International Institute for Energy Systems Integration

Multi-Infrastructure Approaches for Gas and Electricity Distributions Systems

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May, 28th 2014 - Copenhaguen

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1. Gas: the French context
2. Upstream optimization
3. Downstream optimization

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France Gas Infrastructure

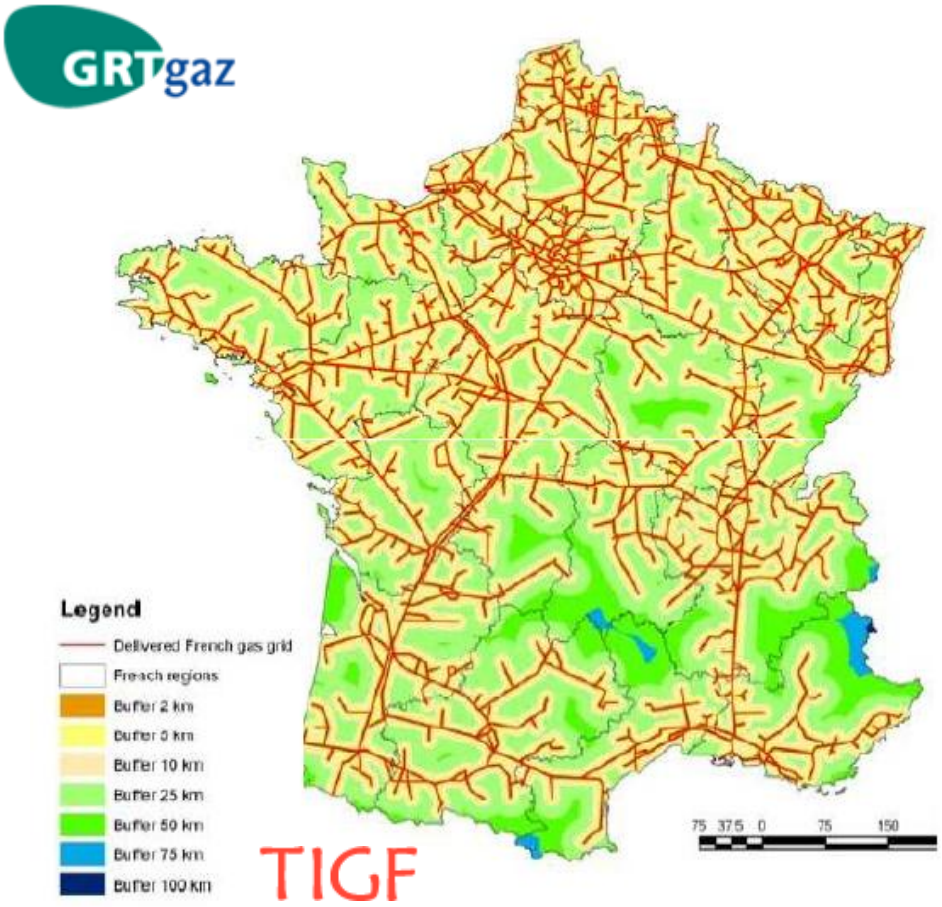
Transport distribution network (P>16 bar)

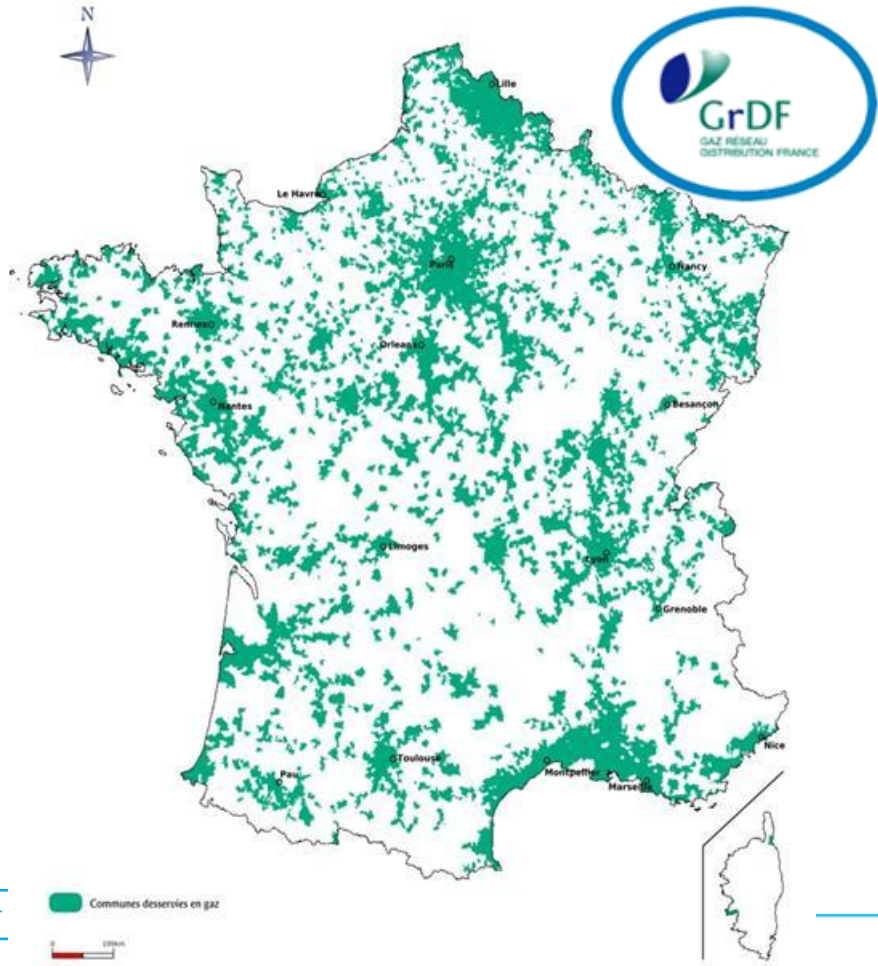
GRTgaz et TIGF : 93% of the territory in a 25 km radius

Transport distribution network (P>16 bar)

GrDF : 77% of France population covered

9 500 communities





GrDF - a Distribution System Operator in an open gas market

Domestic & commercial

Commercial only

30 gas suppliers

Gas distribution network

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1 grid, 1 operato*

11 millions customers

A neutral and independant DSO, operating the gas network for all suppliers and customers
A legal monopoly with a unique regulated tariff

GrDF : 2013 key figures

A distribution network…

- Network length: 195 000 km

… shipping gas to final customers

- 310 TWh
- 30 supplyers
- 11 millions customers

… owned by communities

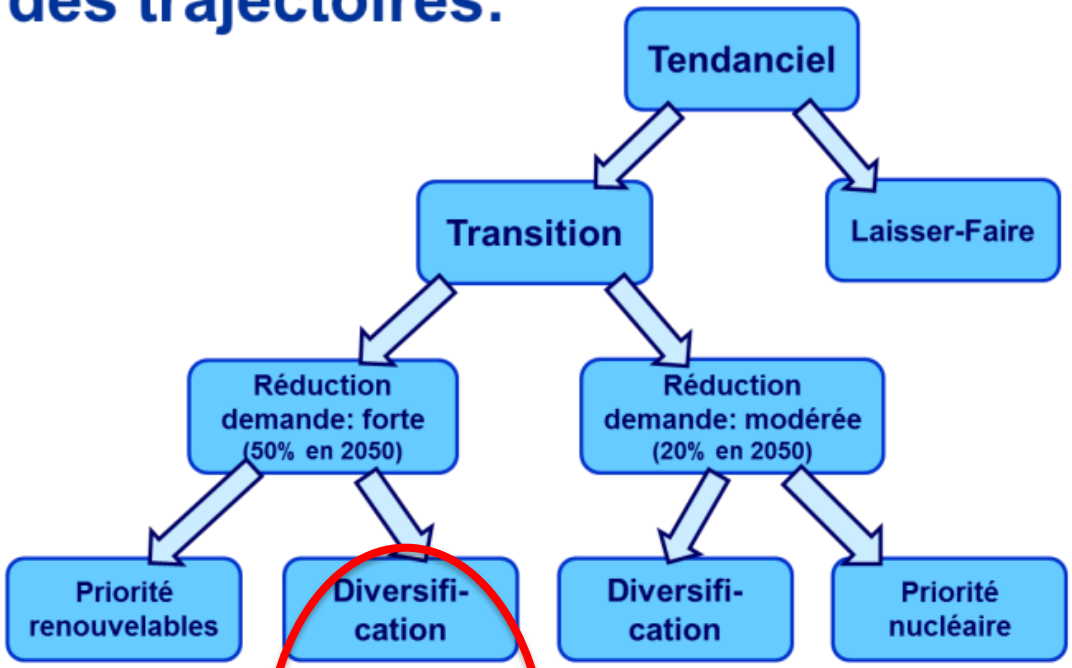
- 9 500 communities with concession contracts
- Accounting for 77% of the French population

A robust business model

- 2 800 MEUR of turnover
- 700 MEUR invested every year

GrDF strong contribution to the public debate on energy transition in 2013

Logique des trajectoires:

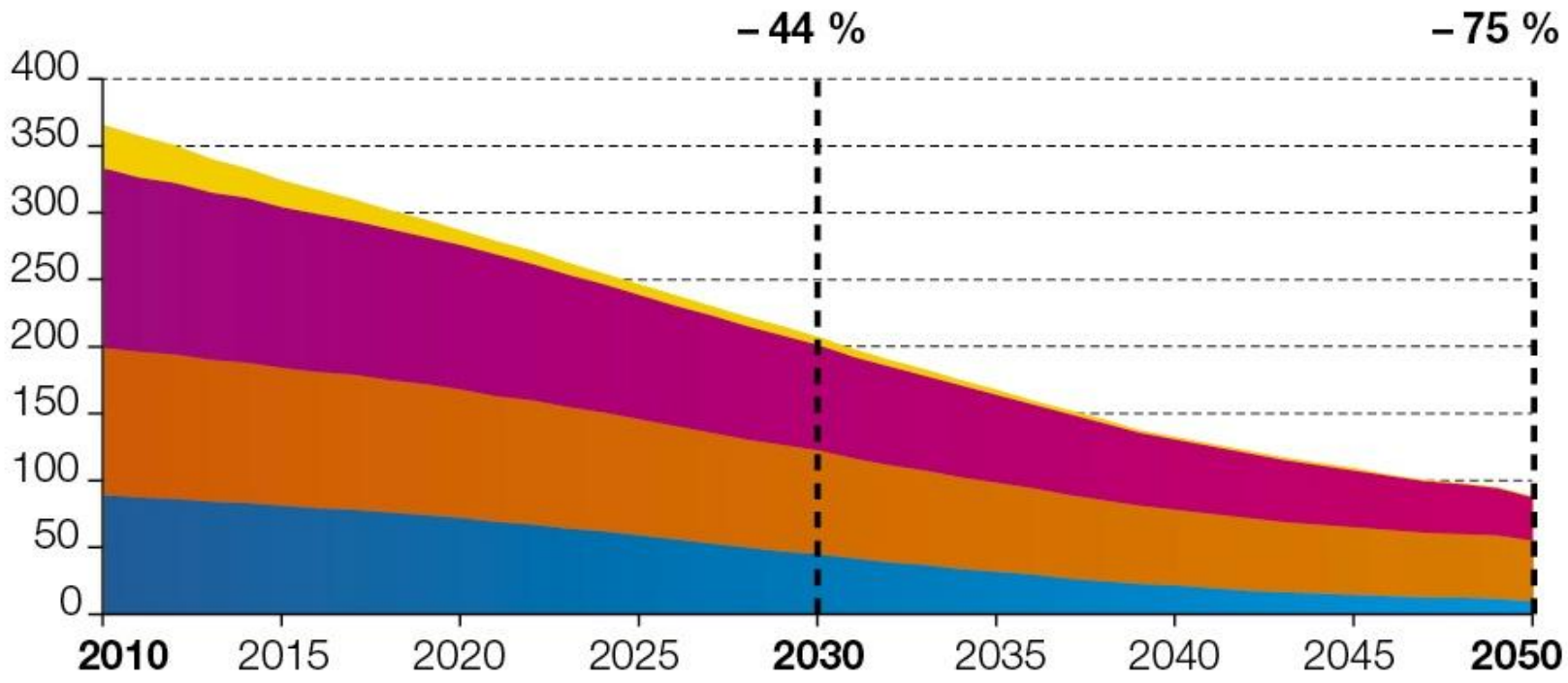


Les trajectoires

sont explorées par les scénarios suivants:

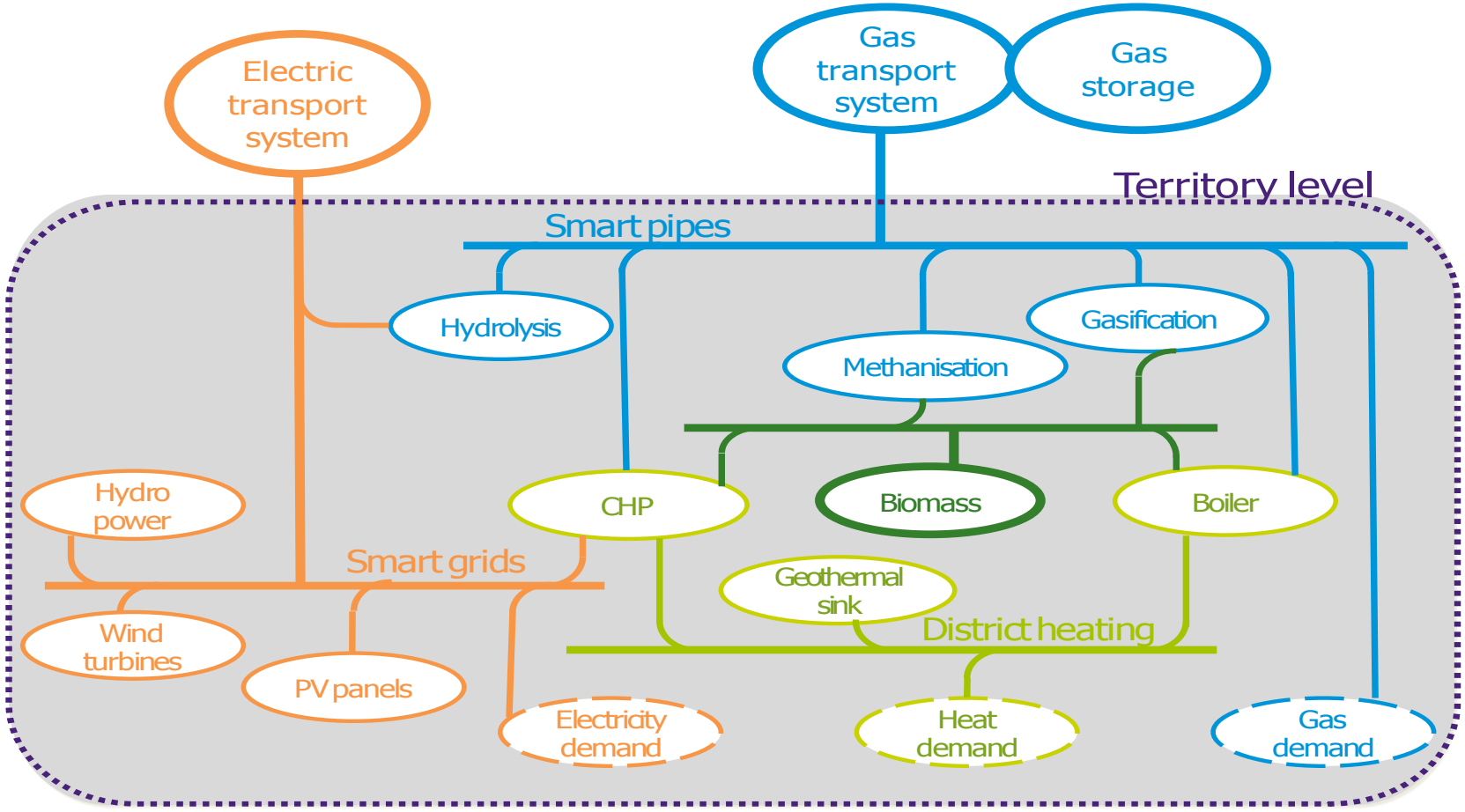
SOB	EFF	DIV	DEC
négaWatt	ADEME	ANCREdiv	Négatep
Greenpeace	GRDF	RTEnouvmix	RTEmed
WWF	ANCREsob	DGECame	ANCREele
Global Chance	ENCILOCARBrenf		UFE

France – Energy Roadmap
Energy Transition National Debate



- Electricity and heat generation
- Transport
- Industry and Agriculture
- Residential and Tertiary

Towards smart energy networks



GrDF at the heart of next energy transition

New Gas resources

- Conventional and non conventional natural gas
- Biomethane from anaerobic digestion, gasification and microalgae
- Power-to-gas

Grid evolution

- IT, big data, open data, nanotech, drone
- Smart meters
- Smart gas grid
- Smart networks

New consumers needs

- Low energy and zero net energy buildings
- Ecodistrict
- Sustainable mobility NGV & bioNGV
- Decentralized generation
- Digital

GrDF implements a proactive strategy to anticipate new business

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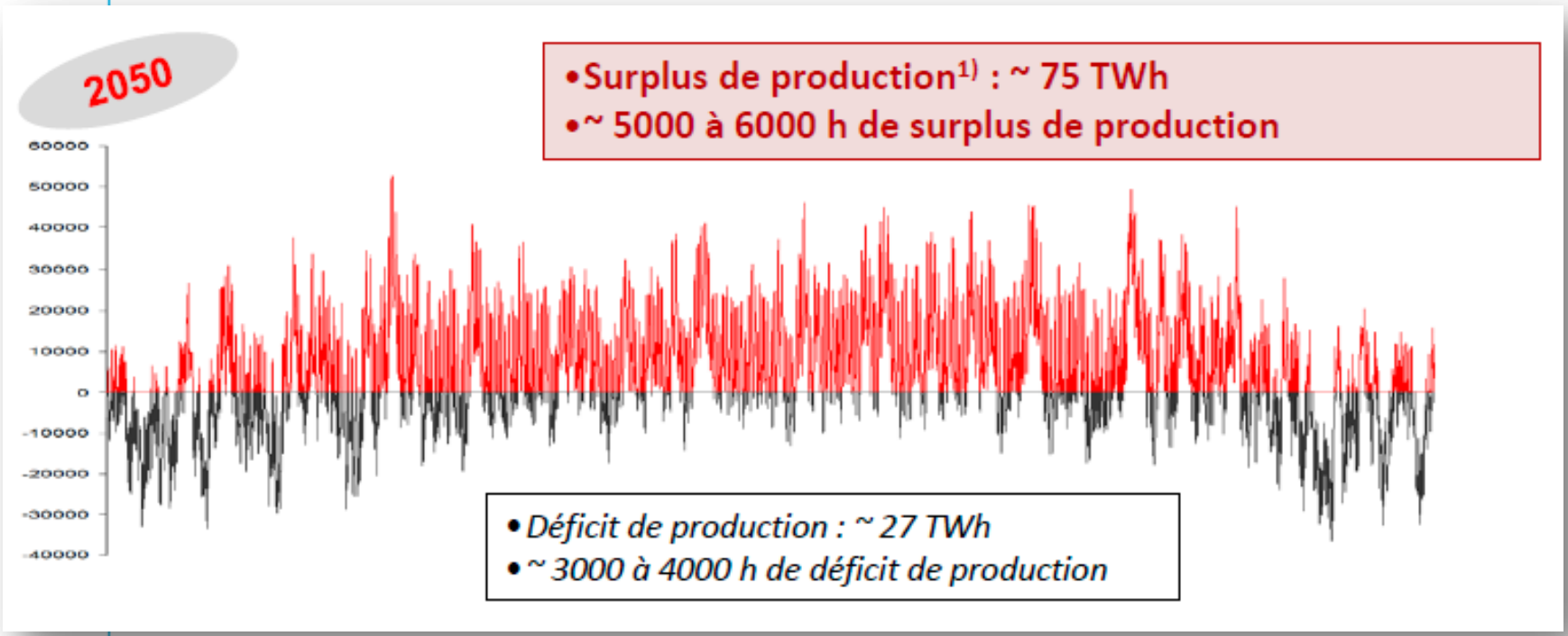
Electricity storage – Key figures

