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CO_2 emissions mitigation potential in Vietnam's power sector

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Motivation

Vietnam is most affected by **climate change:**

- Sea-level rise, 0.3m - 1m over next 100 years, could lead to a capital loss of 17 billion USD every year (WB, 2008).
- Flood damage, drought, typhoons will intensify by 2070. About 80-90% of populations directly affected by typhoons (UNDP, 2007).

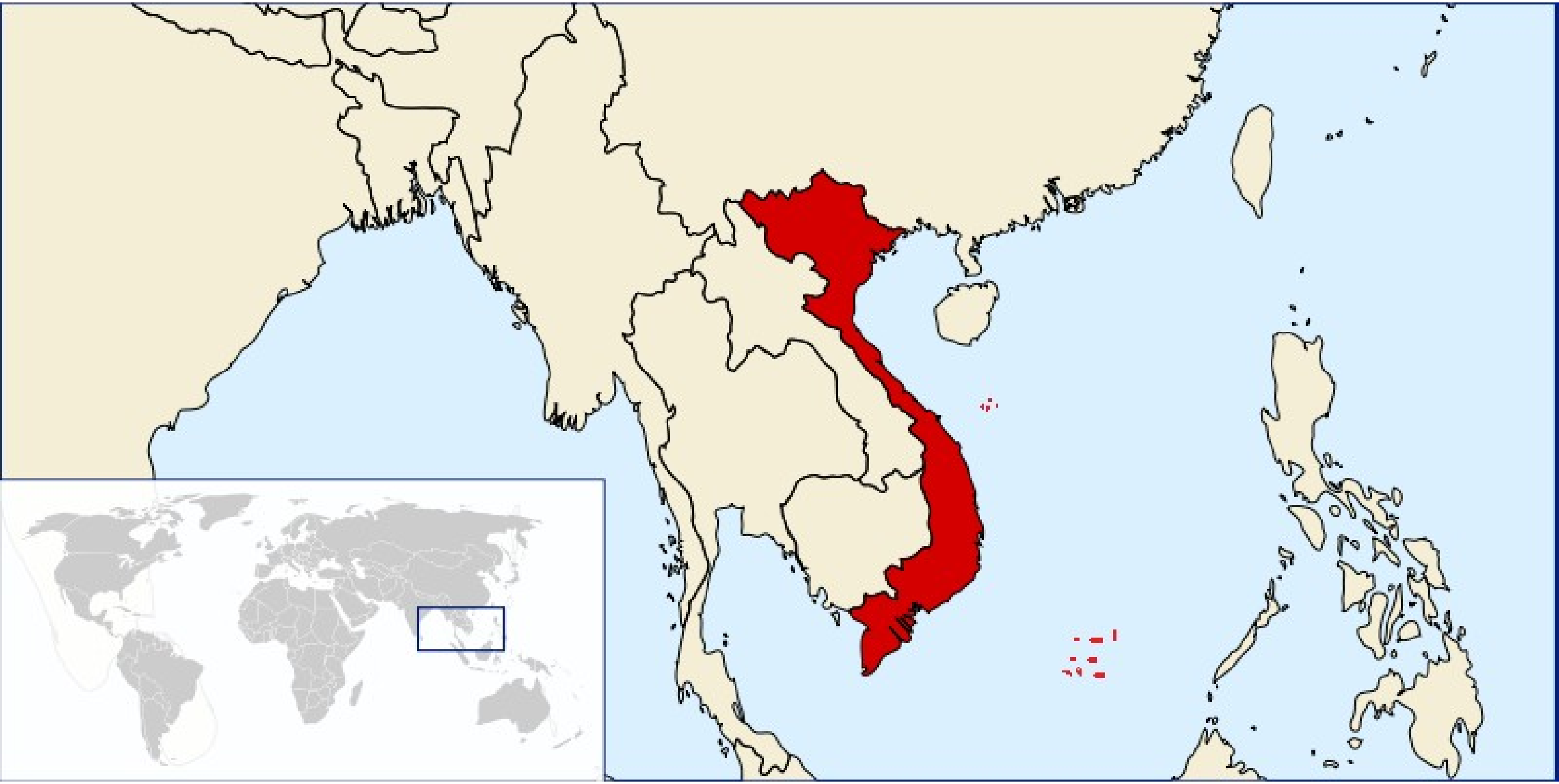
Local health and environmental effects:

- Air pollutants brought about 22% of chronic pneumonia cases and 1/3 of respiratory inflammation in Vietnam during 2001-2003 (USAID, 2007).

