Estimation of CO_2 Emission Reduction Potential in Major Countries in 2020 and 2030

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Objectives

Å To estimate CO_2 emission reduction potential in 2020 and 2030 with simplified methodologies

ï for 5 major energy sectors (industry, power, transportation and domestic & commercial sectors)

ï in 9 major countries (US, EU27, China, Japan, India, Indonesia, South Africa, Brazil and Russia)

ï assuming that advanced technologies will be spread out in the major countries by 2030

Å To show the possible impacts of diffusion of the advanced technologies in the major countries under a new framework in which major countries have their nationally determined commitments

Background

Å Under the future climate regime, nationally determined commitment of each individual country can be a key element

Å ñTechnologyò plays absolutely an essential role under the regime

Å Japan will contribute to address climate change with advanced ñstate-of-the-artò technologies

Å The likely scenario under the future climate regime is:

 ï Each individual country makes an effort to increase the use of the advanced technologies as much as possible under the nationally determined commitments

Methodology

Å Simplified methodology, rather than complicated model

Å Why simplified?...

ï Easy to be understood/re-caluculated/traced compared/modified by anyone without specialised knowledge

ï Lesser requirement for detailed/expensive data set (which is often unavailable for developing countries)

ï Allowing many countries to estimate their CO_2 emission reductions potential as a common ground of understanding

Data

Å Employ the data such that:

  ï Reliable (e.g. authorised by government/ governmental agency and published by established research instituteé)

  ï Publically available in the world (e.g. UN, IEA, IMF, OECD dataé)

Å Use uniformed predicted values for macro economic indicators such as GDP and population in 2020/2030 across the all sectors to ensure consistency

Sectors

- Industrial sector
  - Iron & Steel
  - Cement
- Transportation sector
  - Passenger vehicle
- Power sector
  - Thermal power plants (coal and gas)
- Domestic & commercial sector
  - Electric appliances
    - Refrigerator
    - Air conditioner
    - Lighting

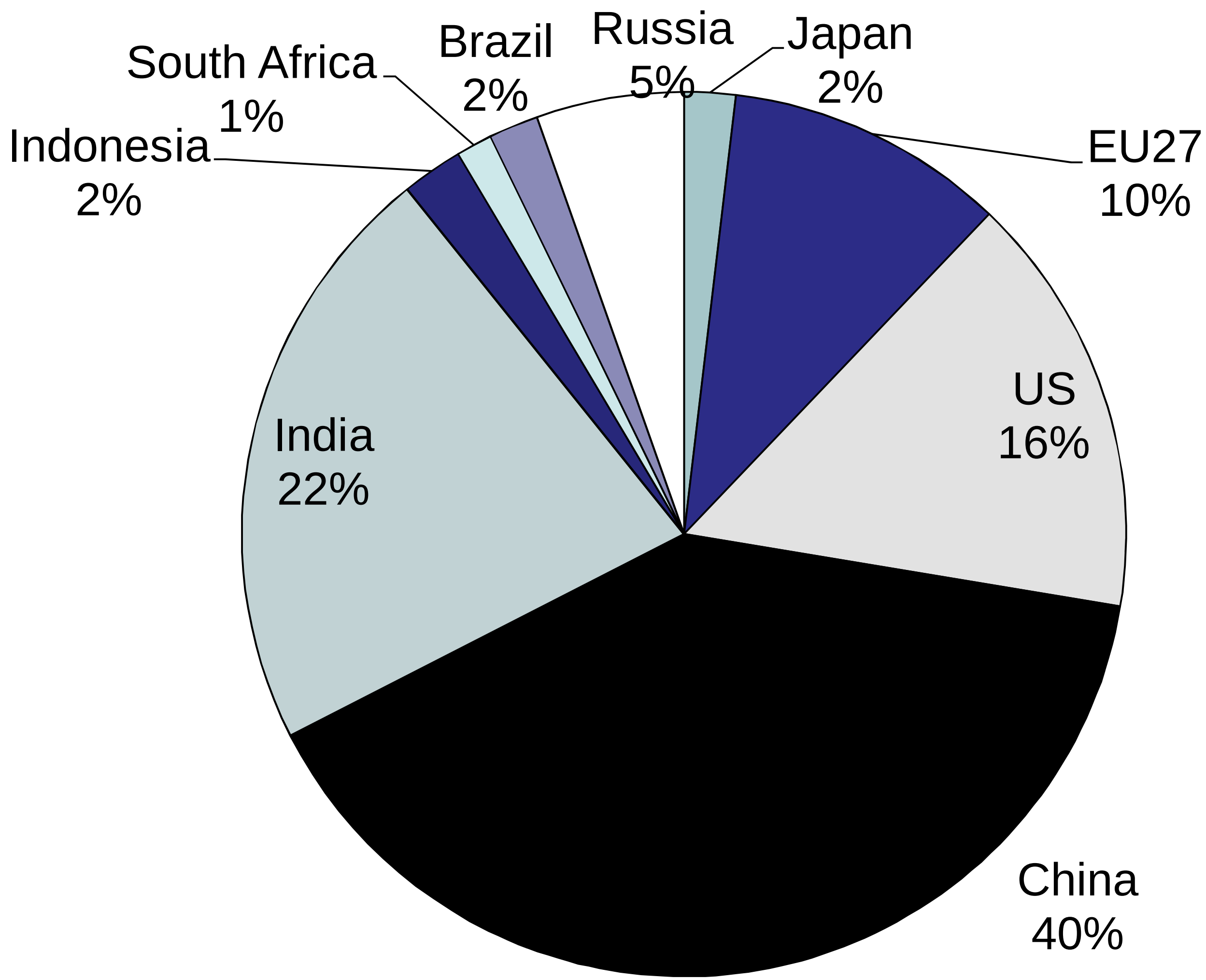
Estimated CO_2 emission reduction potential in 2020 and 2030: Summary Table