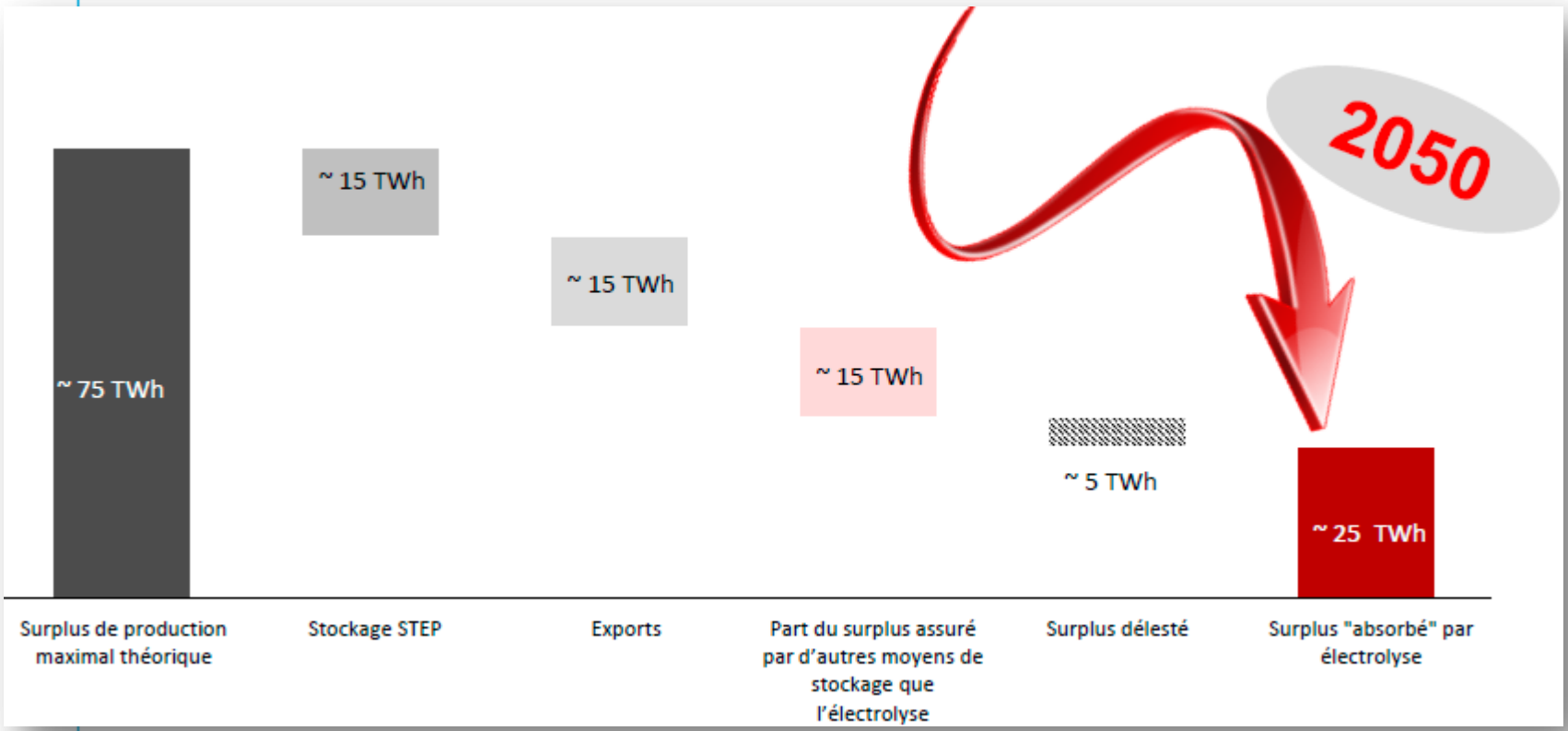
- Gas and electricity consumption in France are roughly the same: 400 TWh per year
- Gas storage capacity is 300 higher in energy than the electricity storage capacity (137 TWh vs. 0,2 TWh)
- It is equivalent to a 130-day reserve for gas (4 months of consumption) and 8 hours for electricity
- 10 millions of electric vehicles equiped with 25 kWh battery would be equivalent to 0,2 TWh (8hours)

In 2050, excess of renewable electricity production could reach up to 75TWh (5000 to 6000h) and require massive storage capacities



Source: GRTgaz, E-Cube study

In 2050, excess of renewable electricity production could reach up to 75TWh (5000 to 6000h) and require massive storage capacities



