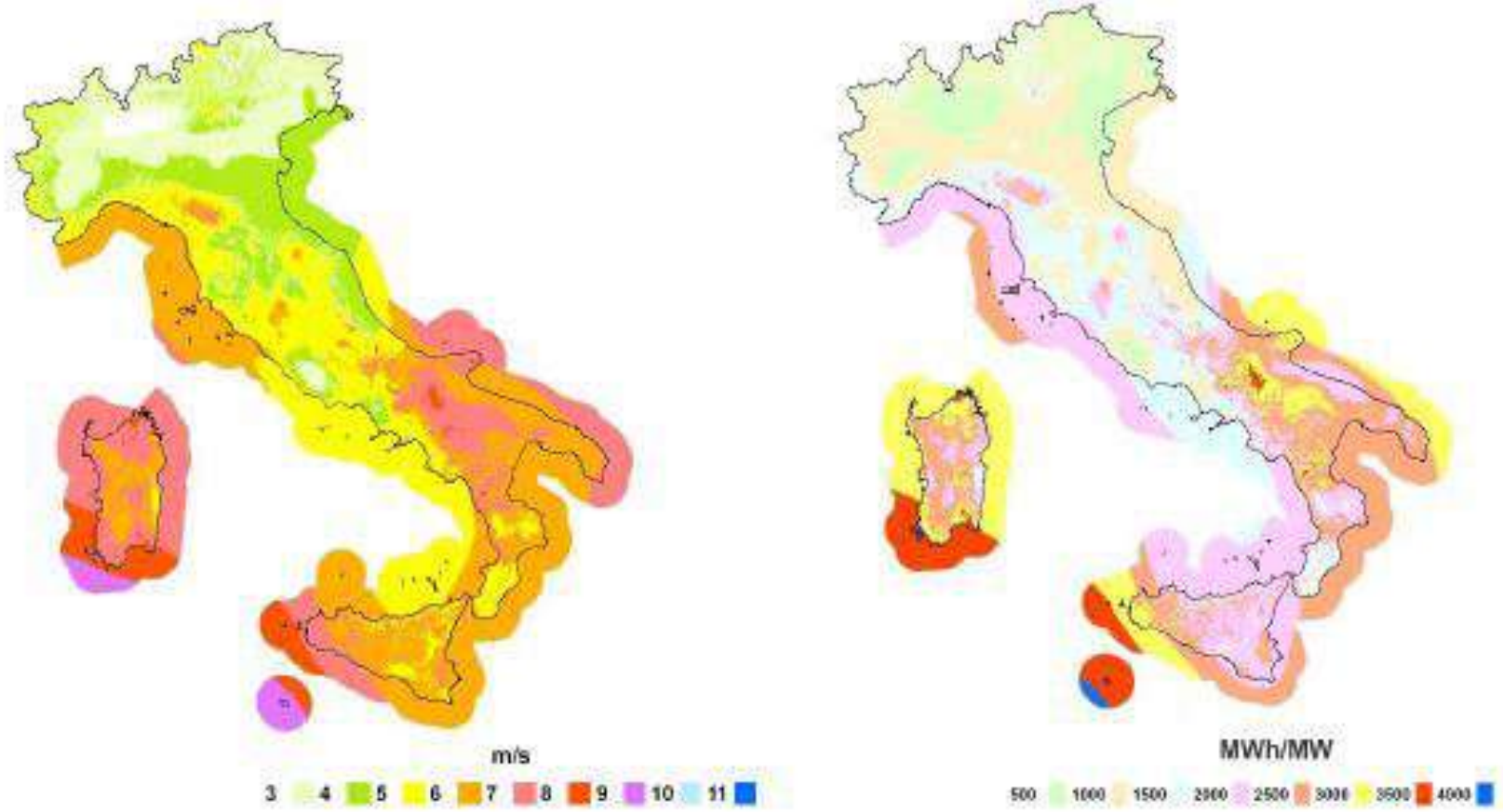
One of the areas with local congestion caused by wind power in South of Italy (source: Terna)



Evolution Wind Production Curtailment (source: Terna). (1) Actual production (2) Curtailed production

Network congestion caused by RES generation
Example of Italian system

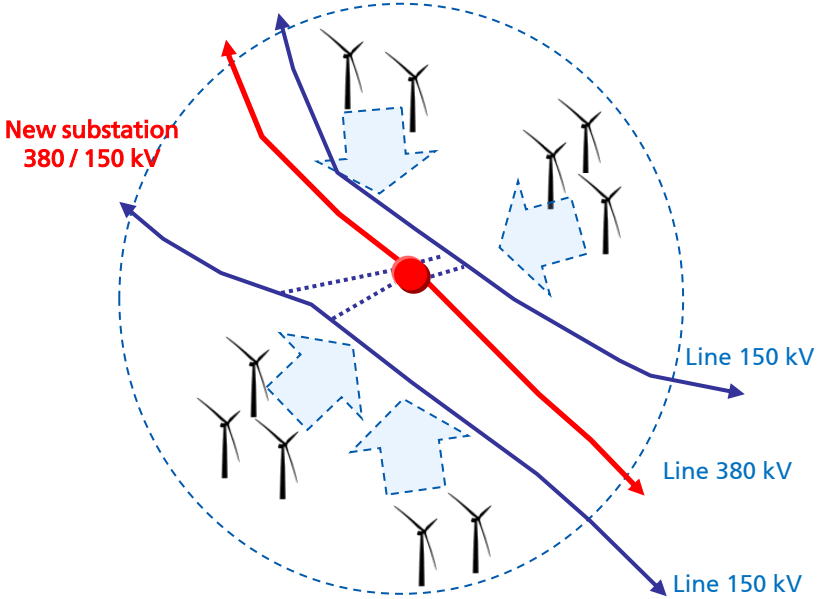
- **Distribution of average wind speed and potential production (from Wind Atlas)**



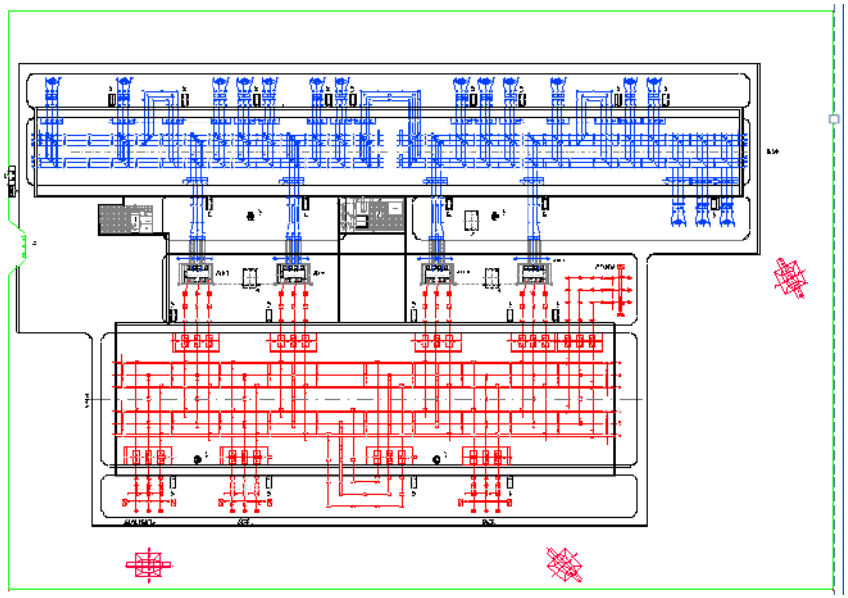
Source: Terna

Network congestion caused by RES generation
Example of Italian system

- **Clusters for RES power plants**
- **Current problems in the network planning:**
  - Optimization of RES clusters maximizing the exploitation of the existing infrastructures, including the 380 kV level
  - Increase the meshing of EHV and HV network to reduce network congestion
  - Reduce the environmental impact of the new 150 kV infrastructures