IEE JAPAN

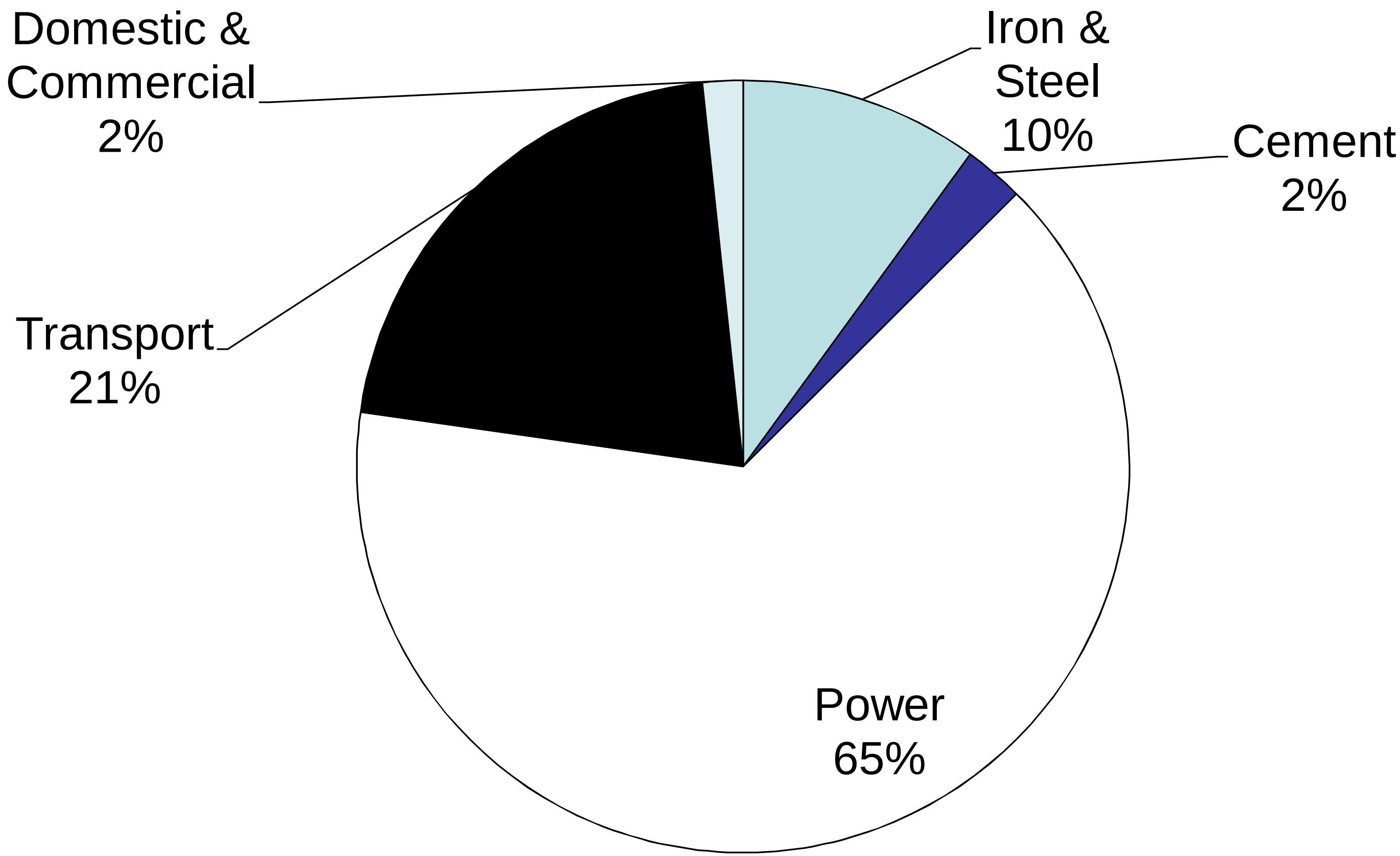
($Mt\text{-}CO_2$ p.a.)