Source: GRTgaz, E-Cube study

Gas grids as energy storage and flexibility provider

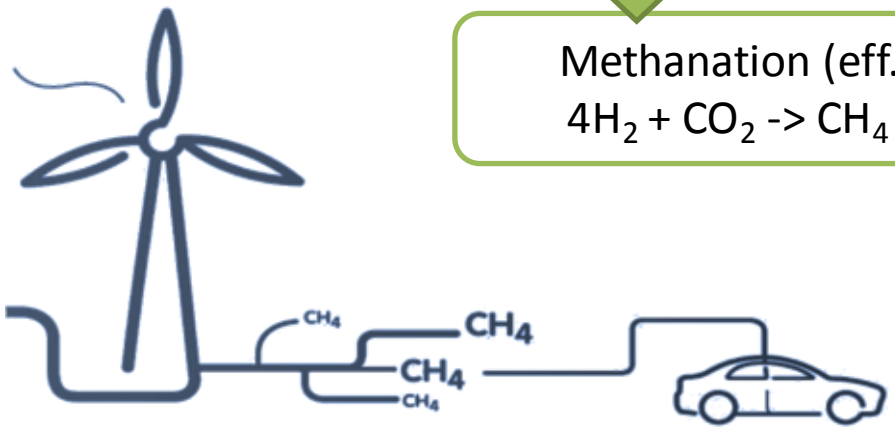
Electric network

Water electrolysis (eff. < 80%)
$2H_20 \rightarrow 2H_2 + O_2$

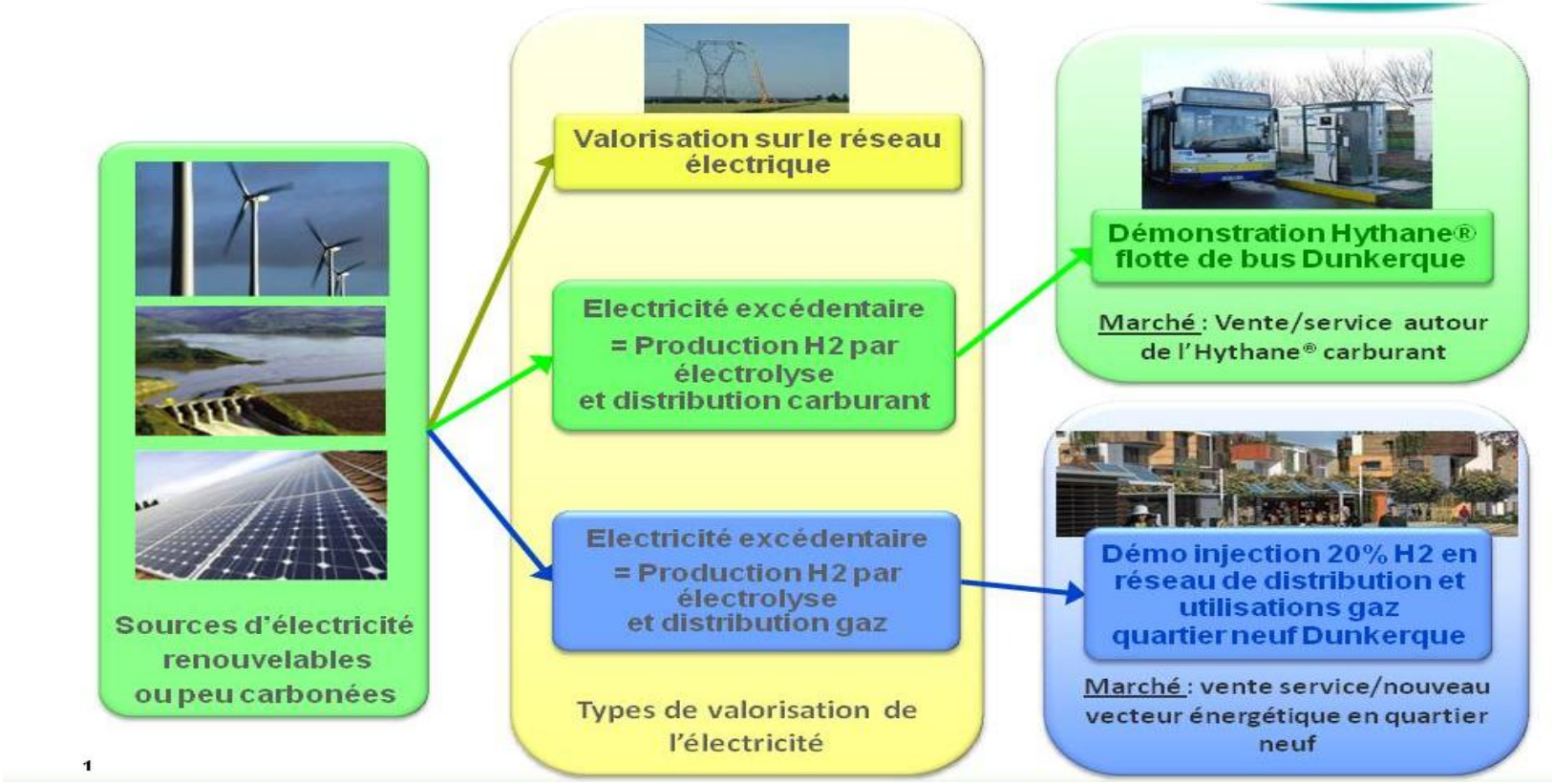
H_2 up to 6% in natural gas

Methanation (eff. < 80%)
$4H_2 + CO_2 \rightarrow CH_4 + 4H_2O$

Natural Gas Network



GRHYD – 16MEUR incl. 2MEUR Subsidy

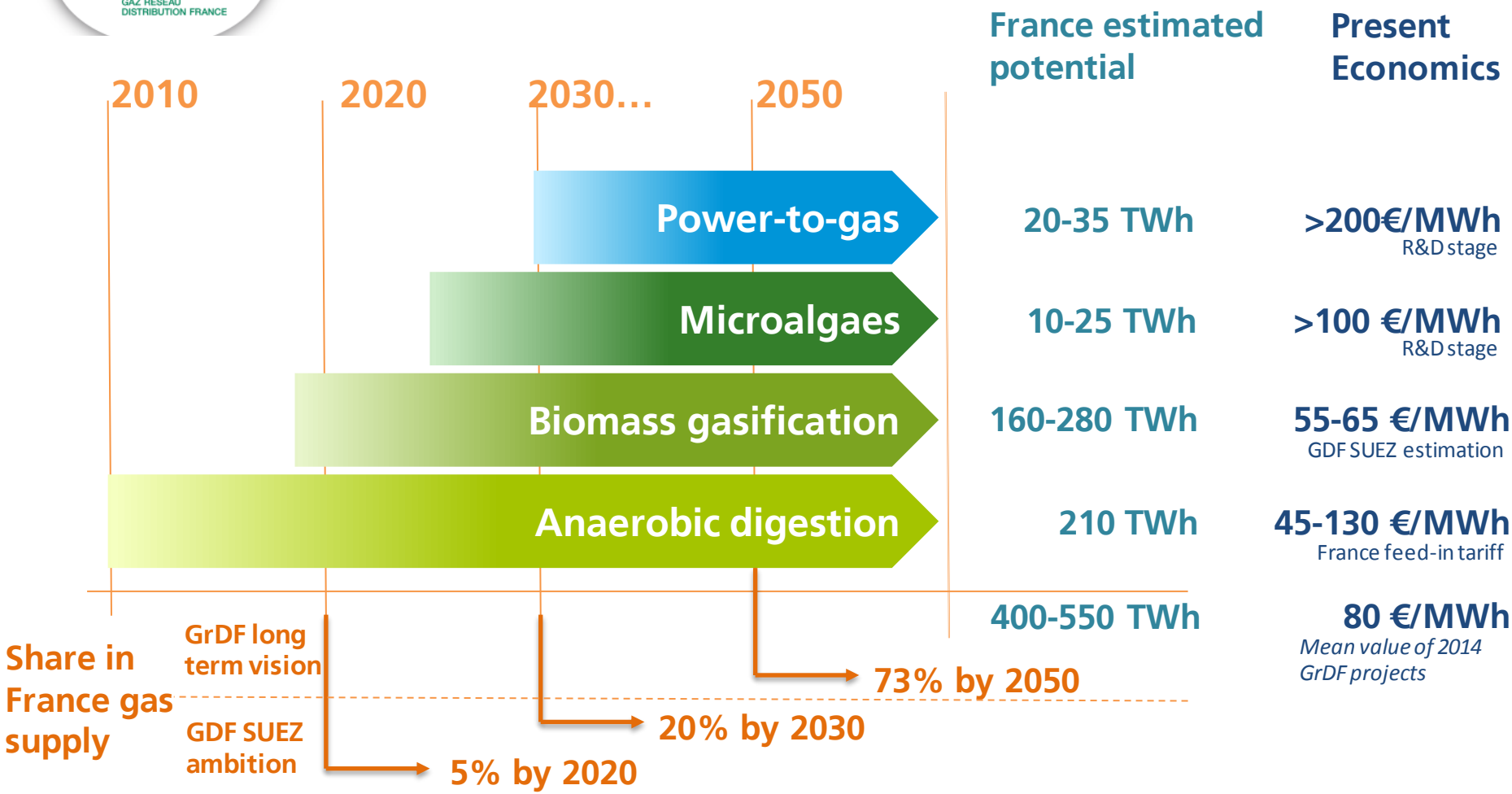


Power-to-gas in european scenarios

Pays	Nom	Année	Champ	Objectif	Hydrogène ou méthane ?	Motorisation à terme	Quantification excédents ?
DE	Leitstudie BMU	2011	complet	GES -80 à -95%	H2 et CH4	elec 14% + H2 17% + hydride (dont bio)	Oui - détails
DE	DVGW - PIK	2013	complet	GES -80%	H2 d'abord, CH4 ensuite	Hybride (70%) + CH4 (30%)	Oui - détails
DE	F-ISE	2013	complet	GES -80%	CH4 seulement si ambitieux	100% ENR	Oui - détails
DE	Kombikraftwerk2	2013	elec	100% ENRe	CH4 seulement	-	Oui - détails
DE	VDE	2012	elec	100% ENRe	Non	-	Non
DE	UBA (UmweltBundesAmt)	2013	complet	GES -95%	PtH2 et/ou PtCH4 et/ou PtL	elec 20% + reste E-fuel	Oui - détails CH4
DK	DCC/Green Energy	2010	complet	100% ENR	Non	elec 60% + bio (gaz+liquid)	Non
DK	SEV 2030	2010	complet	100% ENR	H2 (pas référence à CH4)	elec 50% + bio (gaz) + H2	Oui - détails
DK	IDA 2050	2009	complet	100% ENR	H2 et discussion CH4	elec 50% + H2 40%	Oui - détails
FR	ADEME - vision 2030-2050	2013	complet	GES -75%	H2, CH4 possible	Hybrides (38%) et élec (28%)	Non
FR	NégaWatt	2011	complet	GES-95% - ENR 90%	CH4 seulement	20% elec reste biogaz et gaz	Oui
FR	GRDF	2013	complet	GES -75%	H2 et discussion CH4	biogaz 73% elec 14%	Oui
FR	ANCRE	2013	complet	GES -75%	H2 et/ou CH4	pas détaillé	Non
EU	EU trends 2050	2013	complet	80-100 % ENRe	Non	surtout électrique	Non
EU	ECF Roadmap 2050	2010	elec	80% décarboné	Pas de choix technique	-	Non
EU	GP Battle of the Grids	2011	elec	100% ENRe	Non	-	Non
CH	OFEN	2012	complet	GES 1t/hab.	Non	elec 35% + bio 30% + gaz 5%	Non
CH	AES	2012	elec	100% ENRe	Non	-	Non
BE	Vers 100% d'ER en Belgique	2013	complet	100% ENR	H2 et discussion CH4	pas détaillé	Oui - détails H2
NL	ECN Roadmap NL	2011	complet	GES -75%	Discussion ouverte	Elec + biomasse (sans détail)	Non
GB	ZCB	2013	complet	100% ENR	CH4	Elec et CH4, pas H2	Oui - détails CH4
IRL	STORE	2013	elec	80% ENRe	Non	-	Non
SE	Energy scenario for Sweden	2011	complet	100% ENR	Non	Elec + biomasse (sans détail)	Non
SCAN	Nordic 2006-2030	2006	elec	GES-70% 2030	H2	elec + fuelcells + fossil	Oui -détails H2

Comparaison des scénarios E&E consultant, Hespul 2014

The green gas roadmap implementation

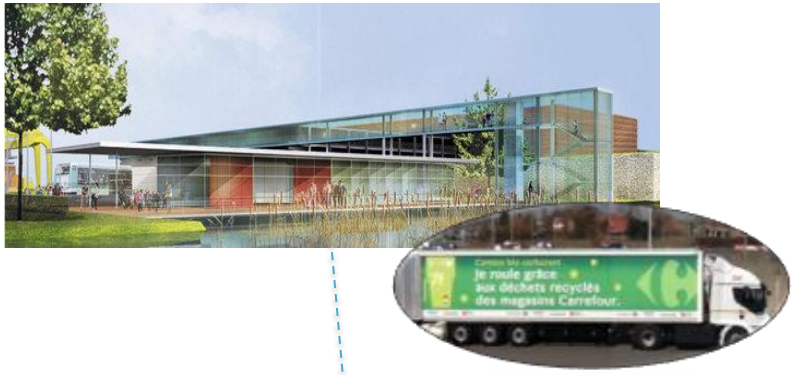


Green gas generation is already a reality for GrDF with 3 injecting site and more than 380 in the projects pipe

17

The 3 first biomethane injection successes

Lille Métropole
Municipal waste and bioCNG



Bioénergie de la Brie
Agricultural waste

Sydeme (Moselle)
Municipal waste and bioCNG

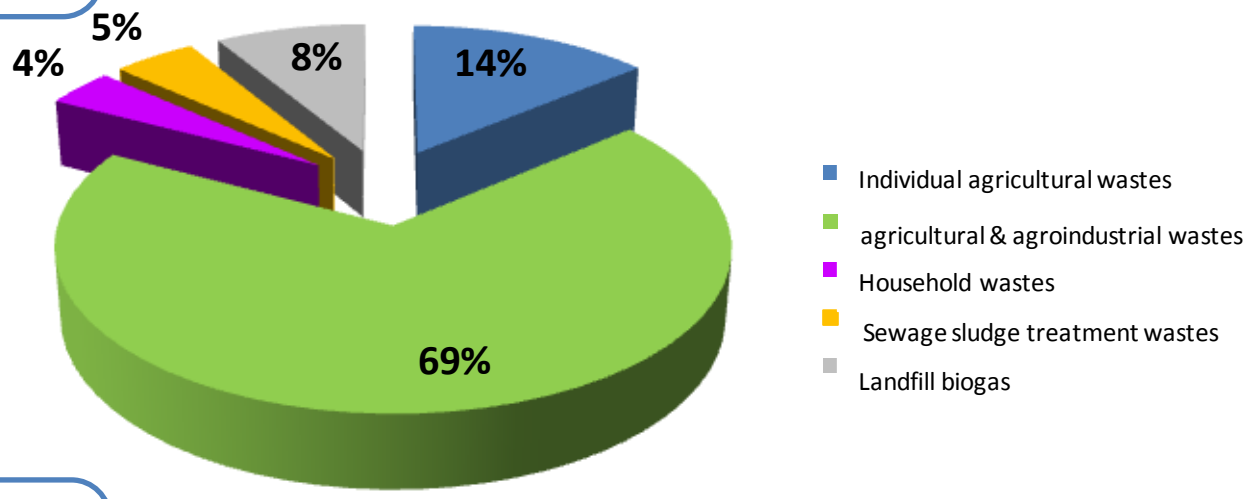
10 to 15 new projects to be connected to GrDF grid in 2014