Outline and key results

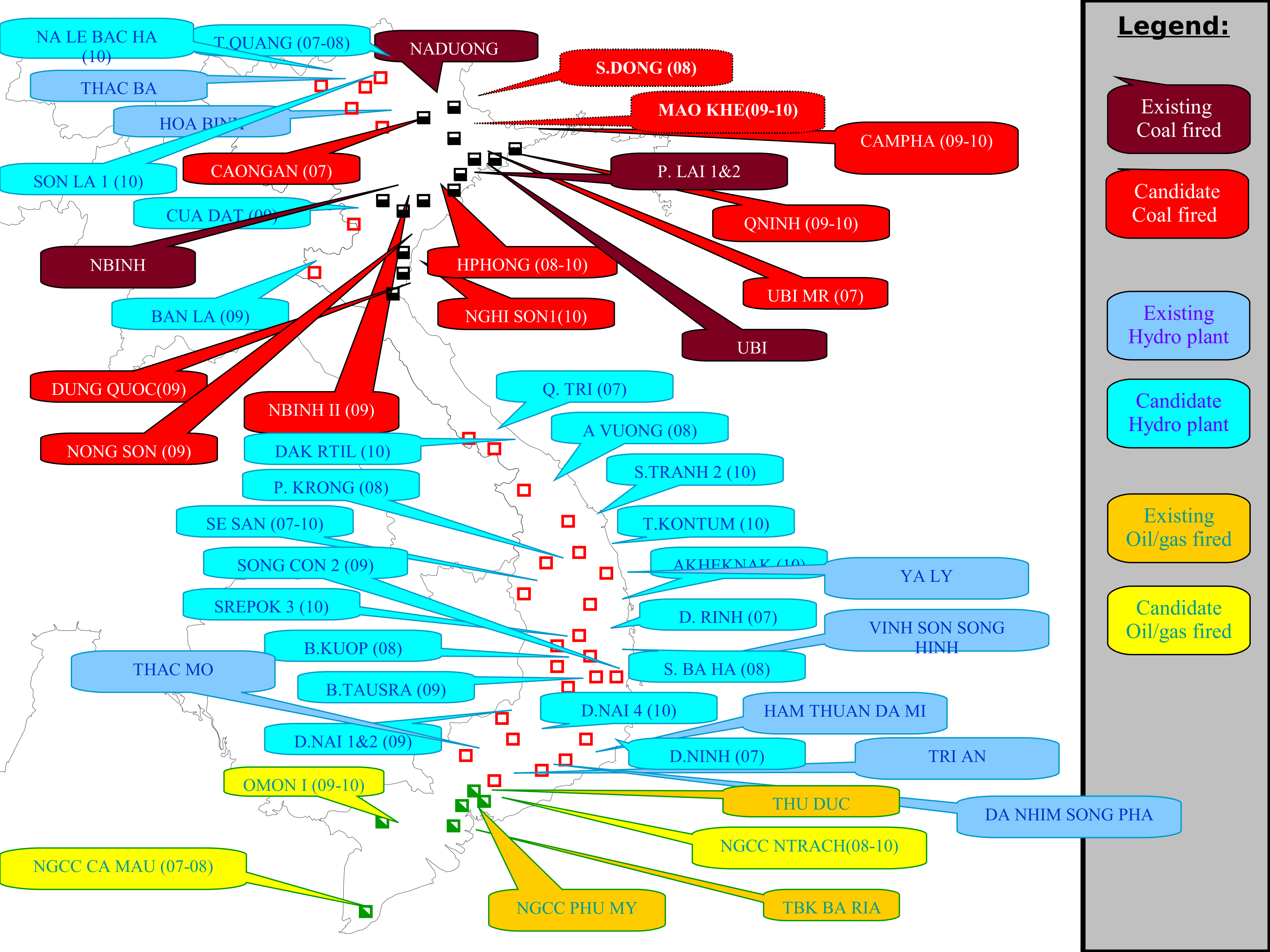
1. **Vietnam power sector up to 2030.**
2. **Integrated resource planning (IRP) model.**
3. **Results:**
   - **Fossil fuels are expected to dominate: CO_2 ++**
   - **Nuclear , wind, and demand-side management each have >10% reduction potential at 10$/tCO2**