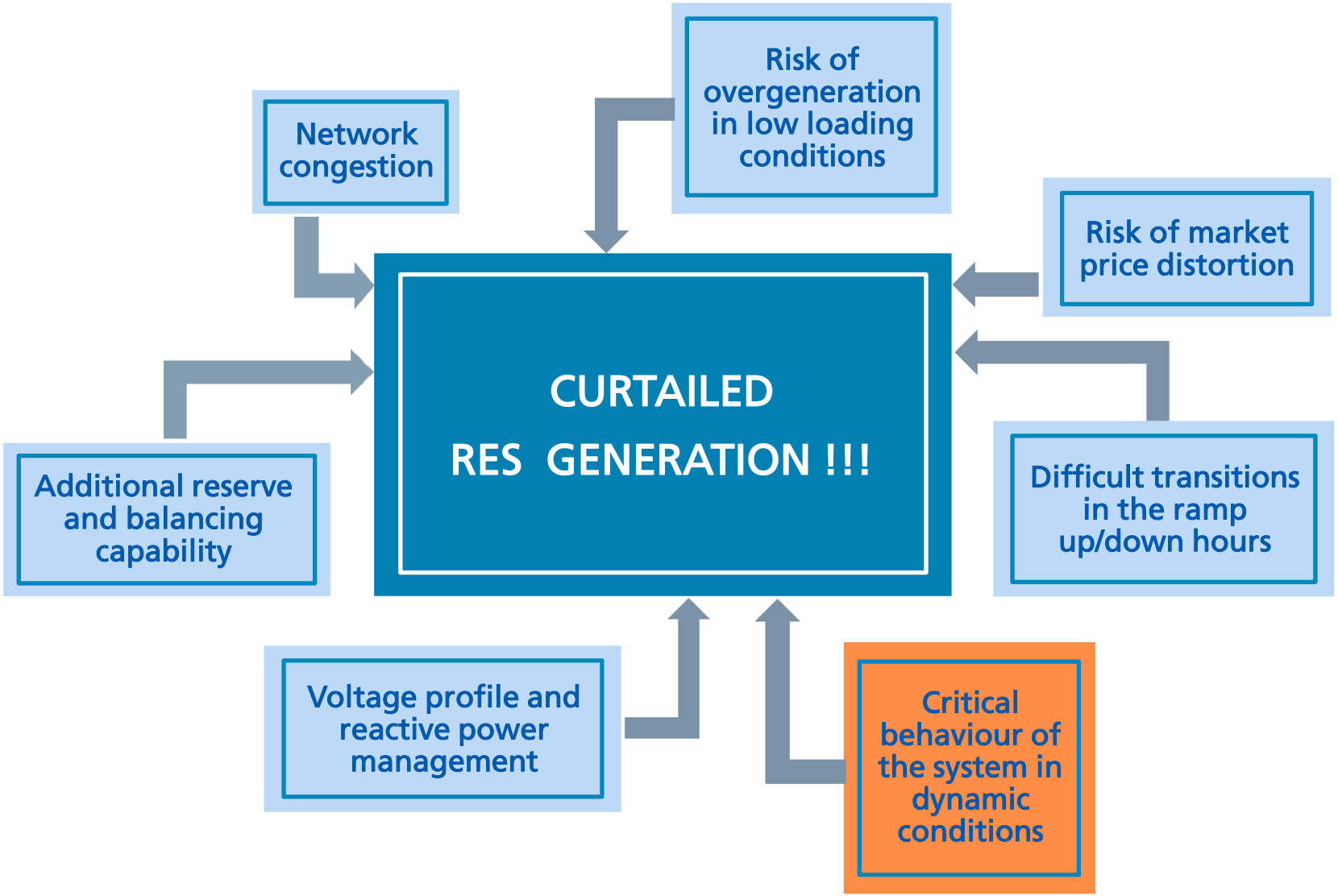
Production Area: over 200 MW



Layout of substation 380/150 kV

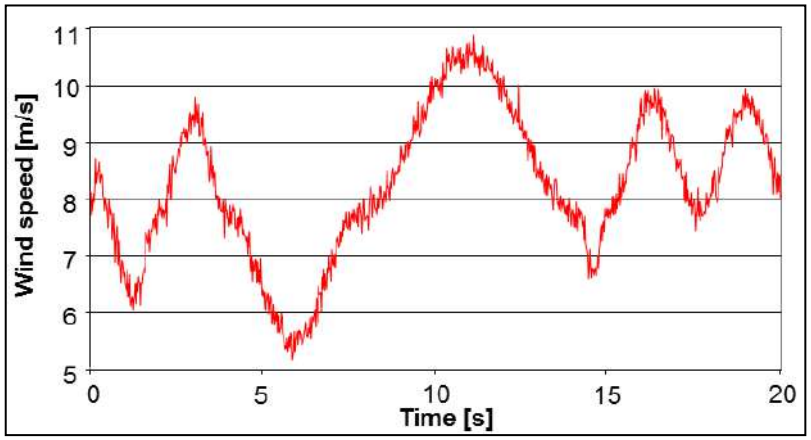
Source: Terna

Barriers to overcome to enhance generation from non-programmable RES



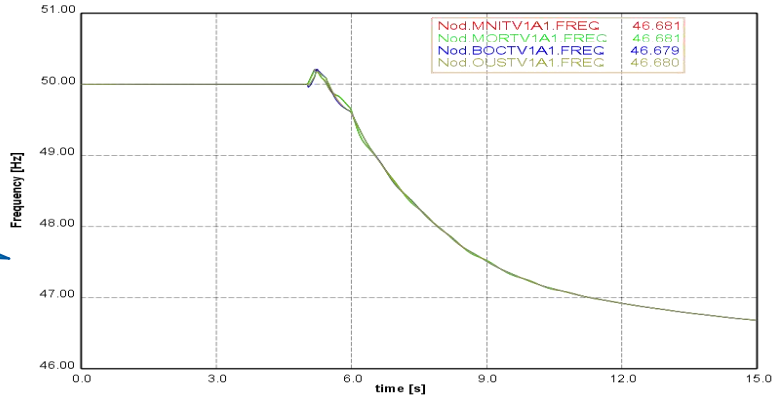
Critical behaviour of the system in dynamic conditions

- **Critical dynamic behaviour caused by:**
  - Intermittency in RES generation causing a higher stress on the conventional units to balance the system
  - Faults (e.g.: short circuits on a network component)



Risk of cascading effect leading to the system collapse

Frequency (Hz)



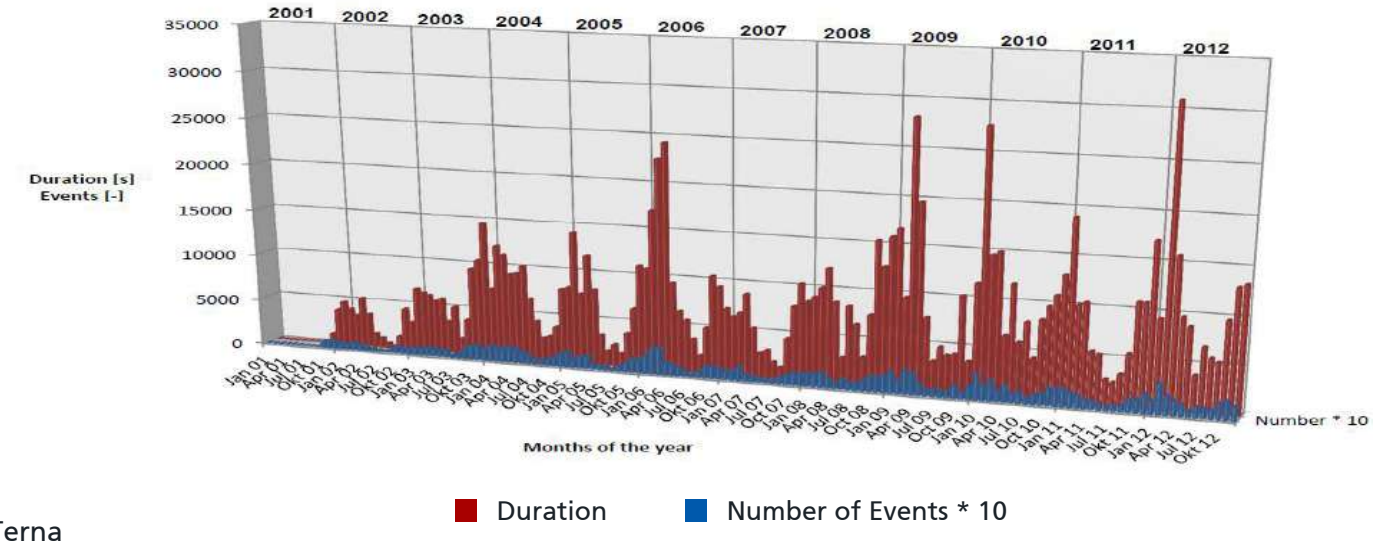
Critical behaviour of the system in dynamic conditions

- **Total inertia of the power system degraded with the increased share of wind and solar power plants ➡ large frequency deviations from nominal value during disturbances**

From rotating generators with high inertia to static productions with zero inertia

Critical behaviour of the system in dynamic conditions

- **Risk of over-frequency (not included in the current ENTSO-E policies)**
  - This risk increases due to the limited control capabilities of RES power plants and the need for maintaining the regulating power in the system
  - the periods with over-frequency operation (50.1 Hz) longer than 30-40' are becoming more frequent
  - the risk of accidents during such periods has increased



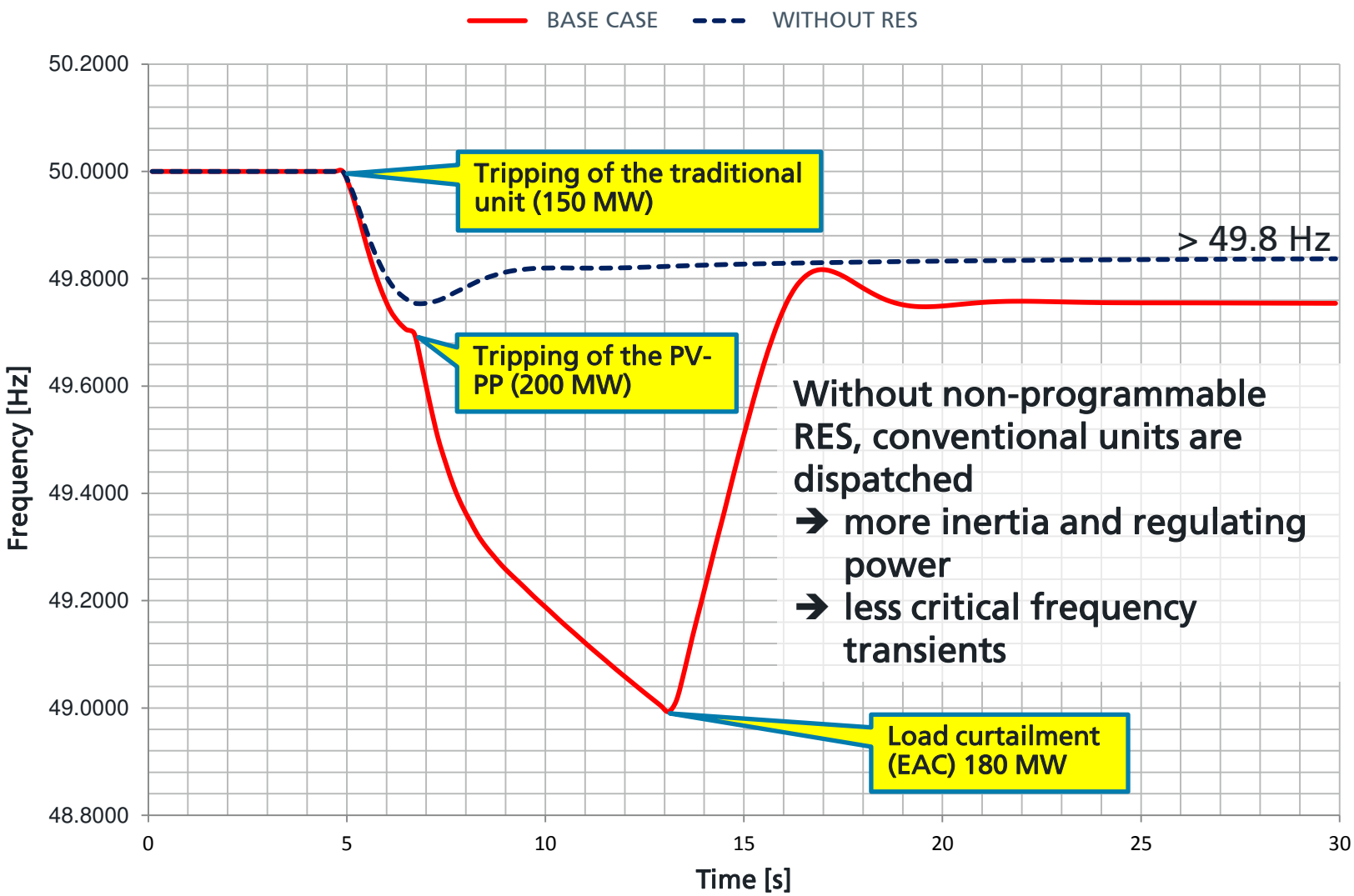
Source: Terna

Critical behaviour of the system in dynamic conditions
Example of the Sicilian power system