		Japan	EU27	US	China	India	Indonesia	South Africa	Brazil	Russia	Total
Iron & Steel	2020	8.6	17.3	8.7	388.1	94.3	NA	4.5	7.1	18.2	**546.8**
	2030	8.4	20.4	10.2	407.6	134.9	NA	6.5	9.1	22.0	**619.1**
Cement	2020	1.9	9.3	7.9	123.4	13.6	NA	NA	1.7	3.5	**161.3**
	2030	1.9	9.4	9.4	108.4	20.4	NA	NA	2.1	3.9	**155.5**
Power	2020	27.8	190.9	262.4	638.4	483.9	61.9	45.3	17.0	114.7	**1,842.3**
	2030	56.7	185.7	427.4	1,739.6	1,156.4	121.8	60.7	24.8	232.3	**4,005.4**
Transport	2020	46.4	399.1	446.8	97.2	8.4	7.3	8.5	53.1	64.2	**1,131.0**
	2030	45.4	410.1	489.9	173.6	12	9.9	12.2	75.5	74.4	**1,303.0**
Domestic	2020	2.5	6.2	16.1	17.0	8.4	2.6	1.2	0.4	1.1	**55.7**
	2030	3.5	8.5	22.2	37.1	21.6	6.7	2.2	0.9	1.5	**104.1**
Total	**2020**	**87.2**	**622.8**	**741.9**	**1264.1**	**608.6**	**71.8**	**59.5**	**79.3**	**201.7**	**3,737.1**
	2030	**115.9**	**634.1**	**959.1**	**2466.3**	**1345.3**	**138.4**	**81.6**	**112.4**	**334.1**	**6,187.1**