Purification unit

GrDF injection unit

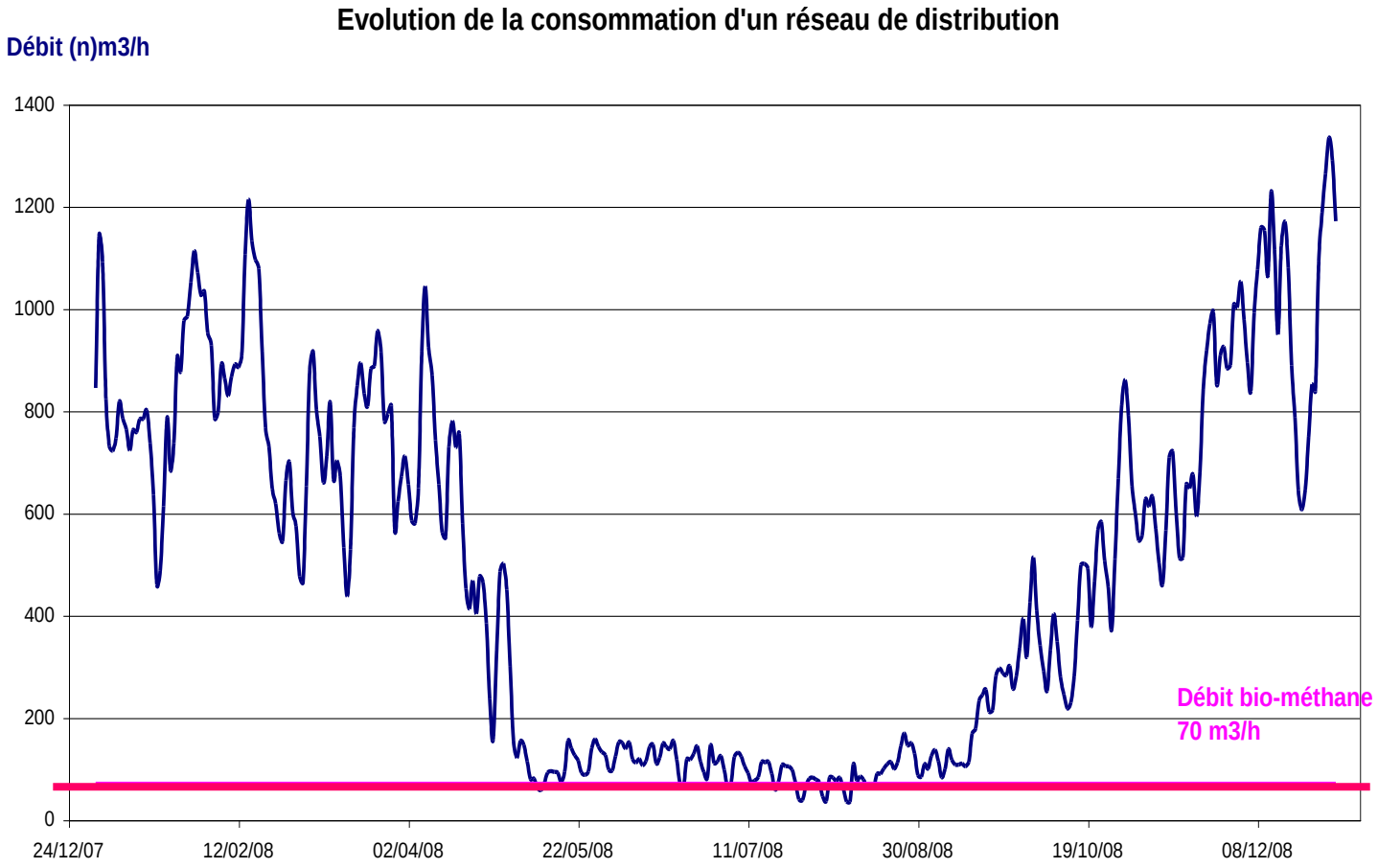
Digester

69% of projects are based on agriculture and agroindustrial waste



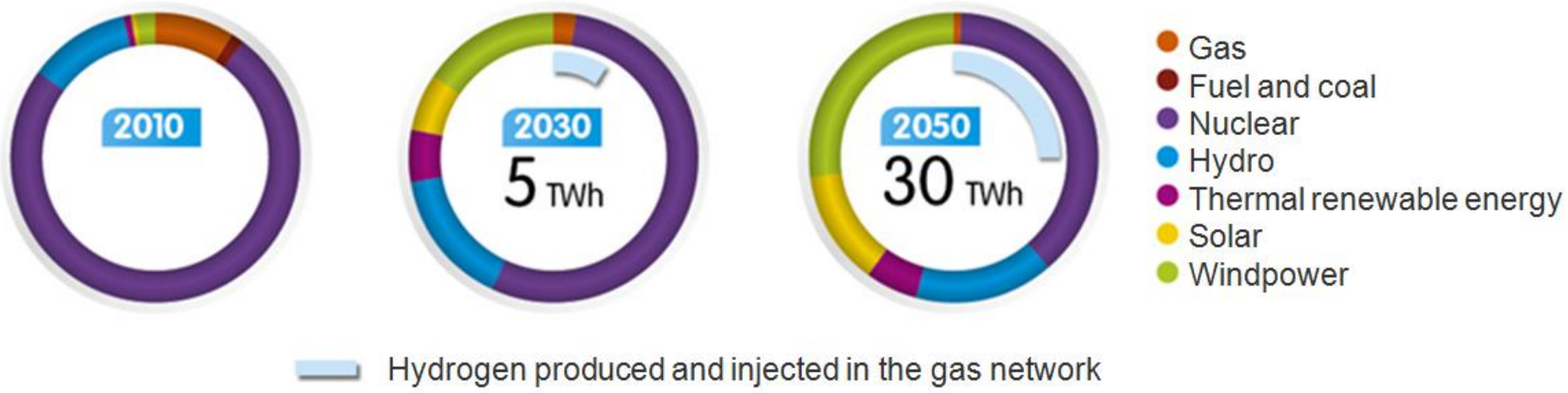
Average flowrate of projects : 200 m^3/h
(~20 GWh/year)

Example of biomethane integration



The green gas roadmap implementation

Electricity sources and hydrogen production in TWh per year



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Electric power in 2012: +6% vs. 2010, +11% vs. 2011

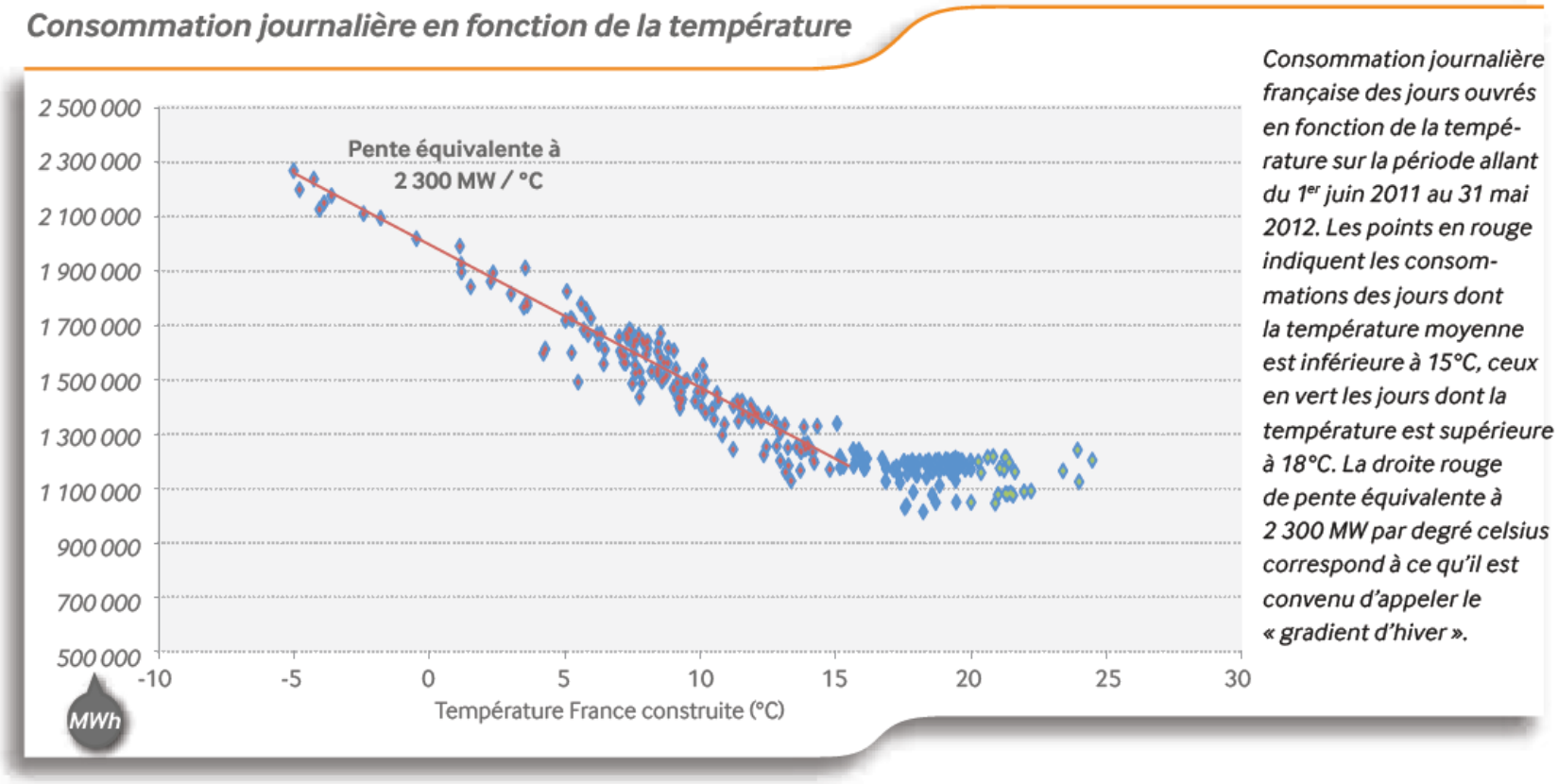
*Historique des maxima annuels de consommation constatés depuis 2001**

Mercredi 08/02/2012	**102 100 MW**
Mardi 04/01/2011	91 820 MW
Mercredi 15/12/2010	**96 710 MW**
Mercredi 07/01/2009	**92 400 MW**
Lundi 15/12/2008	84 420 MW
Lundi 17/12/2007	**88 960 MW**
Vendredi 27/01/2006	**86 280 MW**
Lundi 28/02/2005	**86 020 MW**
Mercredi 22/12/2004	81 400 MW
Jeudi 09/01/2003	**83 540 MW**
Mardi 10/12/2002	**79 730 MW**
Lundi 17/12/2001	**79 590 MW**

**En gras sont indiqués les maxima absolus*

Source: RTE

Demand correlation to temperature: 2300MW/°C



Source: RTE

Demand correlation to temperature: 2300MW/°C

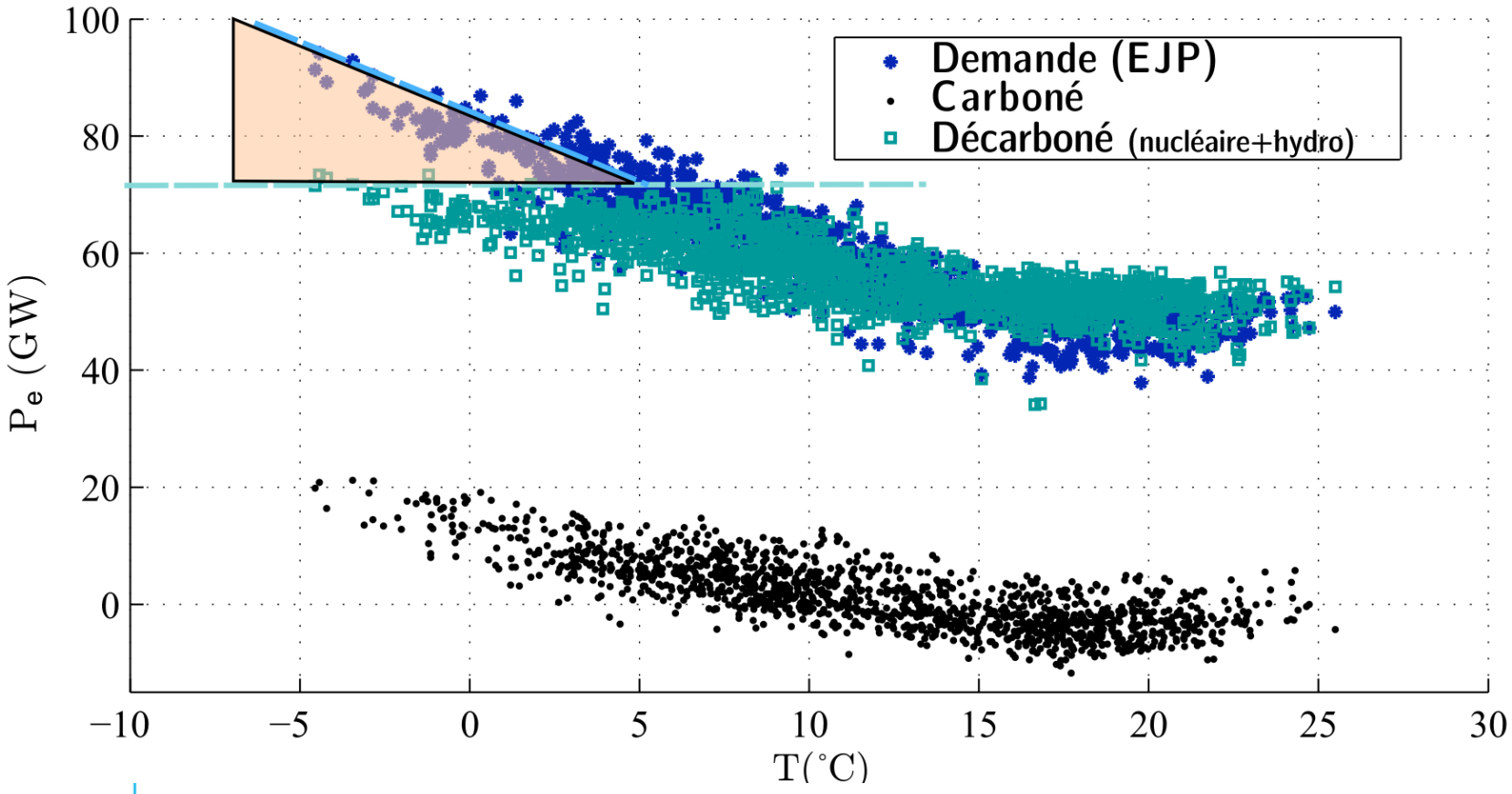
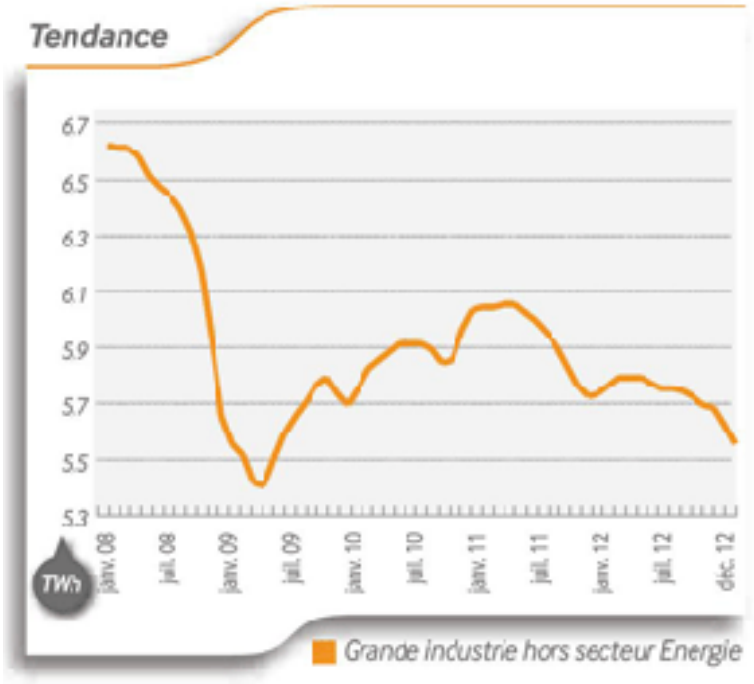
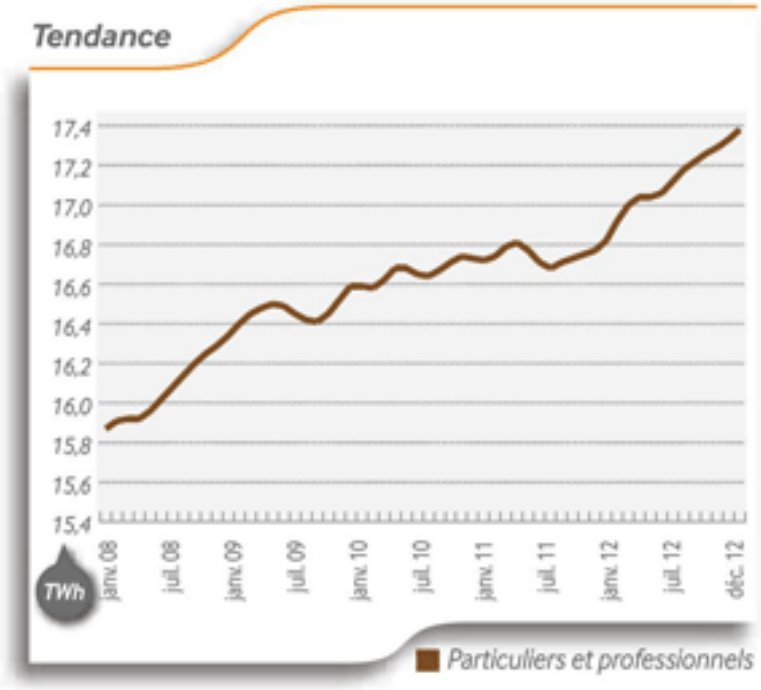