1. Present situation and trends



Next map: power plants being installed in VN by 2010

Source: Institute of Energy of Vietnam, 2006



Legend:
Existing Coal fired
Candidate Coal fired
Existing Hydro plant
Candidate Hydro plant
Existing Oil/gas fired
Candidate Oil/gas fired
NA LE BAC HA (10)
T.QUANG (07-08)
NADUONG
S.DONG (08)
THAC BA
MAO KHE(09-10)
HOA BINH
CAMPHA (09-10)
CAONGAN (07)
SON LA 1 (10)
P. LAI 1&2
CUA DAT (09)
QNINH (09-10)
NBINH
HPHONG (08-10)
UBI MR (07)
BAN LA (09)
NGHI SON1(10)
UBI
DUNG QUOC(09)
NBINH II (09)
NONG SON (09)
Q. TRI (07)
A VUONG (08)
DAK RTIL (10)
S.TRANH 2 (10)
P. KRONG (08)
SE SAN (07-10)
T.KONTUM (10)
SONG CON 2 (09)
AKHEKNAK (10)
YA LY
SREPOK 3 (10)
D. RINH (07)
VINH SON SONG HINH
B.KUOP (08)
THAC MO
S. BA HA (08)
B.TAUSRA (09)
D.NAI 4 (10)
HAM THUAN DA MI
D.NAI 1&2 (09)
D.NINH (07)
TRI AN
OMON I (09-10)
THU DUC
DA NHIM SONG PHA
NGCC NTRACH(08-10)
NGCC CA MAU (07-08)
NGCC PHU MY
TBK BA RIA

7.4%yr^{-1} GDP Growth, 2000-2005

Sector	2000	2001	2002	2003	2004	2005
Agriculture, Forest & Fishing	4.6	3.0	4.1	3.2	3.4	3.8
Industry & Construction	10.1	10.4	9.4	10.3	10.3	11
Service	5.3	6.1	6.5	6.6	7.5	8.2
Total	6.8	6.9	7.04	7.24	7.7	8.5