Estimated CO_2 emission reduction in 2030 by country

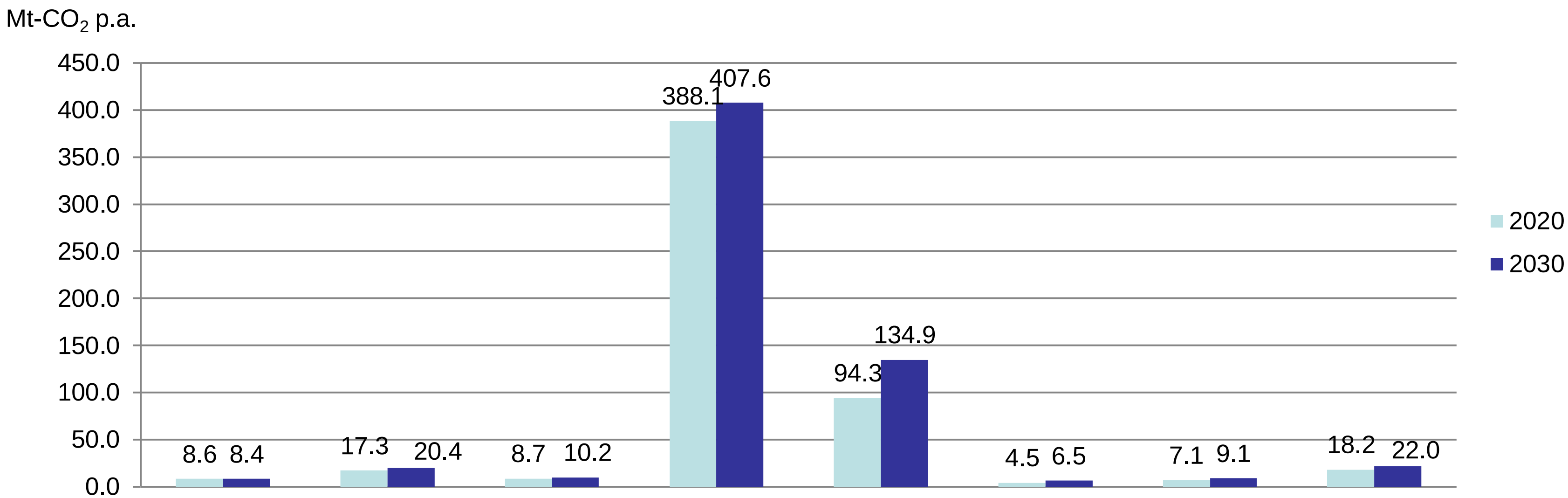


Estimated CO_2 emission reduction in 2030 by sector



Estimated CO_2 emission reduction potential in 2020 and 2030: Iron & steel sector

Å The estimated CO_2 emission reduction in this sector in 2030 is equivalent to around 40% of the 2010 emissions level



	Japan	EU27	US	China	India	South Africa	Brazil	Russia
CO_2 emissions in 2010 (Mt-CO_2)	**80.5**	**98.4**	**49.3**	**968.4**	**115.0**	**19.6**	**27.8**	**138.0**
CO_2 emission reduction potential based on the 2010 BAT(t-CO_2/t steel)	**0.080**	**0.100**	**0.121**	**0.639**	**0.777**	**0.321**	**0.180**	**0.234**
Predicted annual of steel production in 2030 (Mt)	**100.2**	**266.0**	**109.0**	**699.0**	**278.0**	**33.0**	**73.0**	**126.0**

Iron & steel sector: Methodology and data

Å ñCO_2 emission reduction potential in 2030ò=

ñCO_2 reduction potential per unit of production with the 2010 BAT (t-CO2/t steel)òx

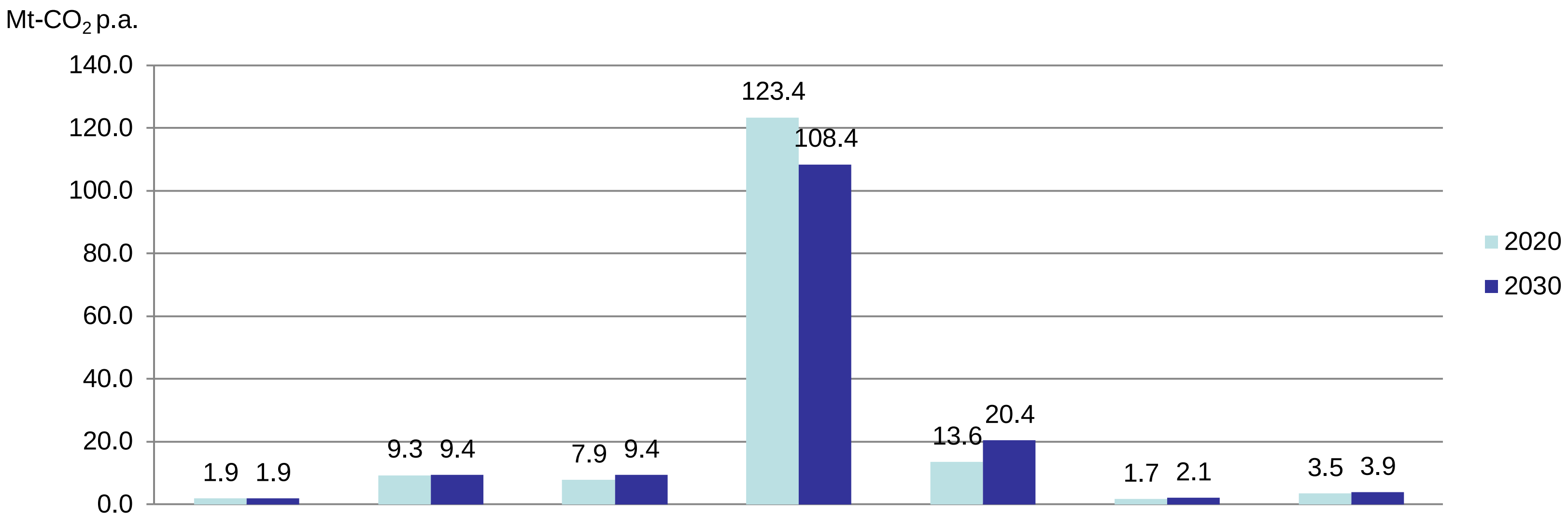
ñPredicted amount of annual steel productions in 2030ò