- **Scenario May 18th, 2011, h10 a.m.**
- **Island operation of the Sicilian power system (out of service of the links with the rest of Italian network):**
  - Demand 2250 MW
  - Wind production 260 MW (installed capacity 1700 MW)
  - Photovoltaic production 200 MW (400 MWp)
- **Generation tripping**
- **Frequency transients under 49.7 Hz**
- **Tripping of Photovoltaic Power Plant (PV-PP)**
- **Load curtailment**

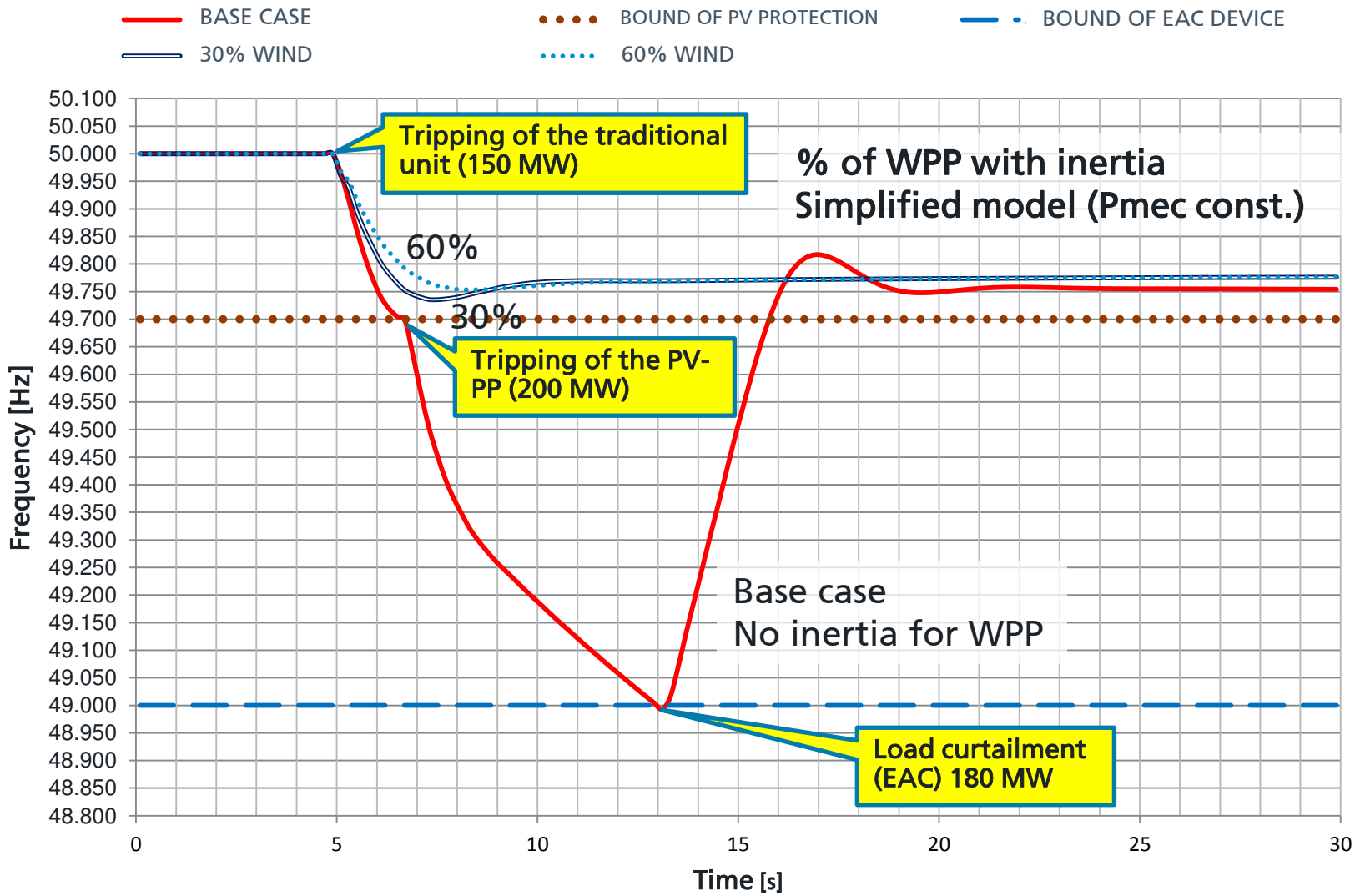
Source: RSE (Ricerca sul Sistema Elettrico)

Example of the Sicilian power system
Case (0) – Only with traditional generation



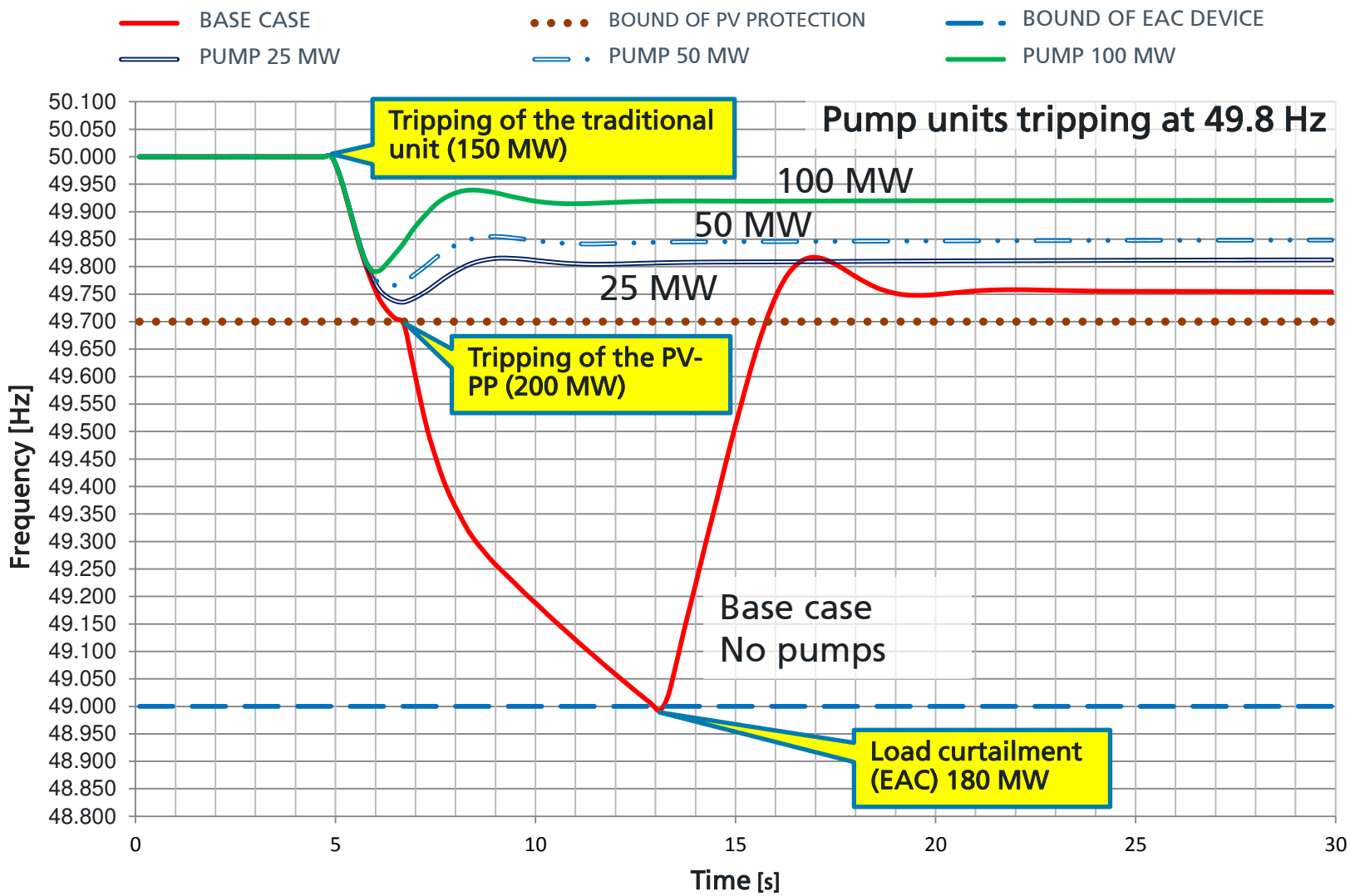
Source: RSE (Ricerca sul Sistema Elettrico)

Example of the Sicilian power system
Case (1) – Wind retrofitting with inertia



Source: RSE (Ricerca sul Sistema Elettrico)

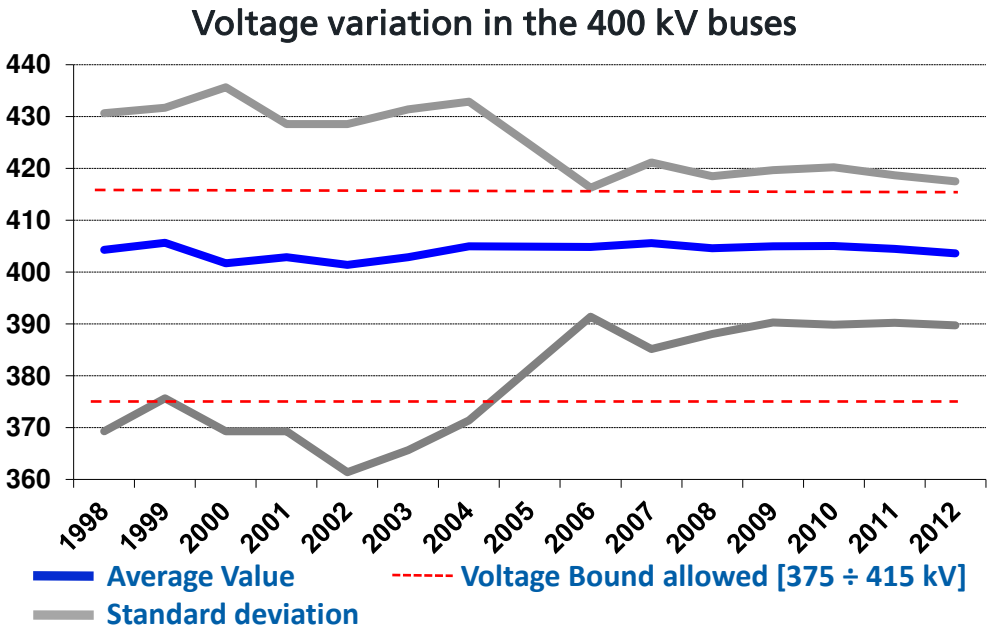
Example of the Sicilian power system
Case (2) – Pump units operation (Storage)