Source: General Statistics Department of Vietnam, 2006

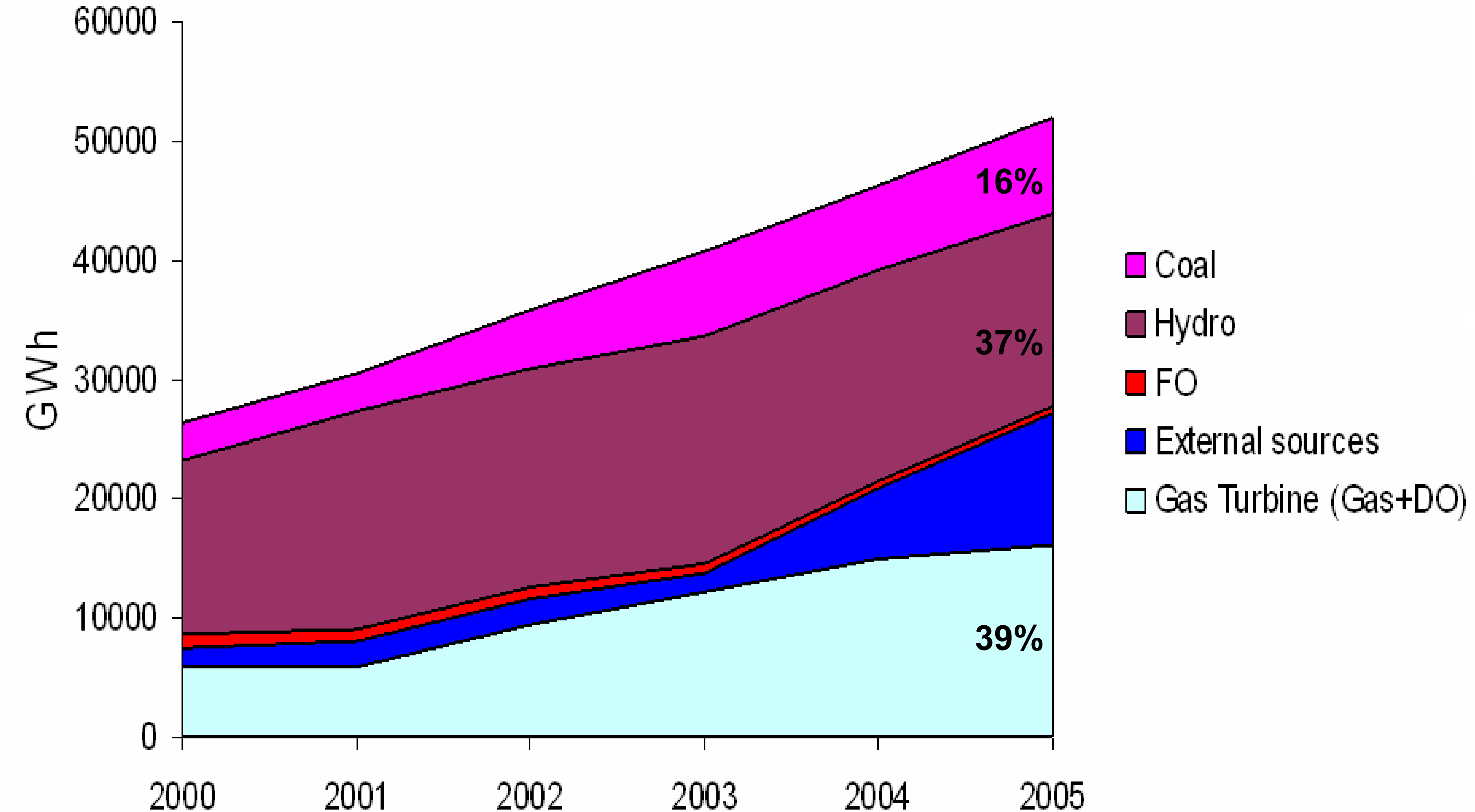
Power generation grows faster

Installed capacity in 2005	**Generation** in 2005	Average annual growth rate	
		Total generation (2000-2005)	Thermal generation (2000-2005)
11340 MW	52.05 TWh	15.2%	22.4%