Å ñCO_2 reduction potential per unit of production with the 2010 (t-CO_2/t steel)òis based on ñEnergy savings potentialñ(GJ/t steel) in ñIEA-ETP 2012ò(IEA 2012)

Å ñPredicted amounts of annual steel productions in 2020 and 2030ò are taken on production growth rates for low demand scenario in ñIEA-ETP2012ò(IEA, *ibid*.)

Estimated CO_2 emission reduction potential in 2020 and 2030: Cement sector

Å The estimated CO_2 emission reduction in this sector in 2030 is equivalent to around 20% of the 2010 emissions level



	Japan	EU27	US	China	India	Brazil	Russia
CO_2 emissions in 2010 (Mt-CO_2)	**21.1**	**93.1**	**63.6**	**498.1**	**42.8**	**18.5**	**32.1**
CO_2 emission reduction potential based on the 2010 BAT(t-CO_2/t cement)	**0.039**	**0.042**	**0.096**	**0.086**	**0.028**	**0.027**	**0.072**
Predicted annual of cement production in 2030 (Mt)	**45.1**	**230.0**	**130.0**	**914.0**	**1,236.0**	**100.0**	**63.0**

Cement sector: Methodology and data

Å ñCO_2 emissions reduction potential in 2030ò=

ñCO_2 reduction potential per unit of production with the 2010 BAT (t-CO2/t cement)ò x

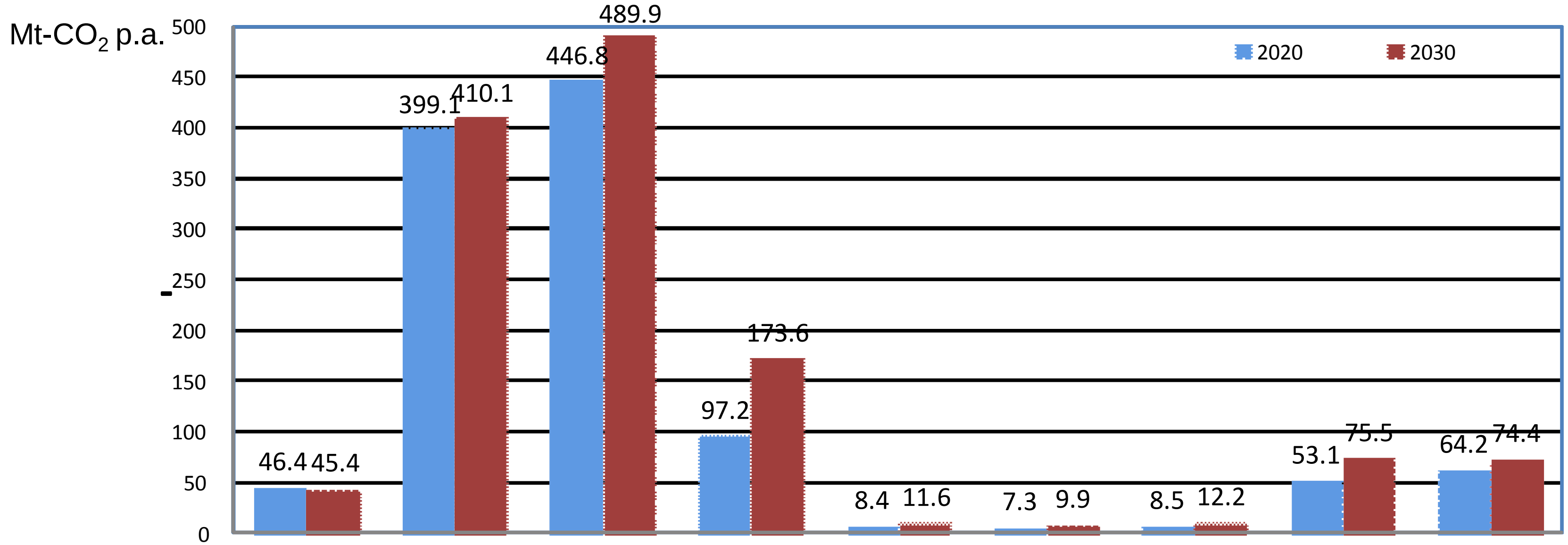
ñPredicted amount of annual cement productions in 2030ò