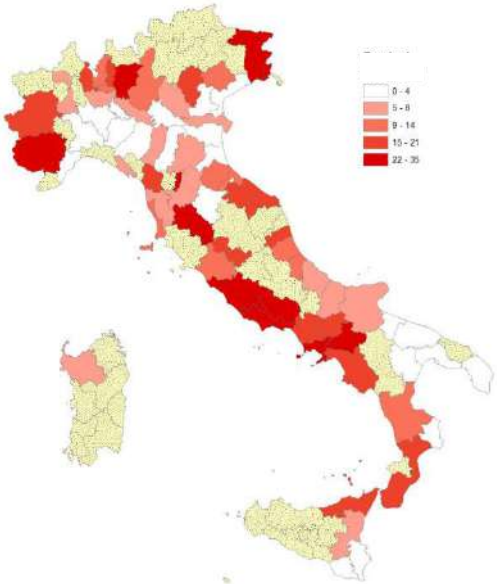
Source: RSE (Ricerca sul Sistema Elettrico)

Voltage profile and reactive power management
Italian example

- **High Voltages in low load conditions and high production by RES**
- **The high production from RES reduces the loading of EHV lines, increasing the voltages in the EHV network (equivalent load of the EHV network is reduced)**



Critical zones

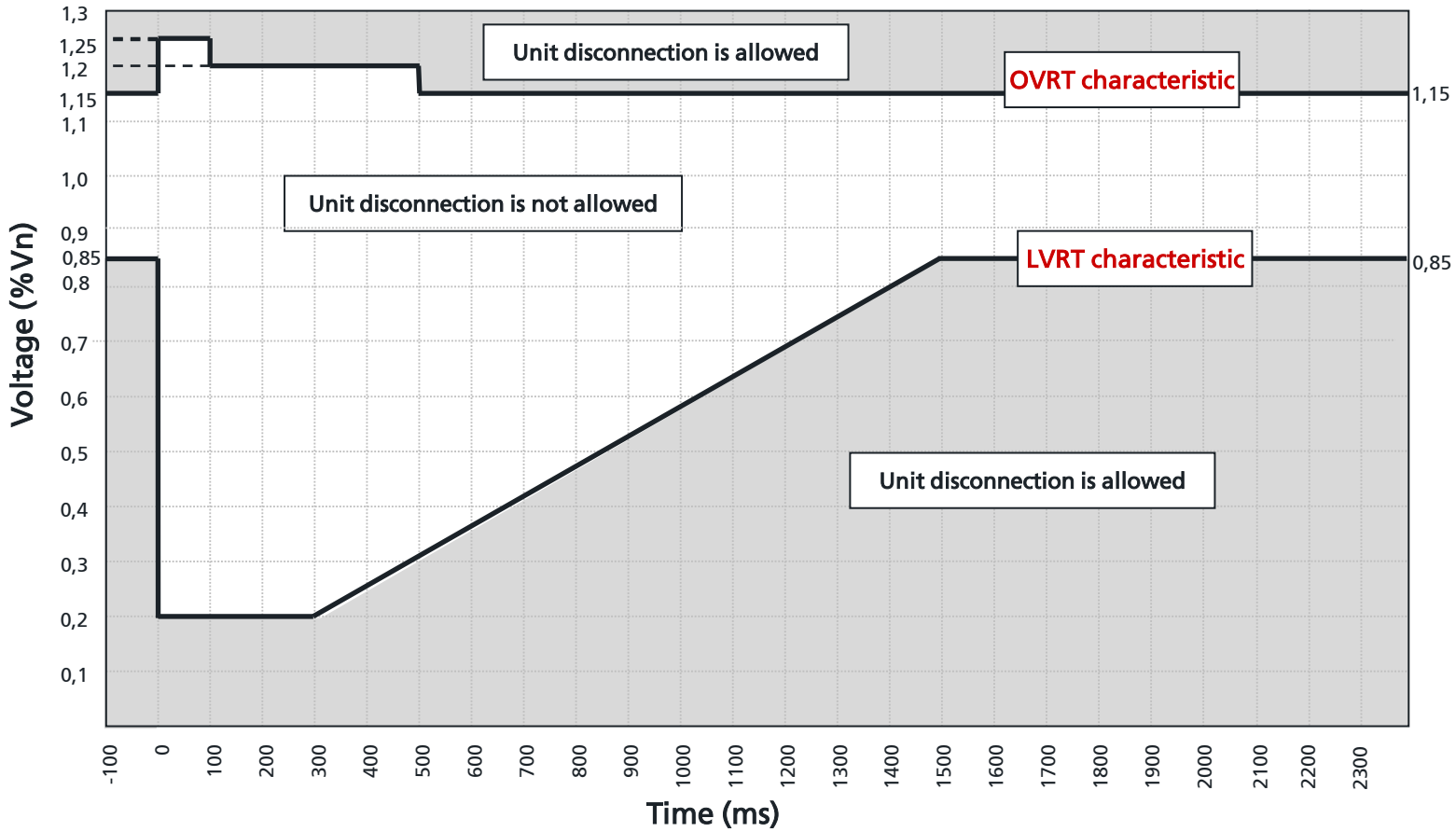


Frequency (%) of voltages > 410 kV (hours with low load, July 2011 – June 2012)

Source: Terna

Voltage profile and reactive power management

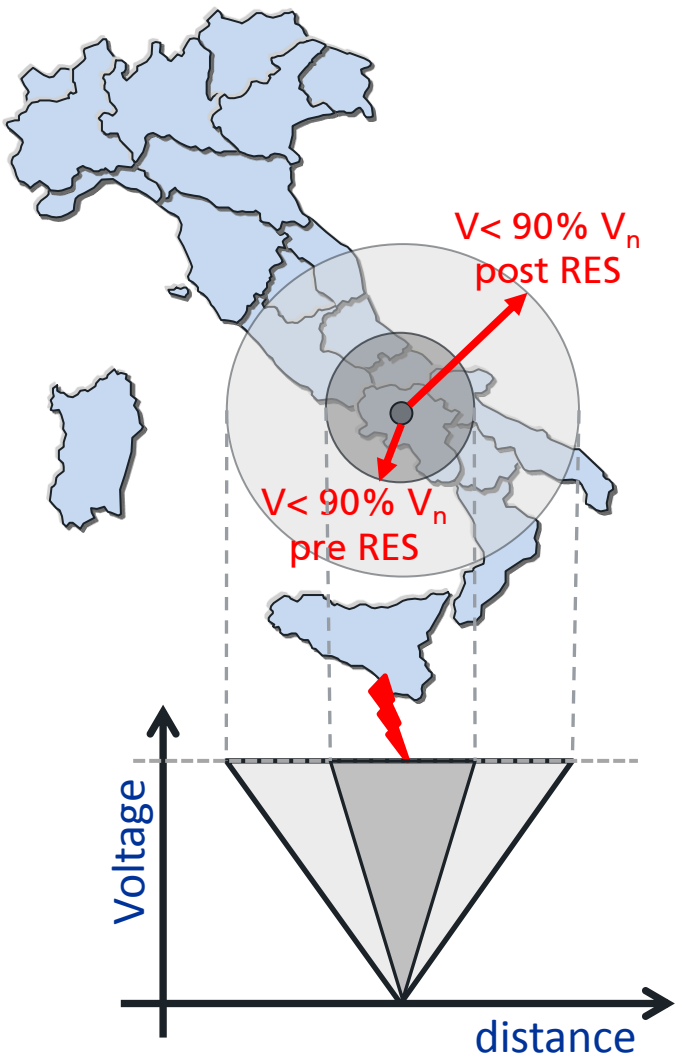
- **Low Voltage Ride Through (LVRT) and Over Voltage Ride Through (OVRT) characteristics**



Source: Terna

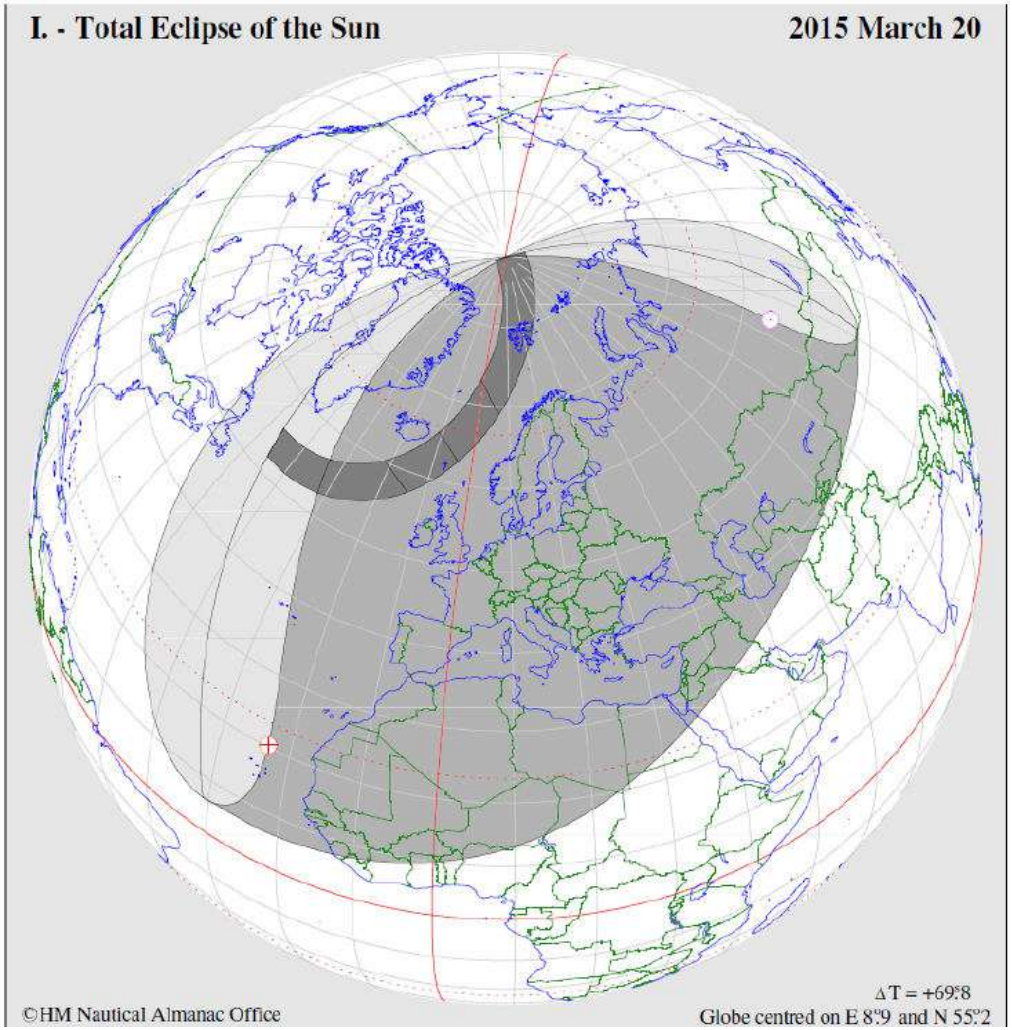
Voltage profile and reactive power management