Fig. Temperature impact on the electricity system from 11/2006 to 05/2012

Sources: RTE data and Météo France

Demand correlation to temperature: 2300MW/°C





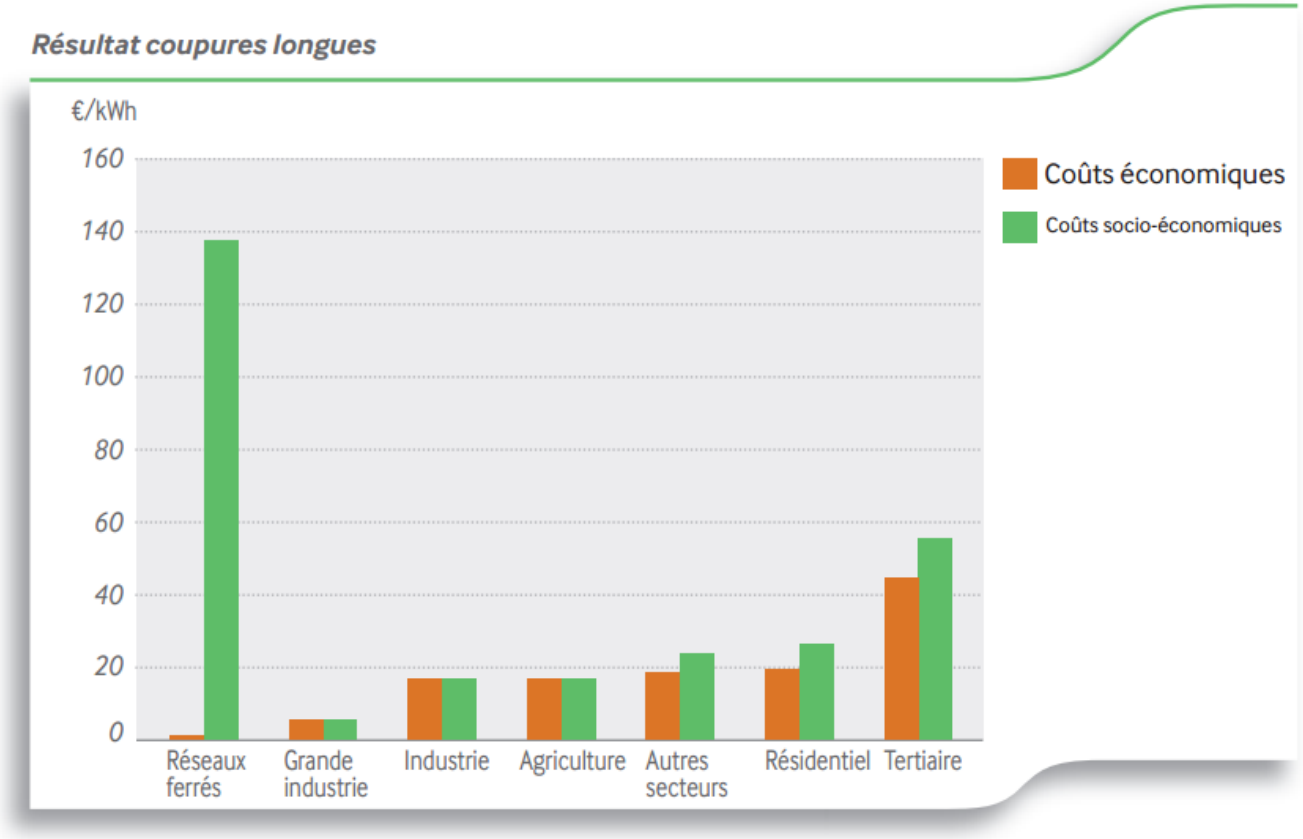
Industry - -4% per year

Residential and tertiay- +2,4% per year

Source: RTE

Grid design criteria - Cost of not distributed energy – avg of 26€/kWh, 200 times cost of energy

Grid reinforcement vs. consumption x probability of failure x cost of NDE



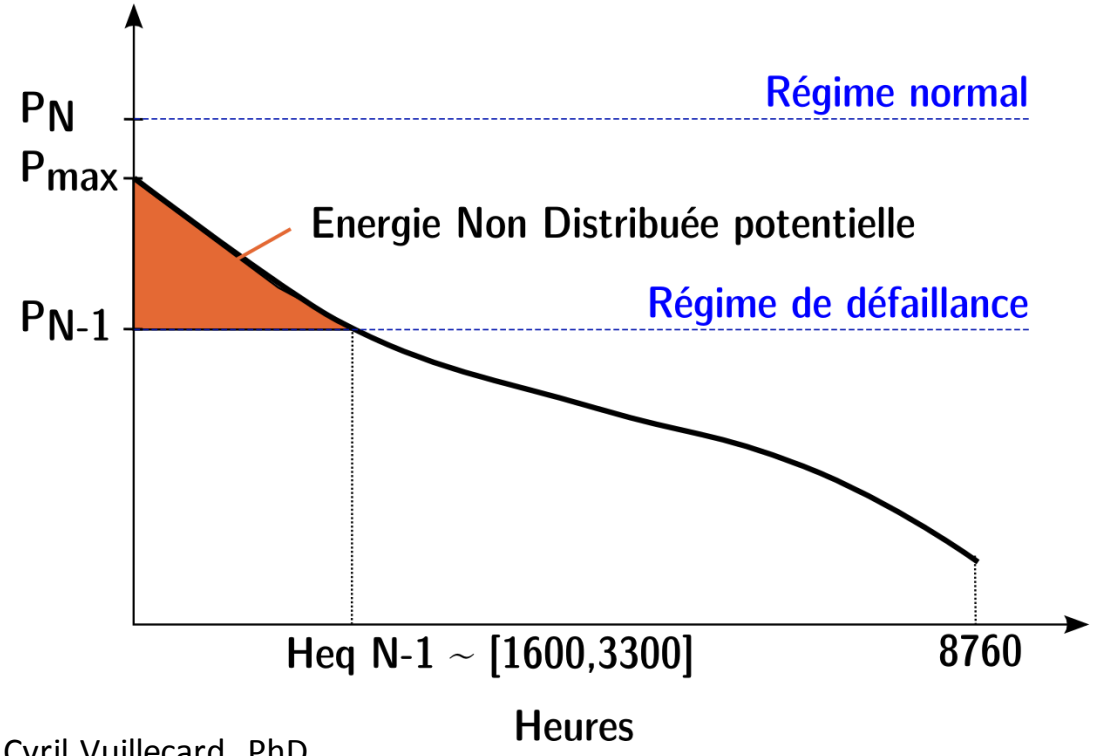
Source: RTE

Cost of not distributed energy – avg of 26€/kWh, 200 times cost of energy

Only «long duration» demand response has an impact on system reinforcement by decreasing the risk of technical failure

A theoretic illustration :

- Pmax < Pn : **short demand response**
- NDE decrease : **long (seasonal) demand response**



Source: Cyril Vuillecard, PhD

Cost of not distributed energy – avg of 26€/kWh, 200 times cost of energy

French demand, normal temp., 2000h, seasonal heating only.