Source: Institute of Energy of Vietnam, 2006

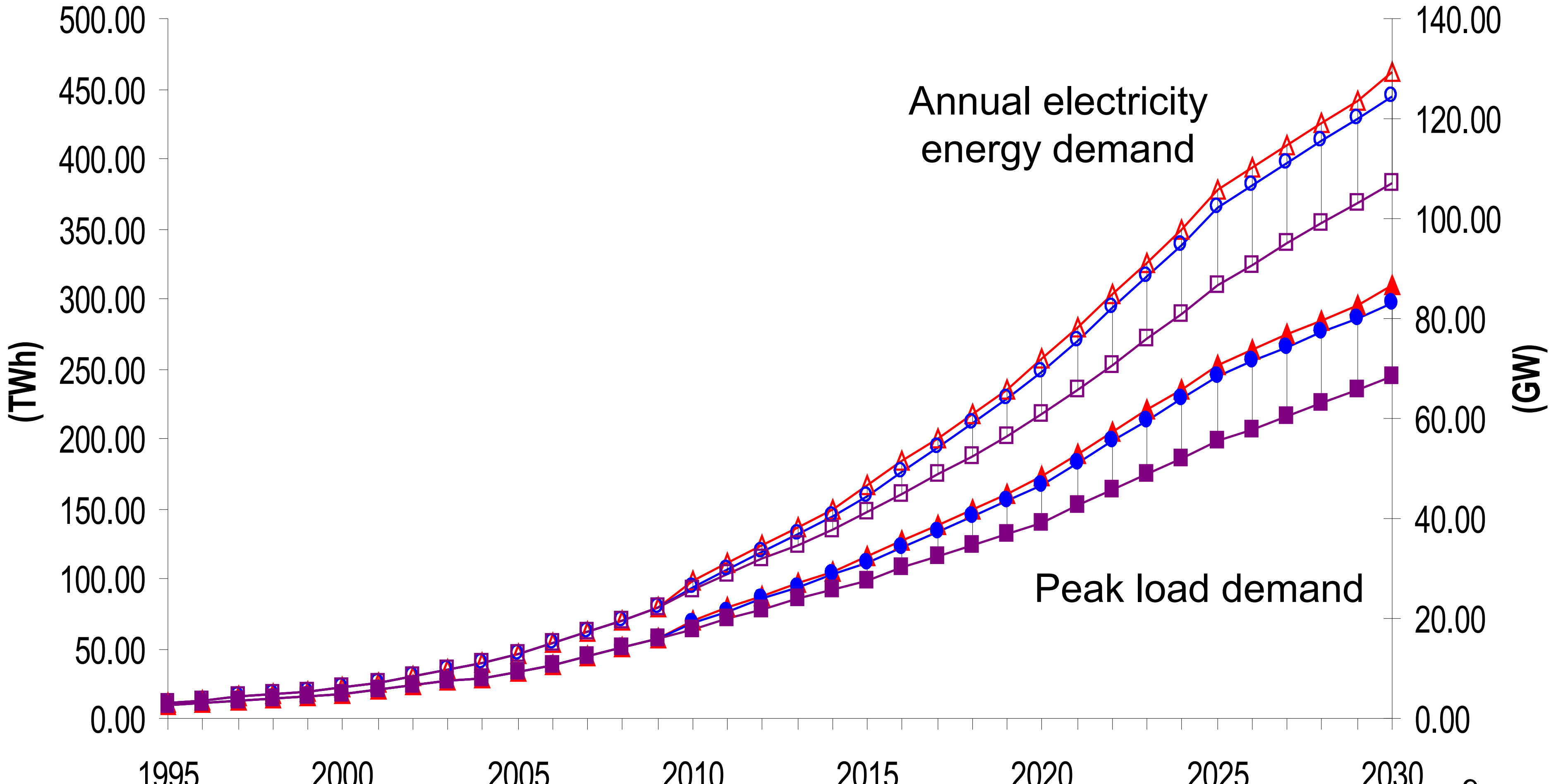
Primary sources, 2000-2005

Source: Institute of Energy of Vietnam, 2006



Electricity demand forecast to 2030

Source: Institute of Energy of Vietnam, 2006



Policy Options

* Improve end use energy efficiency
* Develop renewable energy sources
* Develop nuclear power (2020→)
* Import electricity (Laos, Cambodia, China, 2010→)
* Import coal (Australia, Indonesia, 2015→)
* Import natural gas (ASEAN pipeline, 2016→)

2. The IRP model

Name: Integrated Resource Planning

Structure: Bottom-up technical cost minimization, MILP solved by CPLEX

Institution: Energy Program, Asian Institute of Technology, Thailand

Output: Electricity generation capacity expansion plan, i.e. optimal selection of fuels and technologies

Economic potentials of CO_2 emissions reduction

Internalizing carbon value

Minimize $$TC = SC + CV * \left\{ \sum_{t=1}^{T} (E_t - E_t^{REF}) / (1 + r)^t \right\}$$

where: TC = present value of total generation expansion planning cost

SC = present value of total system costs
= {Capital + O&M + Fuels + DSM + Import}

CV = carbon value (assumed constant in time)

E_t^{REF} = baseline CO_2 emission in year t (optimum with CV=0)
E_t = CO_2 emitted in year t in the case

r = discount rate, T = planning horizon.

Model: constraints

- Technical:
    - Peak demand (2 seasons, 24 demand block/day)
    - Plant availability, reliability
    - Maximum and minimum operation capacity
    - Generating unit availability
- Resources:
    - Hydro-energy
    - Fossil fuels and resources
    - Import availability

Model parameters

•**Plant types:** 15 alternative generation technologies, includes 7 renewables

•**12 fuel prices, growing 1-4% per year**

•**5 DSM options in residential & service sectors:**
+ replace incandescent (IL) by compact fluorescent (CFL)
+ replace fluorescent lamps (FL) by efficient FL

•**Nuclear**: <10 GW (over 2020-2030)

•**Renewable potentials:**
- Small and mini hydro: 4 GW
- Geothermal: 0.4 GW; Biomass: 1.54 GW; Solar: 1 GW
- Wind: 22 GW (limited to 20% of total system capacity)

Scenarios

- **Baseline:** ≈ official plan
  Few renewables, imports of coal, gas & electricity.

- **DSM only:** Replace lamps in households and services.

- **DSM + Nuclear**: 10 GW

- **DSM + Renewables**: 22 GW wind capacity +others

Nuclear or wind assumed to replace 7.5GW imported gas.
Carbon value range from 1 to 30$/tCO2.

3. Results: A fossil baseline

Power sector will rely primarily on fossil fuels:

- Coal is expected to dominate the energy mix (41.3%)
- Gas (32%), Oil (0.3%)
- Import (3.7%)
- Hydro (16.3%) and renewables (only 4%)

Large quantities of CO_2 will be emitted:

- 3.6 Gt CO_2 cumulative 2010-2030
- 2.4 Mt SO_2 and 5.5 Mt NO_X

Demand side management (DSM)
Potential free lunch

More efficient lamps ⇒ significant emissions reductions:

- CO_2 by 14% (over 3.6 Gt)

- SO_2, and NO_X by 5.6% and 5.5%.

⇒due to lower coal-fired capacity: 77 < 82 GW by 2030

The abatement cost is negative

CO2 values that support renewables

1. Wood residue and plantation: 1US/tCO_2$ 2US/tCO_2$

Potentially offer CDM-funded project opportunities.