Å ñCO_2 reduction potential per unit of production with the 2010 BAT (t-CO_2/ t cement)òis based on ñEnergy savings potentialñ(GJ/t cement) in ñIEA-ETP 2012ò(IEA 2012)

Å ñPredicted amounts of annual cement productions in 2020 and 2030òare taken on production growth rates for high demand scenario in ñIEA-ETP2012ò(IEA, *ibid*.)

Estimated CO_2 emission reduction potential in 2020 and 2030: Transportation sector

Å The estimated CO2 emission reductions in this sector in 2020 and 2030 are equivalent to around 35% and 40% of the 2010 emissions level respectively



	Japan	EU27	US	China	India	Indonesia	S. Africa	Brazil	Russia
Predicted number of passenger vehicles in 2030 (Mill.)	60.2	359.3	180.7	161.4	24.7	10.3	11.3	64.0	47.1
Predicted distance travelled in 2030 (km)	8,938	12,500	17,600	10,000	8,000	10,000	10,000	12,000	13,000
Predicted fuel efficiency in 2030（liter/100km）	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
Fuel efficiency in 2010 (liter/100km）	6.7	7.0	9.7	7.7	5.6	7.2	7.7	7.3	8.3
CO_2 Emissions from passenger vehicles in 2010 (Mt-CO_2)	201	848	1,401	395	145	93	36	148	140