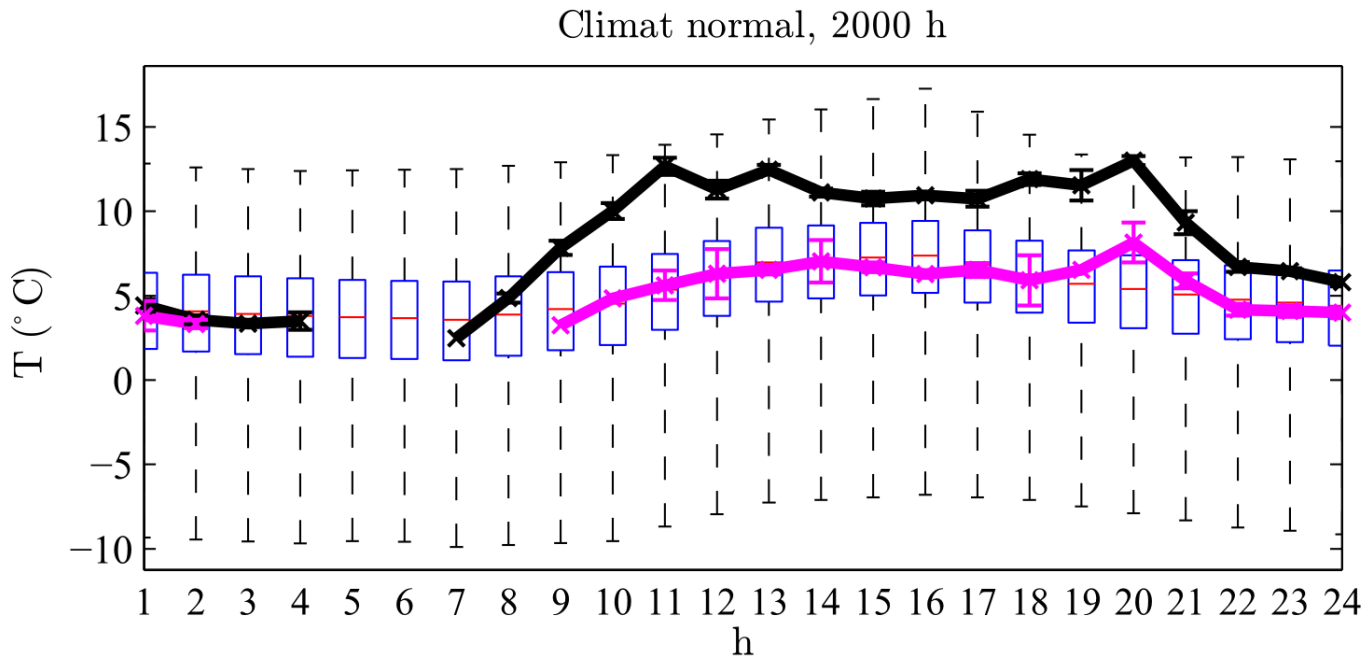


Fig. Hourly temperatures for the top 2000h and distribution over 32 years *RTE* and *MétéoFrance*

Source: Cyril Vuillecard, PhD

Cost of not distributed energy – avg of 26€/kWh, 200 times cost of energy

Demand response frequency impacting technical failure risk

% heure	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Semaine	53	45	43	46	0	0	39	62	88	98	100	97	98	91	88	89	91	99	99	100	93	74	73	67
Weekend	46	42	0	0	0	0	0	0	40	54	53	51	44	49	43	36	46	46	61	83	61	43	44	46

Winter time frequency of demand response impacting technical failure risk

Source: Cyril Vuillecard, PhD

Heating appliances

- Bi-energy technologies:
  - Hybrid boilers
  - Micro-cogeneration

Electric heating

Boilers (woord, gas, fioul)

Electric heat-pumps

Hybrid boilers

Micro-cogeneration

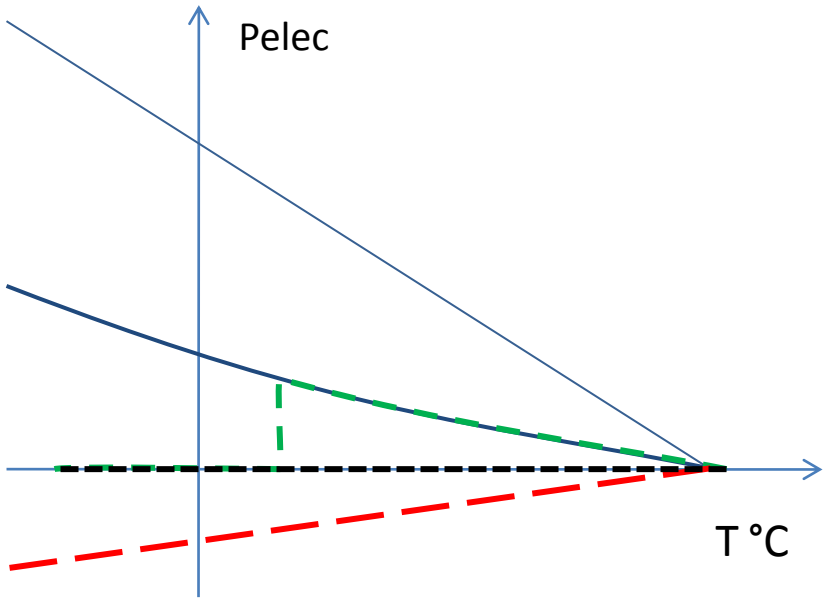


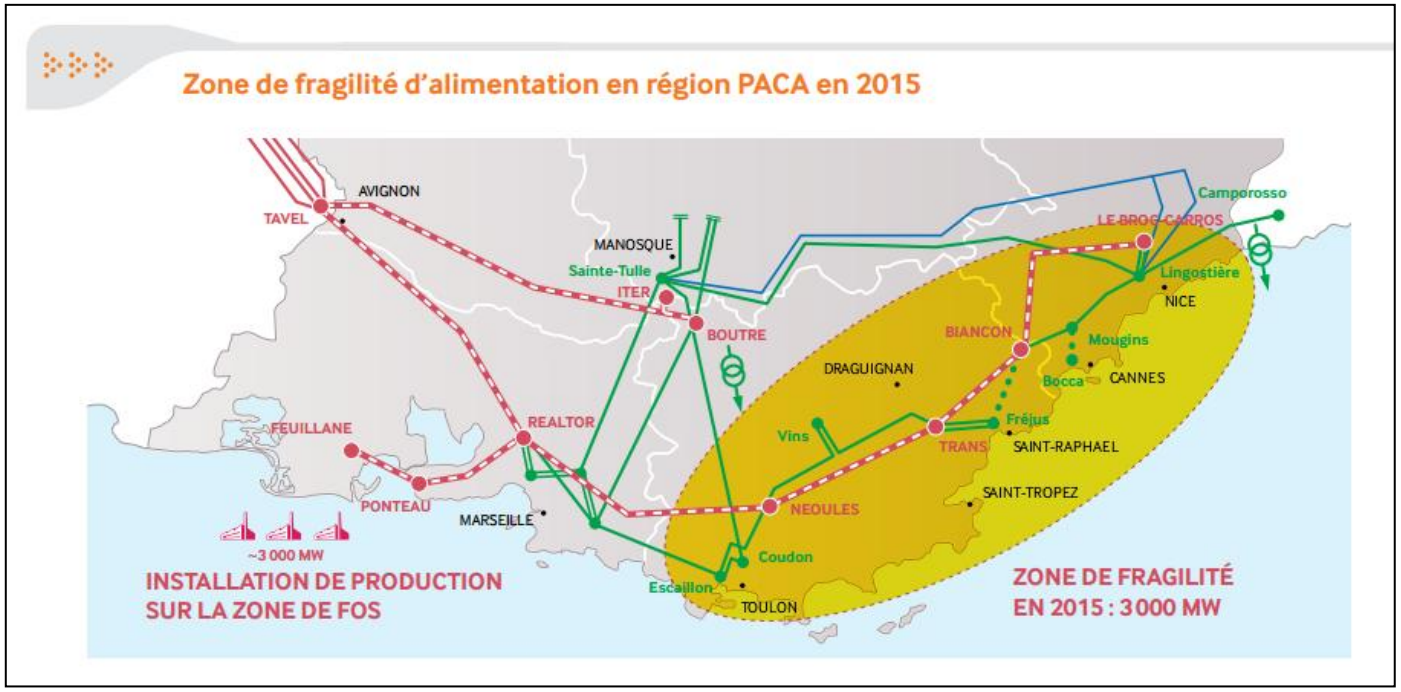
Fig. Illustration of the impact of different heating appliances

Source: Cyril Vuillecard, PhD

Les technologies bi-énergie répondent aux enjeux de maîtrise de la demande en PACA

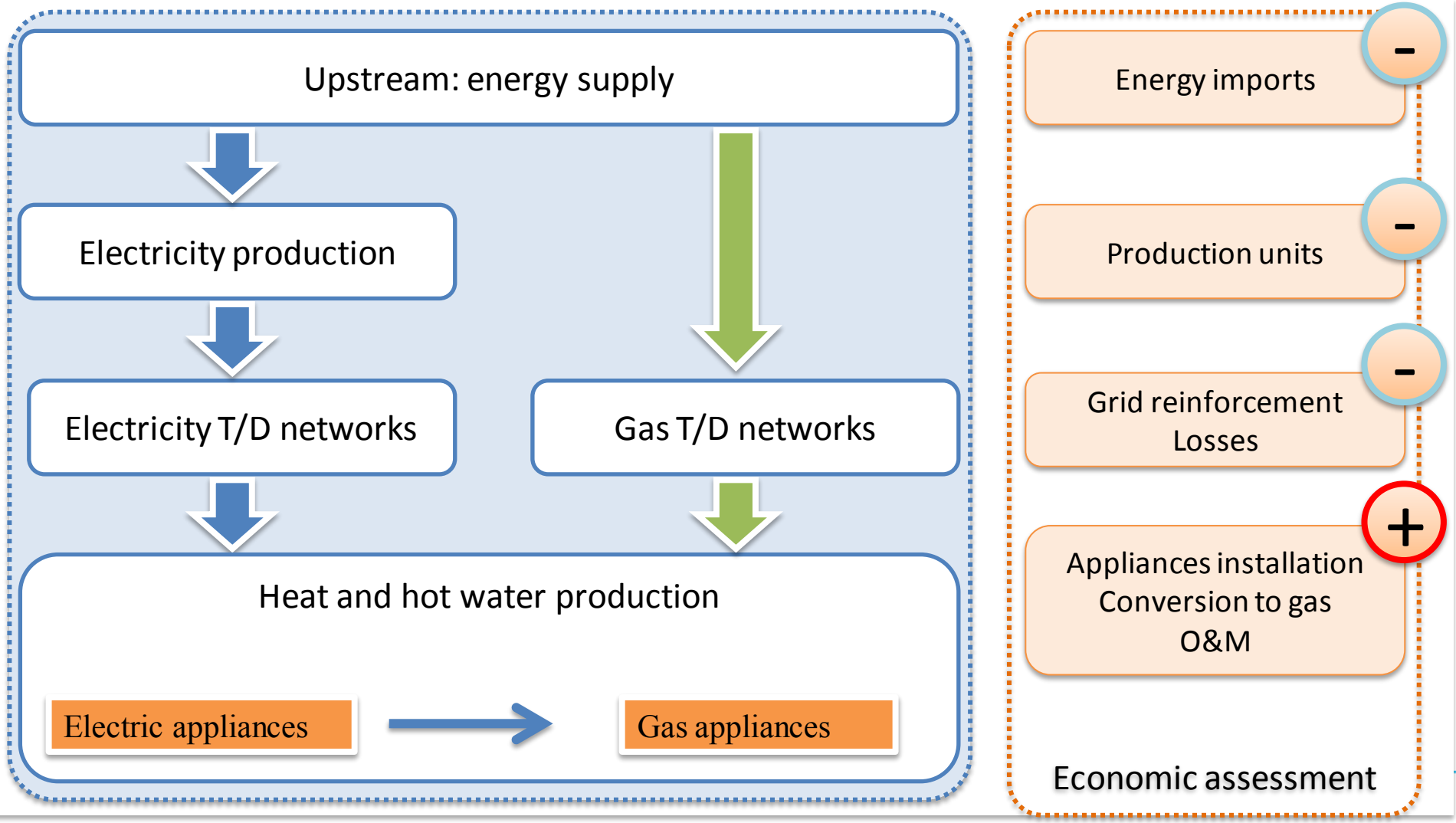
PACA (source : bilan prévisionnel RTE 2011)