2. Wind:

2US/tCO_2$ → 5 US cent/kWh sites (small potential)

3US/tCO_2$ → 5.5 US cent/kWh sites

4US/tCO_2$ → 6 US cent/kWh sites

5US/tCO_2$ → 6.5 US cent/kWh sites

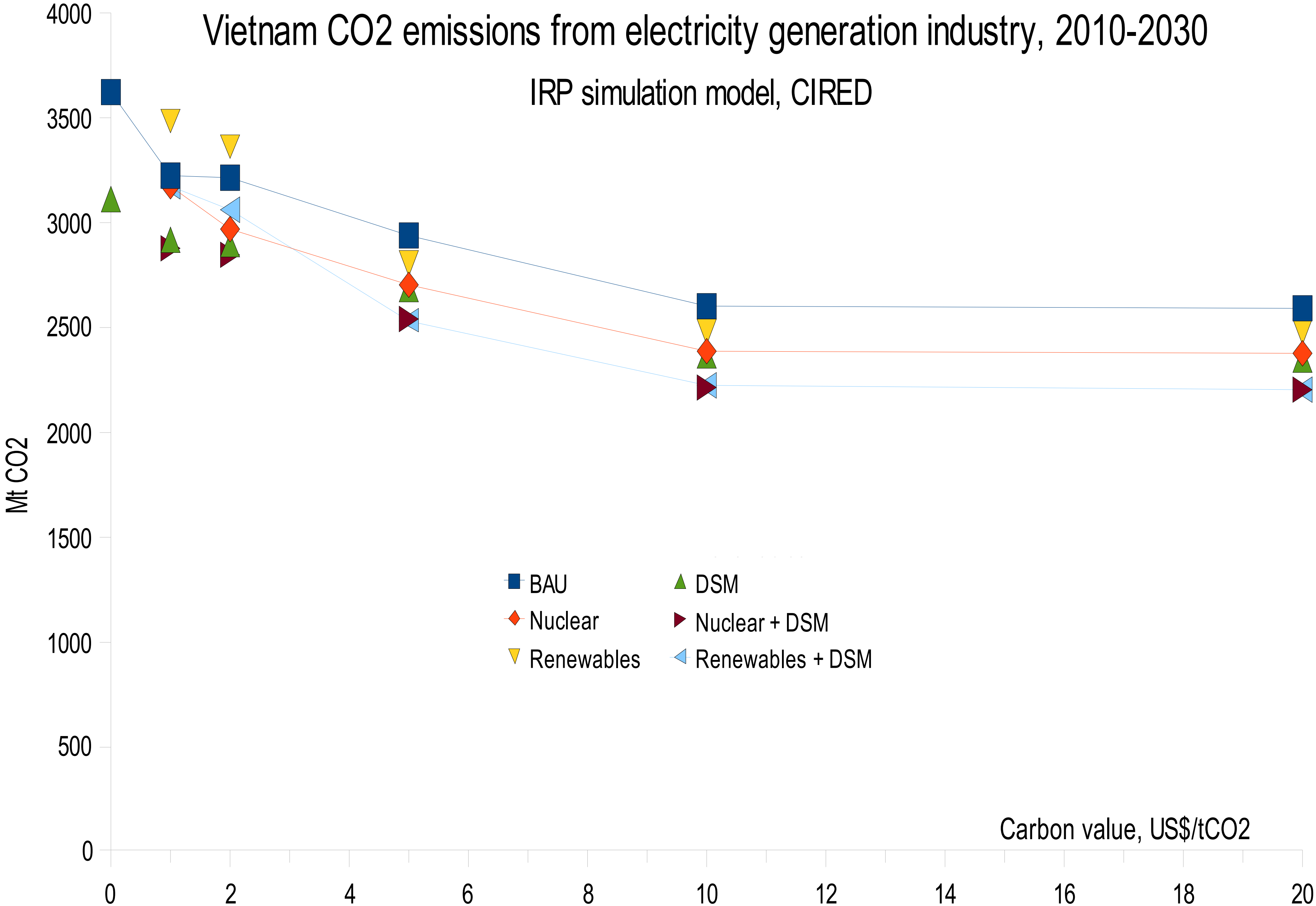
Wind generation in Vietnam has a large potential

3. Solar: not cost-effective in the model

Need strong climate policy, technological innovation, or local conditions.

Nuclear: also a significant potential of CO_2 emission mitigation

Cases	Emissions	Carbon value (US$/tonCO2)					
		0	1	2	5	10	20
TRP-Baseline	Total cumulative CO2 (Mton)	3621.3	3221.3	3209.8	2931.7	2599.1	2586.0
	CO2 reduced (Mton)	-	400.0	411.5	689.7	1022.3	1035.4
	CO2 reduced (%)	-	**11.0**	11.4	19.0	28.2	28.6
TRP-Nuclear	Total cumulative CO2 (Mton)	-	3173.9	2963.8	2703.2	2383.4	2375.8
	CO2 reduced (Mton)	-	447.4	657.6	918.2	1237.9	1245.5
	CO2 reduced (%)	-	**12.4**	18.2	25.4	34.2	34.4
TRP-Renewable	Total cumulative CO2 (Mton)	-	3482.5	3360.6	2804.0	2478.3	2474.2
	CO2 reduced (Mton)	-	138.8	260.8	817.3	1143.0	1147.2
	CO2 reduced (%)	-	**3.8**	7.2	22.6	31.6	31.7