Transportation sector: Methodology and data

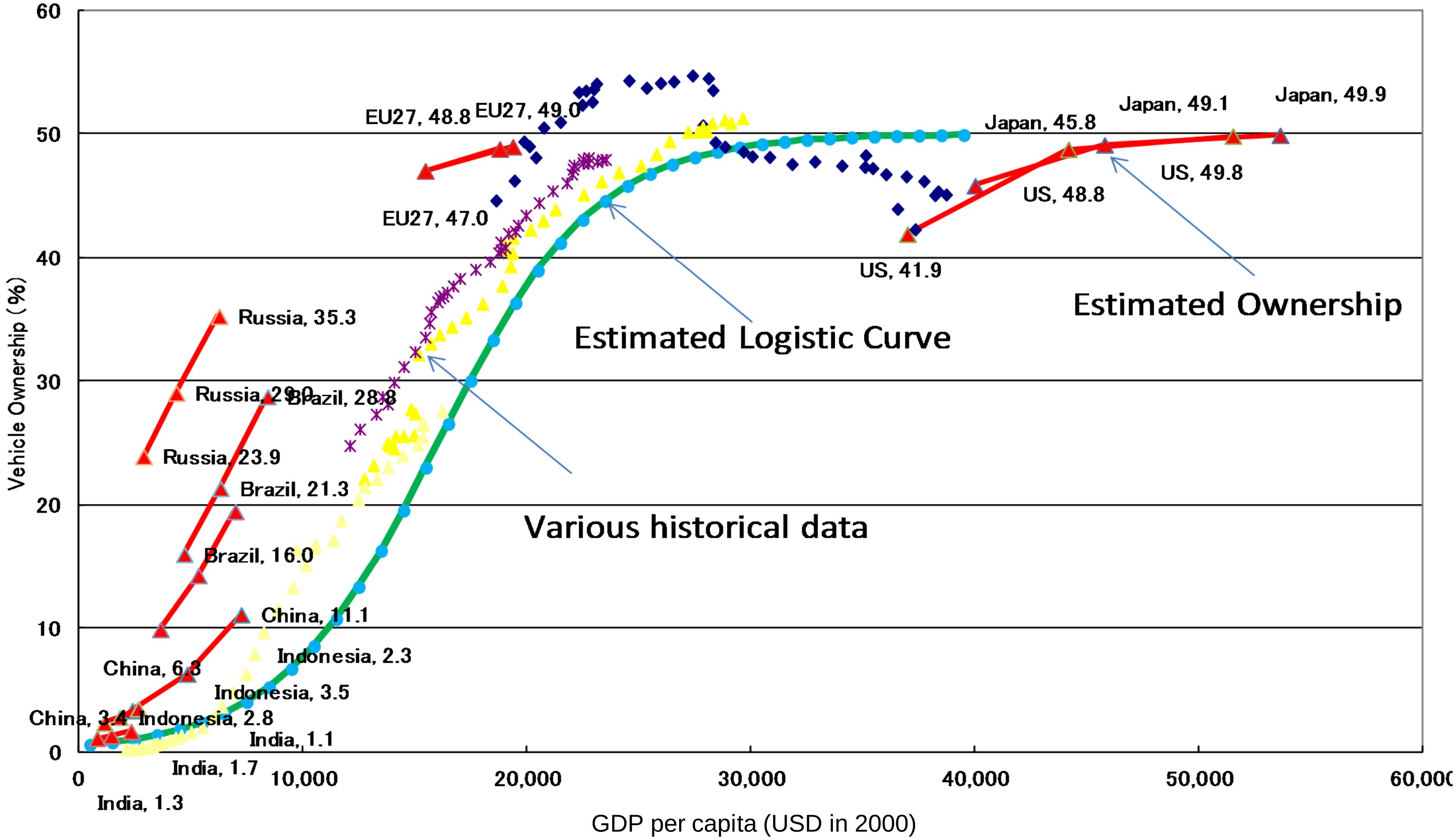
Å ñCO_2 emissions reduction potential in 2030ò=
{(ñPredicted number of passenger vehicles in 2030ò x
ñPredicted distance travelled in 2030ò) x
(ñPredicted fuel efficiency in 2030ò ï ñFuel efficiency in
2010ò)} x ñEmission factor for petrolò

Å ñFuel efficiency in 2010ò is assumed as BAU taken from GFEIôs theoretical fuel efficiency for new passenger vehicles in 2005

Å ñPredicted fuel efficiency in 2030ò is equivalent to that of hybrid car (e.g. Toyota Prius 1.8) in 2010