- Impact of the Distributed Generation (DG) on the Voltage
- Icc WPP (fully converters) ≈ 1.1 ÷ 1.5 In
- Icc WPP (DFIG) ≈ 1.5 ÷ 2.0 In
- Icc PV units ≈ 1.1 In
- Icc synchronous generators ≈ 4 ÷ 5 In
- The replacement of rotating generators with RES generators decreases the short circuit current (Icc) and increases the area with disturbances on the voltage figures



Source: Terna

Coping with exceptional events in presence of VRE generation: the partial solar eclipse occurred in Europe on 20th March 2015



- ✓ Installed PV capacity in the European synchronous area: **90GW**
- ✓ Potential PV infeed reduction due to the eclipse: **30 GW**
- ✓ Very high ramps down and up

Source: http://astro.ukho.gov.uk/eclipse/0112015/

Coping with exceptional events in presence of VRE generation: the partial solar eclipse occurred in Europe on 20th March 2015

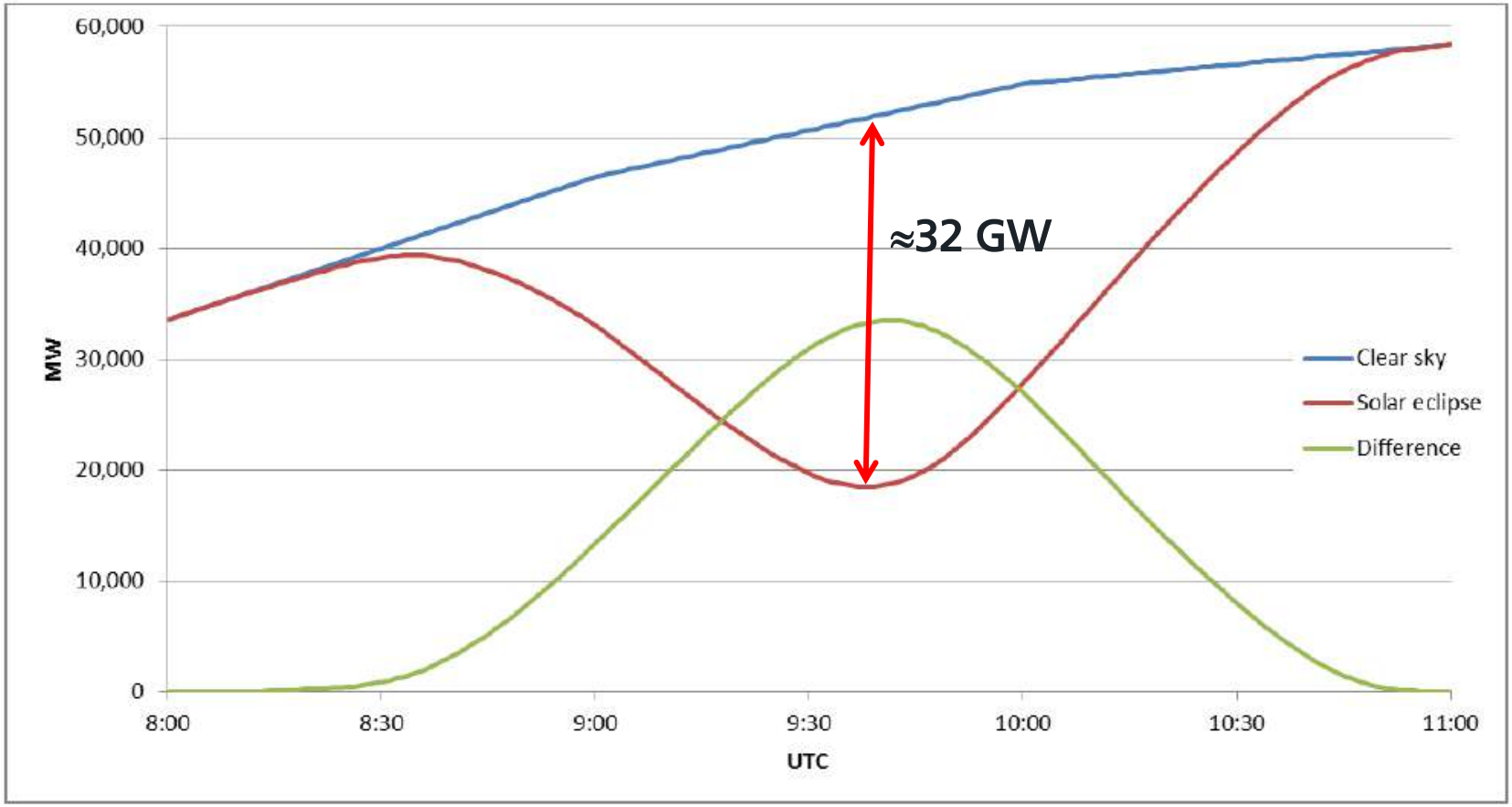
	Start eclipse UTC	End eclipse UTC	Max obscuration	Location
Austria	08:31	10:52	62%	Klagenfurt
Belgium	08:27	10:45	80%	Brussels
Bosnia	08:35	10:54	51%	Sarajevo
Bulgaria	08:44	10:59	40%	Plovdiv
Croatia	08:33	10:53	58%	Zagreb
Czech Republic	08:36	10:57	69%	Prague
Denmark	08:40	10:58	83%	Arhus
France	08:20	10:38	77%	Orleans
Germany	08:33	10:52	76%	Kassel
Greece	08:38	10:51	37%	Larisa
Hungary	08:39	10:59	58%	Budapest
Italy	08:24	10:44	59%	Florence
Luxembourg	08:27	10:46	76%	Luxembourg
Netherlands	08:30	10:48	80%	Nijmegen
Poland	08:45	11:05	67%	Lodz
Portugal	08:02	10:12	70%	Coimbra
Romania	08:48	11:05	47%	Brasov
Serbia	08:39	10:58	51%	Belgrade
Slovakia	08:41	11:01	61%	Banska Bystrica
Slovenia	08:31	10:52	60%	Ljubljana
Spain	08:05	10:18	67%	Madrid
Switzerland	08:24	10:44	70%	Berne
Turkey	09:01	11:03	25%	Ankara

Source: ENTSOE

Duration and max solar obscuration in the continental European countries on 20th March 2015

Coping with exceptional events in presence of VRE generation: the partial solar eclipse occurred in Europe on 20th March 2015

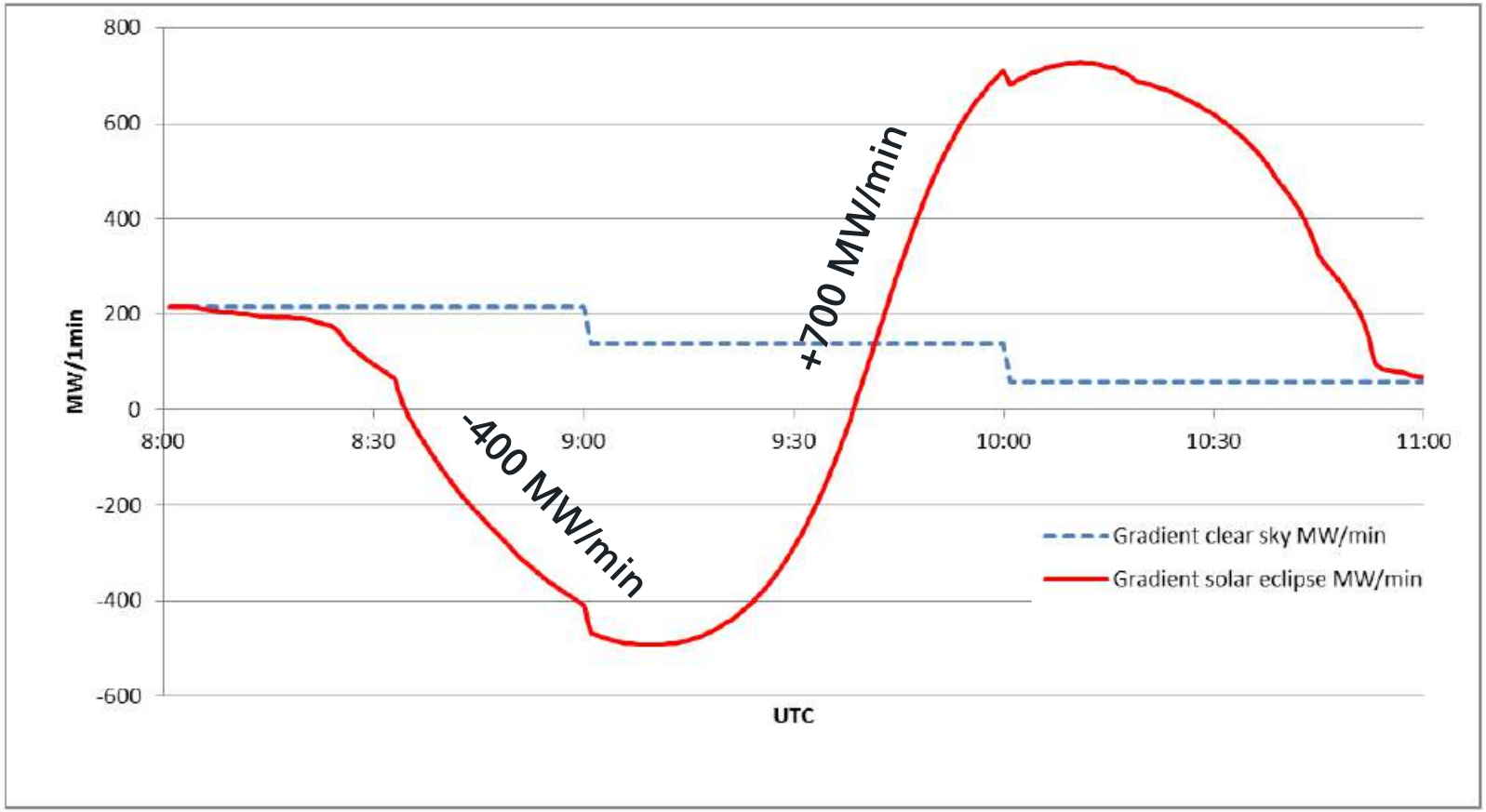
Comparison of expected infeed from solar on March 20 during clear sky conditions with and without solar eclipse (ex-ante simulation)