Vietnam CO2 emissions from electricity generation industry, 2010-2030
IRP simulation model, CIRED
Mt CO2
4000
3500
3000
2500
2000
1500
1000
500
0
0
2
4
6
8
10
12
14
16
18
20
Carbon value, US$/tCO2
BAU
Nuclear
Renewables
DSM
Nuclear + DSM
Renewables + DSM

Climate policy scenarios

Wind accounts for 23%-91% CO_2 mitigation in renewables scenarios. Installing 33 GW of wind capacity with a $10 carbon value lead to 36% reduction.

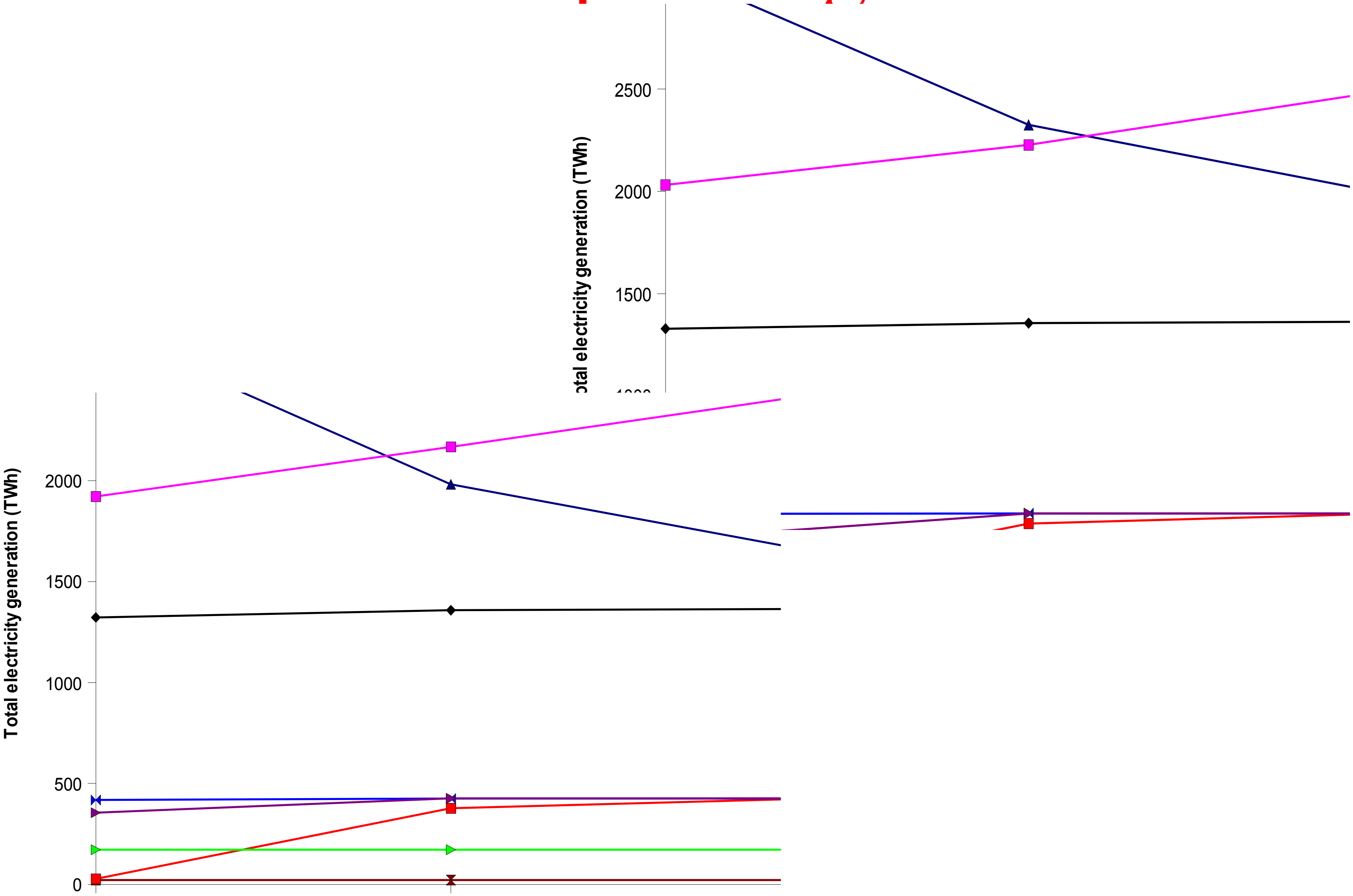
Combine energy efficiency, renewables and $10 carbon value for - 45% below baseline, without nuclear.