Electricity consumption: **+4,4% in volume et +5,3% peak** from 2009 to 2010.
Strong correlation to the temperature: 190 MW/°C during winter time, 64 MW/°C during the summer



Source: RTE

Decentralized energy generation : the future of gas utilization – study illustration



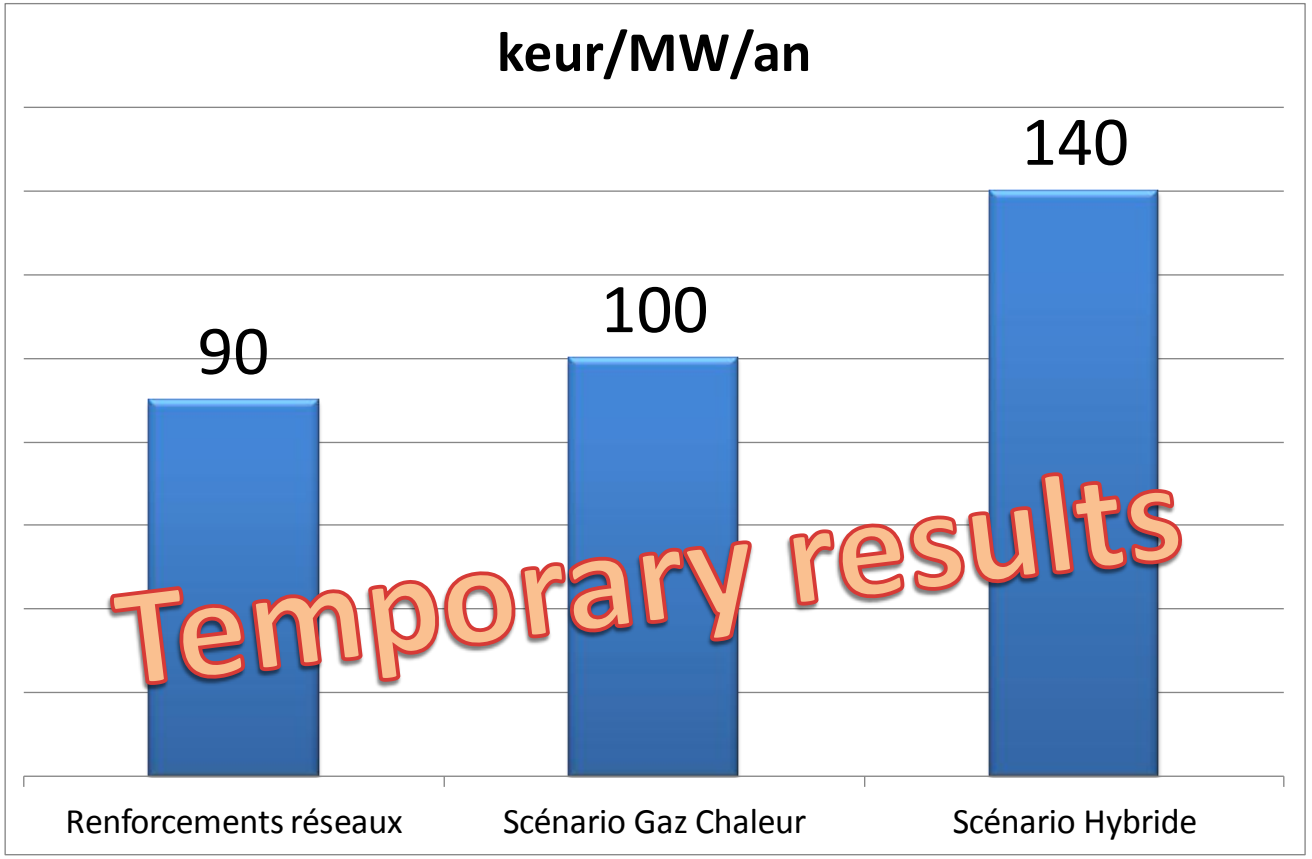
Temporary results

Regional economic efficiency of the different scenarios

Electric heating and standard boilers are replaced by:

Sénario Gaz Chaleur:
condensing boilers

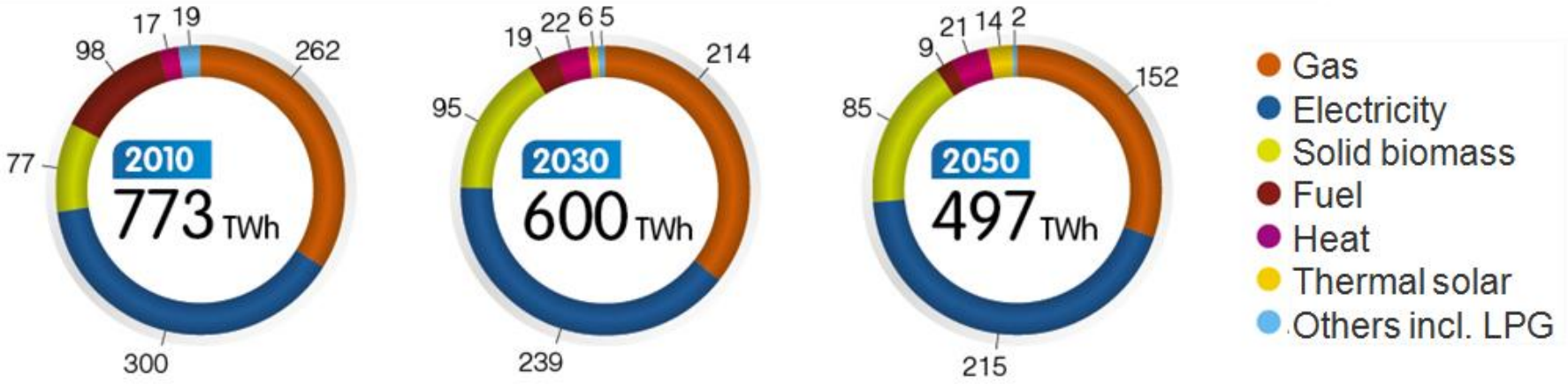
Scénario Hybride:
hybrid boilers



Decentralized energy generation : the future of gas utilization

- The number of dwellings increases from 27 to 37 million from 2010 and 2050.
- Unit consumption decrease: renovation programs (500,000 major renovations per year) and penetration of efficient technologies such as condensing boilers, coupling gas-REN, gas fuel-cell, micro-CHP

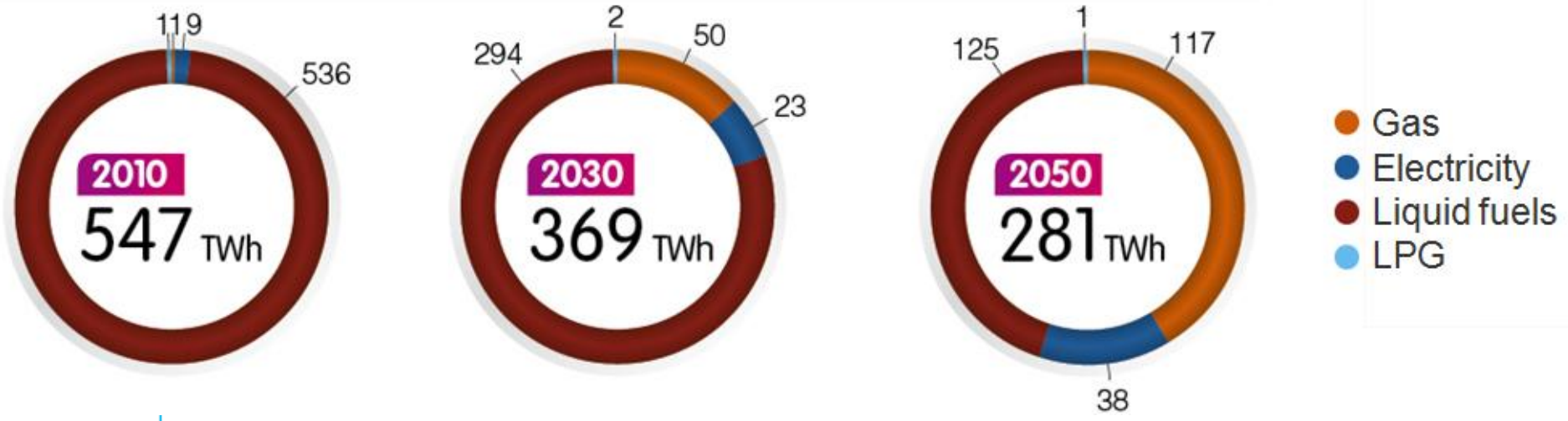
Residential and tertiary final energy consumption (TWh per year)



Electricity and gas mobility

2050 time horizon	Short distance	Medium distance	Long distance
Personal vehicles / Utility vehicles	Electricity	Gas / Diesel, fuels...	Gas / Diesel, fuels...
Bus / autocar		Gas	Gas
Road transport	Gas	Gas	Gas
Fluvial / maritime transport			Gas

Transport energy consumption (TWh per year)



Gas distribution : an history of transitions

Town gas → Natural gas → Renewable gas

Coal
H_2 + CO
Lightning

… cooking…

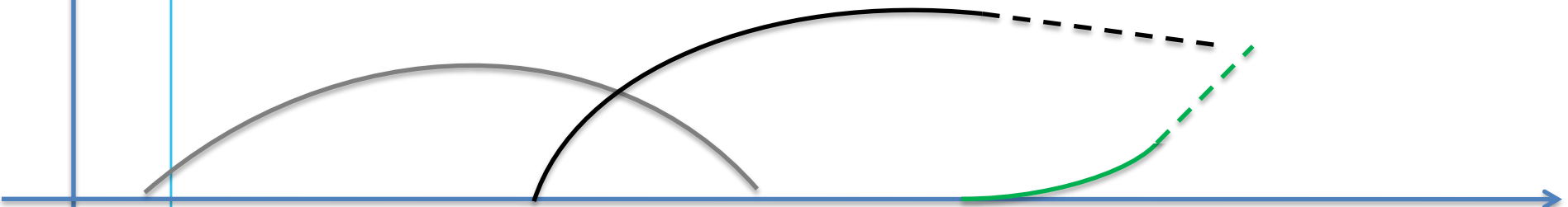
Natural gas
CH_4
…heating, industry…

Natural gas + Renewable
CH_4 + H_2
…mobility

Local production and distribution

Top-down infrastructure

Cooperative infrastructure organizing solidarity between territories



1818 — 1st gas company in Paris, France

1956 — 1st natural gas production in France

1970 — End of town gas

2012… — 1st biomethane injection

… 2050

Gas distribution grid is available for next renewable gas transition

Thank you for your attention.
To follow-up:

> Global vision: Smart Gas Grids and networks (FR)

> Upstream optimization: the GRHYD power-to-gas project (ENG)

> Downstream optimization: pointe électrique française (FR)

> Don't hesitate to contact me:

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- www.grdf.fr