Source: ENTSOE

Coping with exceptional events in presence of VRE generation: the partial solar eclipse occurred in Europe on 20th March 2015

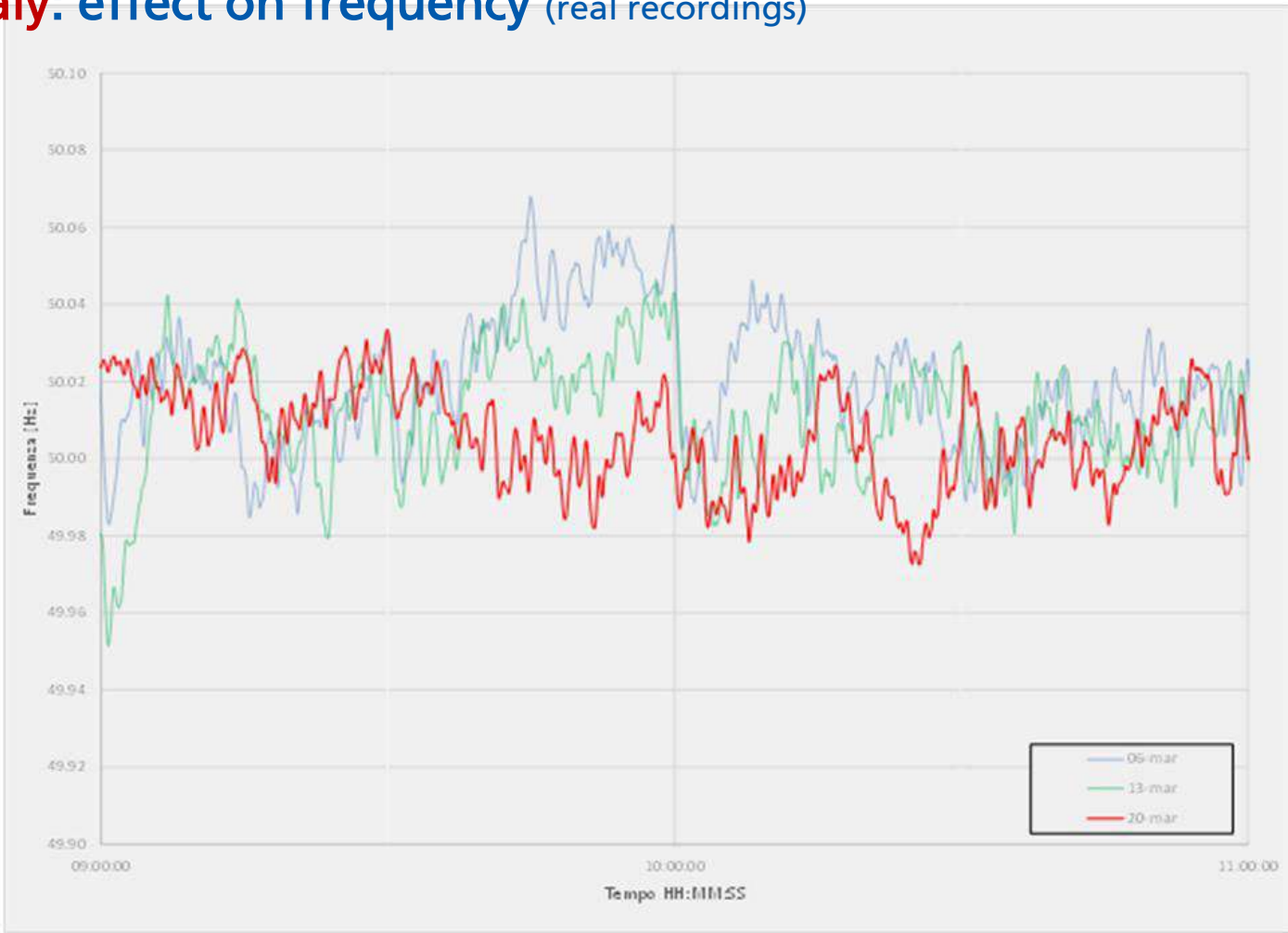
Effect on PV power infeed gradients (ex-ante simulation)



Source: ENTSOE

Coping with exceptional events in presence of VRE generation: the partial solar eclipse occurred in Europe on 20th March 2015

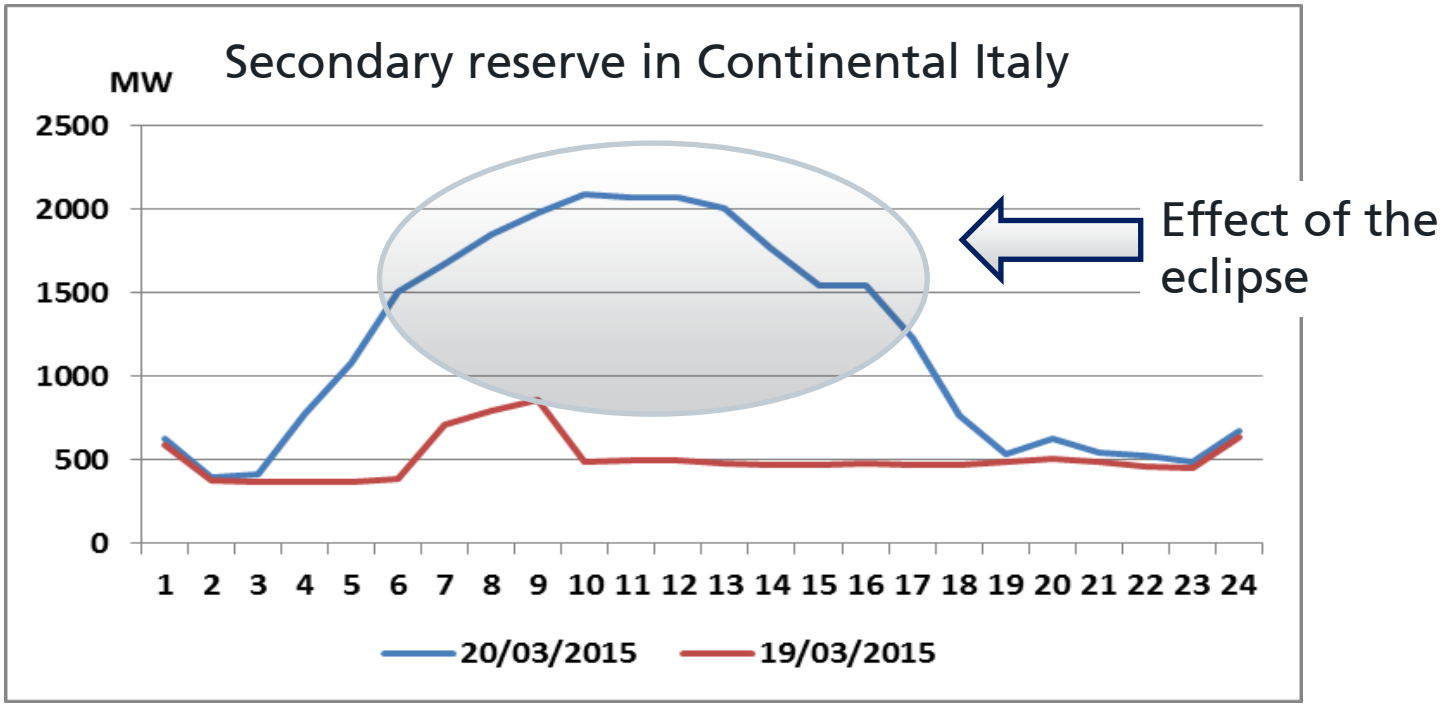
Focus on Italy: effect on frequency (real recordings)



Frequency behaviour during the minutes of max obscuration

Coping with exceptional events in presence of VRE generation: the partial solar eclipse occurred in Europe on 20th March 2015

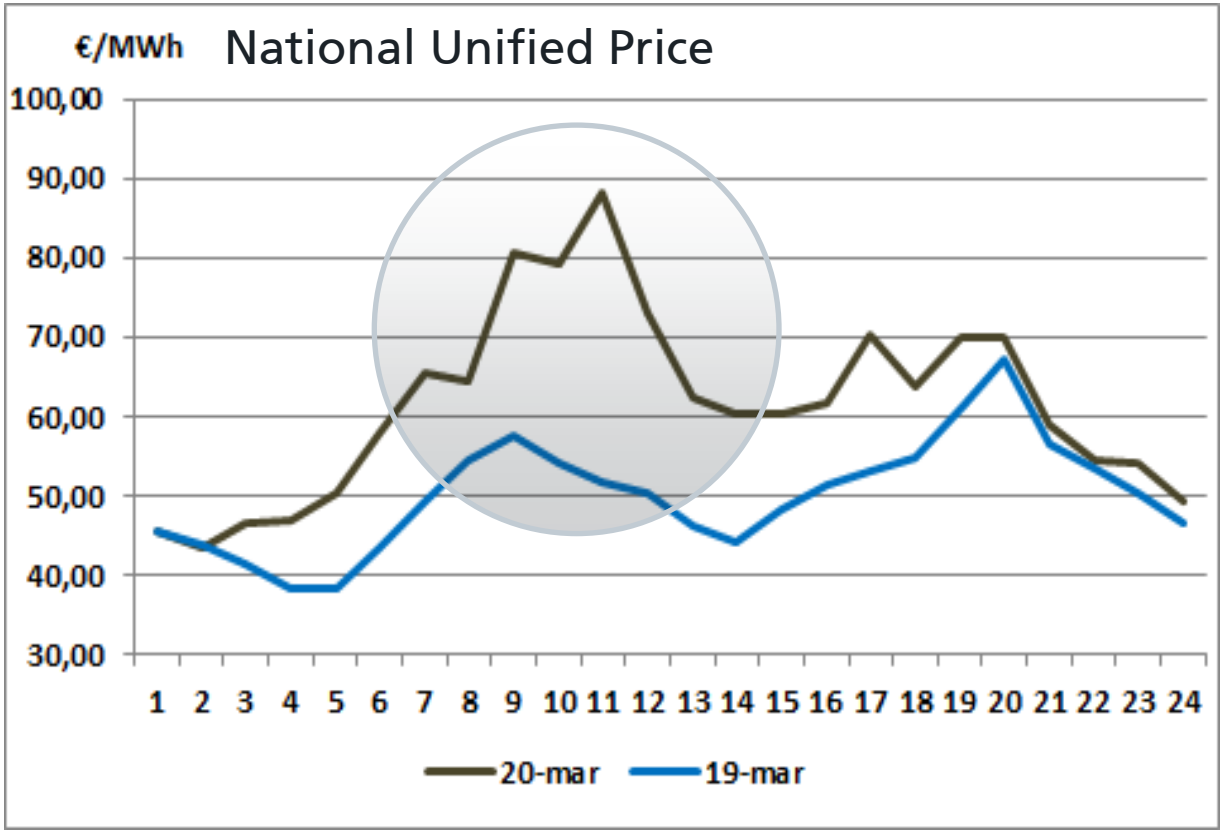
Focus on Italy: effect on ASM (secondary reserve)