4. Summary and conclusions

Baseline: 3.6 Gt CO2 emitted between 2010 and 2030.

DSM (efficient lightning)	- 0.5 Gt CO_2	14%
+ 5 \$/tCO_2	- 0.9 Gt CO_2	30%
+ Nuclear or Wind	- 1.1 Gt CO_2	35%

Towards cleaner optimal generation mix



Optimal plans switch to additional clean generation capacity (GW)

	Carbon value	Wind			Other renewables			Hydro		
		2015	2020	2030	2015	2020	2030	2015	2020	2030
TRP-Baseline	1	0	0	0	0	0	0	2	2	2
	5	0	0	0	0	0	0	2	2	2
	10	0	0	0	0	0	0	2	2	3
	20	0	0	0	0	0	0	2	2	3
TRP-Nuclear development	1	0	0	0	0	0	0	2.29	2.29	2.27
	5	0	0	0	0	0	0	2.29	2.42	2.41
	10	0	0	0	0	0	0	2.37	2.42	2.41
	20	0	0	0	0	0	0	2.37	2.42	2.41
TRP-Renewable development	1	0.05	0	0	0.24	0.61	2.76	2.29	2.34	2.27
	5	1.02	5.65	18.3	0.24	0.61	2.76	2.29	2.42	2.41
	10	1.22	5.65	21.5	0.24	0.61	2.76	2.37	2.42	2.41
	20	1.22	5.65	21.5	0.24	0.61	2.76	2.37	2.42	2.41

Wind power potential & modeling wind turbines

Production cost (US cent/kWh)	Potential (GW)	Energy production (TWh/yr)	Average hours of full power (h/yr)
5	0.294	963	3280
5.5	1.225	3727	3043
6	3.572	10110	2830
6.5	13.46	34904	2593
7	23.659	58608	2477
8	51.689	117320	2270

Technology	Peak	Capacity factor	Upper bound by 2030 (GW)
Wind turbine 1	0.3	0.32	0.9
Wind turbine 2	0.3	0.28	5.2
Wind turbine 3	0.23	0.28	15.9
Wind turbine 4	0.23	0.28	8.1

Determination of upper bound of feasible wind capacity development

Reliability constraint:

$$\sum_{k=1}^{K}\sum_{v=-V}^{t} XE_{kv} * (1 - LS_{kpst}) + \sum_{j=1}^{J}\sum_{v=1}^{t} Y_{jv} * XC_{jv} * (1 - LS_{jpst})$$

$$+\sum_{i=1}^{I}\sum_{r=1}^{R}\left[\left(\sum_{t=1}^{t} Z_{irp} - \sum_{t=1}^{t-1} Z_{irp}\right) * (1 + rm) * P_{irps} * E_{irpst}\right] + \sum_{l=1}^{L} I_{lpst} * (1 - LI_{ltsp}) \ge Q_{pst} * (1 + rm)$$

Σsystem capacity installed (about 100GW)≥ peak demand + reserve capacity

System reserve capacity: 30%-20% of peak demand = 17-25GW

If 20% penetration + 10% additional reserve (22 GW) ⇒wind peak=5.5 GW

If 30% penetration + 10% additional reserve (33 GW) ⇒wind peak= 7.4 GW

In most risky case (no wind), maximum loss of wind peak capacity: 7.4 GW

The minimum remaining reserve capacity : 17-7.4=9.6 GW > 7.4 GW

Characteristics of efficient electricity end use technologies

Sector	Existing energy using equipment to be replaced: Ratings (Watt)	Cost (US$)	Life	Efficiency energy using equipment: Type of appliance	Ratings (Watt)	Cost (US$)	Life (hrs)
Residential & Commercial							
DSM1	40	0.5	1500	CFL	9	6.75	10000
DSM2	60	0.55	1200	CFL	13	6.75	12000
DSM3	75	0.55	800	CFL	18	7.65	12000
DSM4	100	0.6	800	CFL	27	8.10	10000
DSM5	40	1.5	8000	FEF	36	2.26	12000

<u>Note</u>:
CLF : Compact Fluorescent Lamp
EFL : Efficient Fluorescent Lamp