Extra-cost to purchase secondary reserve (ex-ante): 1,5 M€ (+67% w.r.t. the previous day)

Coping with exceptional events in presence of VRE generation: the partial solar eclipse occurred in Europe on 20th March 2015

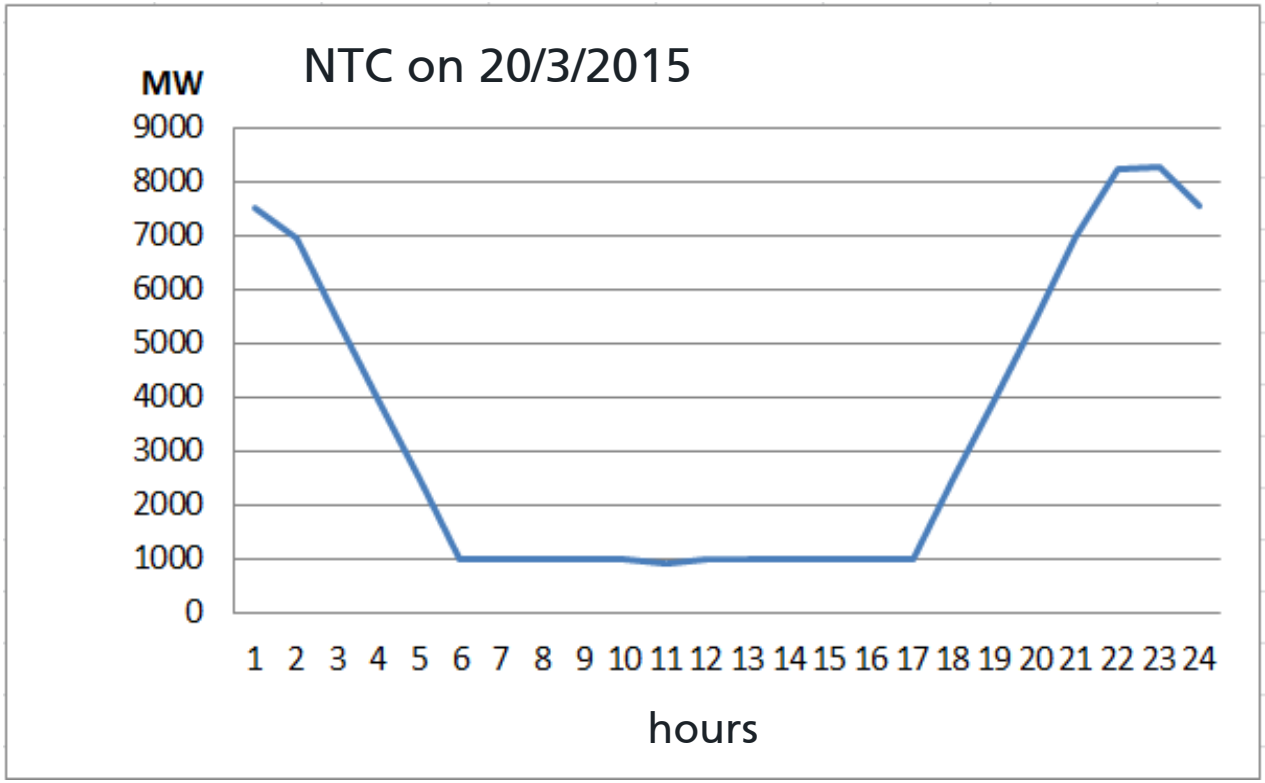
Focus on Italy: effect on Day-ahead market



Average daily Delta price: 11,5 €/MWh
Extra-disbursement for the customers: 10 M€ !

Coping with exceptional events in presence of VRE generation: the partial solar eclipse occurred in Europe on 20th March 2015

Focus on Italy: further actions taken ex-ante



Reduction of NTC for power import: down to 1 GW

Preventive disconnection of 4,4 GW PV

LOOKING AHEAD:
Evolution of RES generation capacity mix in Europe

Load demand trend: four visions recently formulated by ENTSO-E

Vision (year 2030)	Demand incl. Pumping (TWh)	RES penetration	CO2 reduction
V1 Slow Progress	3610	41%	42%
V2 Money Rules	3712	40%	36%
V3 Green Transition	4167	49%	62%
V4 Green Revolution	4327	60%	78%

Peak demand evolution: slow growth in the next decade. CAGR of January peak load ≈1% per year.

Source: ENTSO-E

LOOKING AHEAD:
Decarbonisation targets in Europe

EU targets

2020

20% CO_2 reduct.
20% RES

Proposed in January 2014 by the "Barroso EC; approved by the European Council on Oct. 24th

2030

"at least" 40% CO_2 reduct.
27% RES

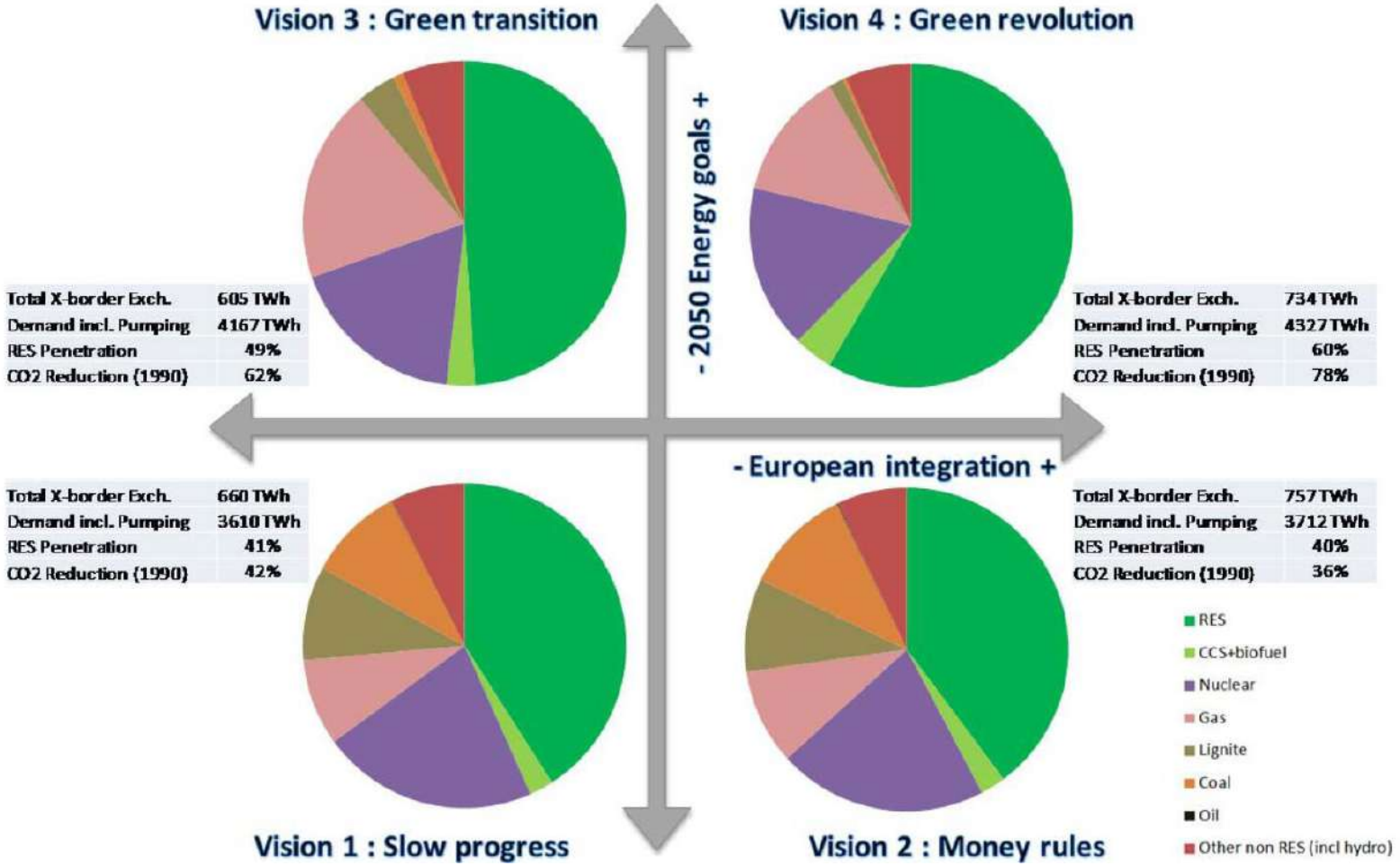
2050

80% / 95% CO_2 reduct.

Full decarbonisation of the power sector

LOOKING AHEAD:
Decarbonisation targets in Europe

Longer term trends



Source: ENTSO-E and CESI elaborations

** Installed RES capacity, compared to less than 230 GW today*

LOOKING AHEAD:
RES generation as the main driver for grid development in Europe

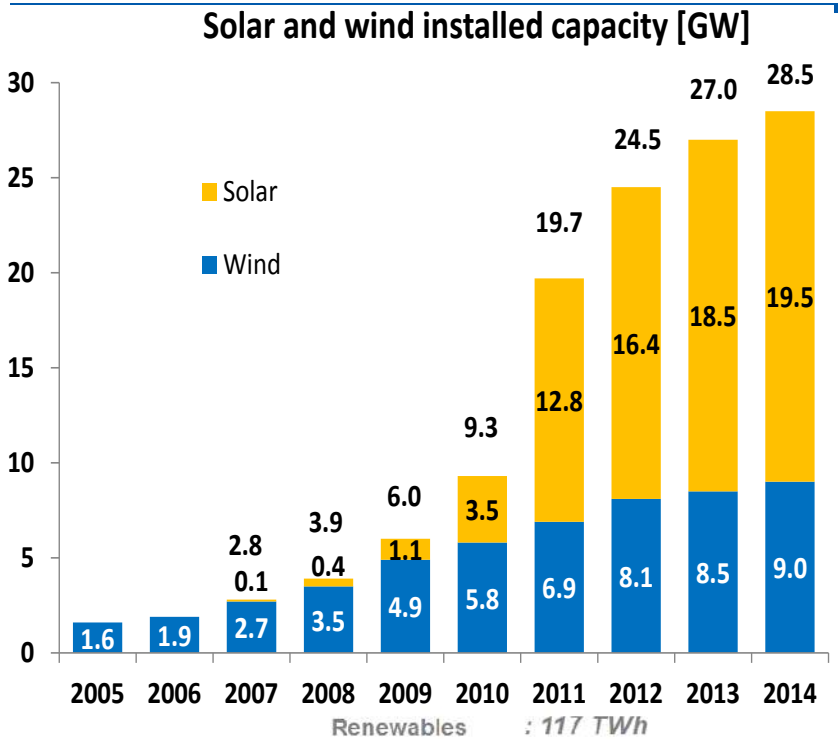
The dramatic change in the generation mix is prompting for substantial investments in the transmission grids.

The TYNDP 2014 of ENTSO-E estimates about 150 b€ of investments by 2030 in transmission grid expansion.

The vast majority of new transmission reinforcements is related to the integration of RES generation: "*approximately 80% of the projects of pan-European significance help integrate RES either by directly connecting RES or by transporting RES power to end-consumers*" *

** ENTSO-E TYNDP 2014*

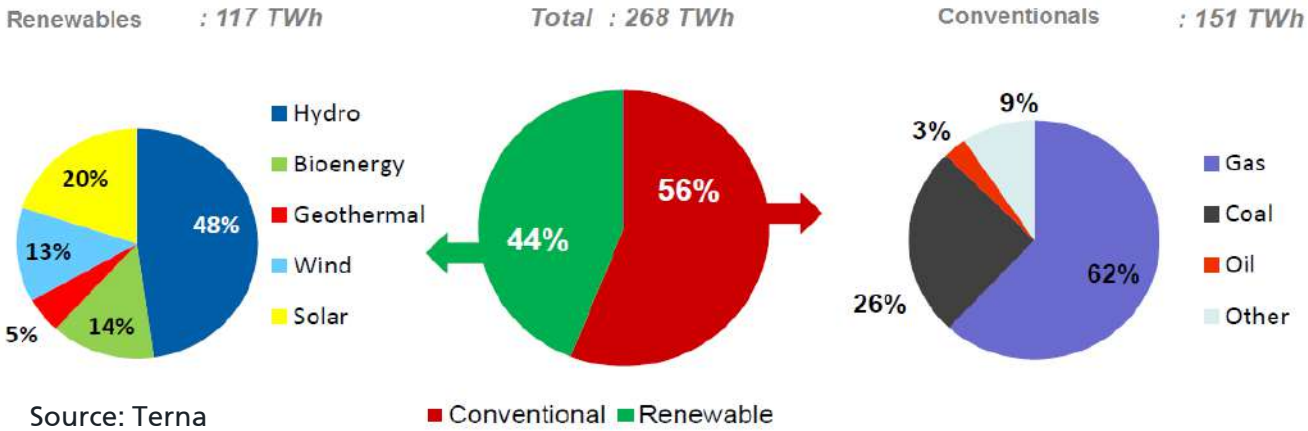
Situation in Italy



Forecasted VRE installation:

- 5-years ahead:
  - 23.5 GW PV
  - 12.7 GW wind
- 10-years ahead:
  - 29.8 PV
  - 15.6 wind

Italian electricity production by fuel in 2014



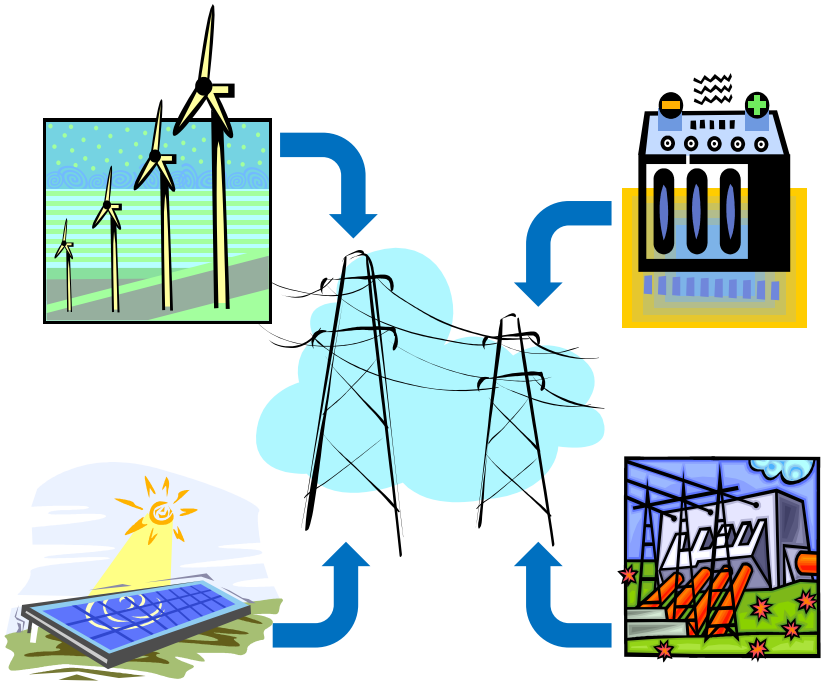
Source: Terna

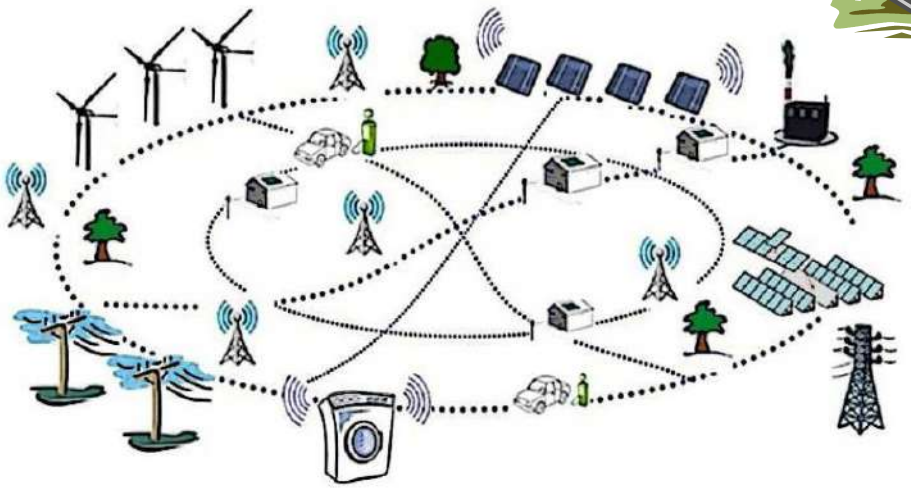
Possible solutions to overcome barriers and maximise penetration of RES generation

- **Energy storage**

Two levels:

1. small scale to smooth high frequency low amplitude intermittency: batteries at s/s
2. large scale for system wide stabilisation: hydro pumping / different policies for unit commitment (higher rate of start up/ shut down of unit : OC TG)

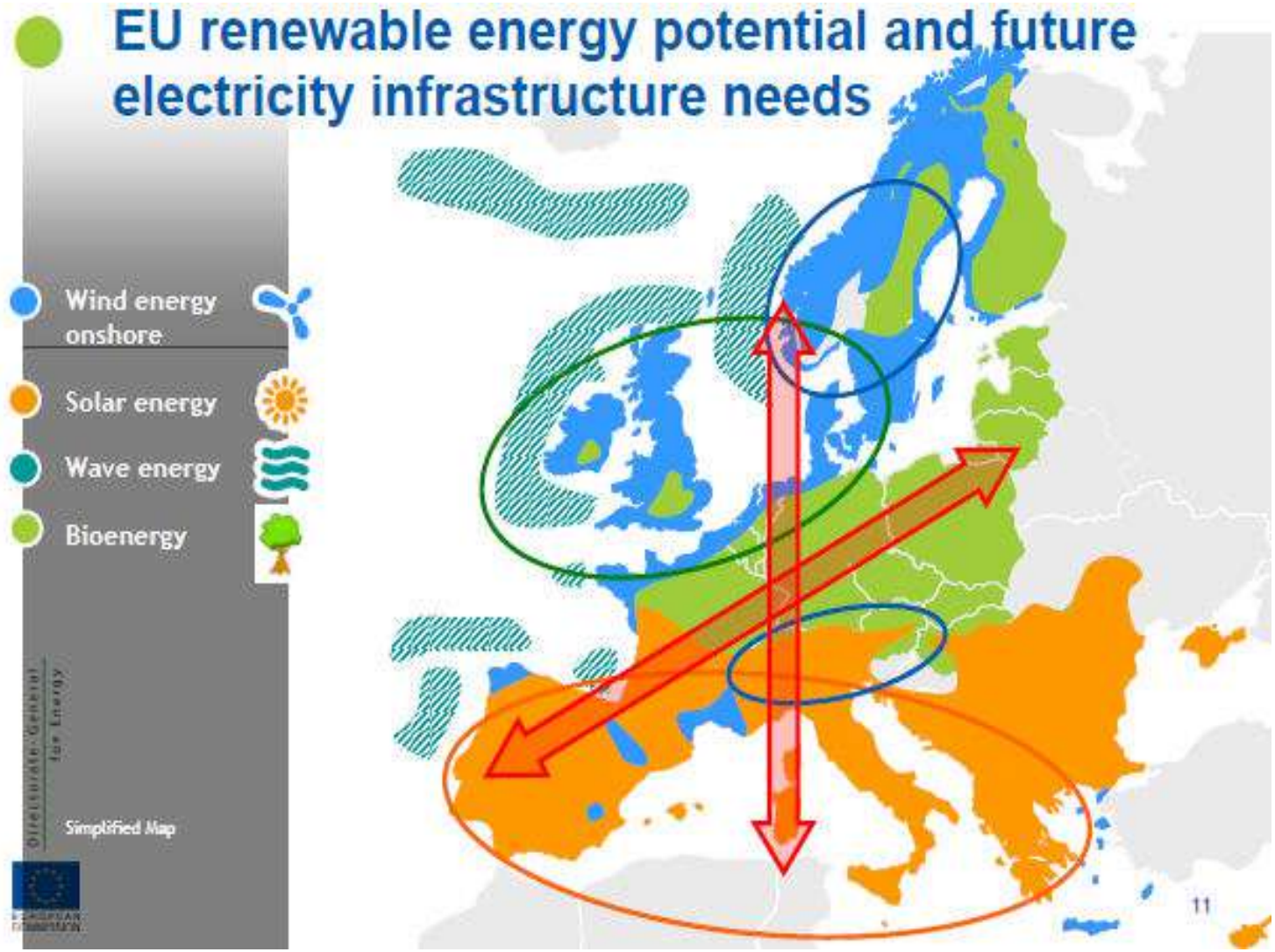




- **Demand responsiveness**

Demand response from users ……. including electric vehicles

The role of transmission infrastructure: the electricity highways



Source: EC

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