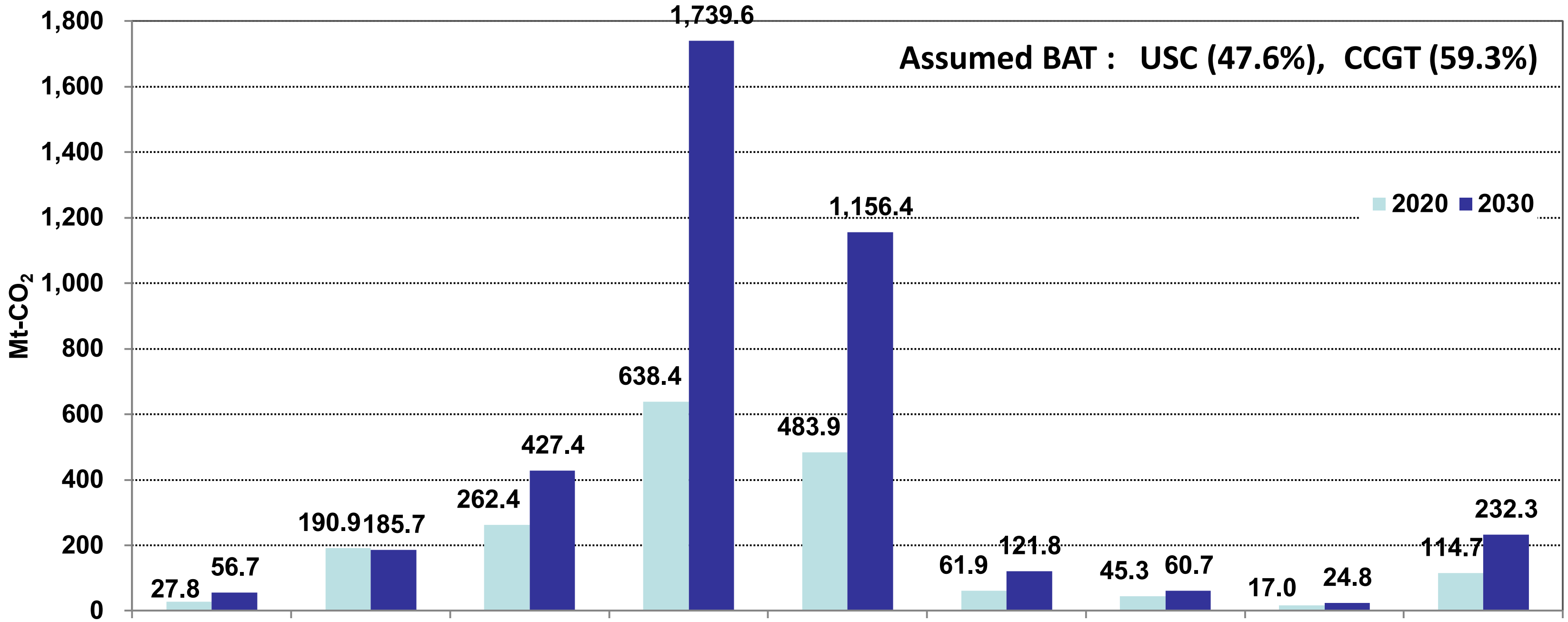
Å ñPredicted distance travelled in 2030ò is based on IEAôs Sustainable Mobility Project (SMP) Model

Predicted number of passenger vehicles in 2020 and 2030: Logistic function



Estimated CO_2 emission reduction potential in 2020 and 2030: Power sector

Å The largest CO_2 emission reduction of 4 billion t-CO_2 p.a. in 2030 is estimated in this sector



	Japan	EU27	US	China	India	Indonesia	South Africa	Brazil	Russia
Predicted generation in 2030 Coal (TWh) Gas (TWh)	322 411	764 422	2,146 1,177	6,837 552	1,916 349	330.7 66.8	284.05 4.37	31 183	270 758
CO_2 Emissions in 2010 (Mt-CO_2)	394.6	1,193.0	2,244.0	3,463.9	774.3	91.5	228.5	26.1	493.2
Power gen efficiency (Ave.) Coal 2010 / 2030 Gas 2010 / 2030	41.3 / 45.5 48.3 / 59.3	37.1 / 47.6 48.3 / 58.5	37.0 / 44.6 47.5 / 58.2	35.2 / 47.0 38.9 / 53.4	26.2 / 47.6 44.2 / 58.0	31.9 / 46.7 39.4 / 55.1	34.2 / 43.6 - / 59.3	30.0 / 45.2 48.7 / 58.6	31.7 / 41.7 34.0 / 53.2

Power sector: Methodology and data

Å ñCO_2 emissions reduction potential in 2030ò=

{(Input $_{2010}$ / Power$_{2010}$ x Power$_{2030}$) ï

[Input$_{2010}$ /(Power$_{2010}$(1-R) + Input$_{2010}$ x BAT x R)

x Power$_{2030}$]}

x EF

where:

Input$_{2010}$ = Gas/coal used for electricity generation in 2010

Power$_{2010}$ = Electricity generated by gas/coal in 2010

Power$_{2030}$ = Predicted value for power generated by gas/coal in 2030

R = Replacement rate of existing capacity by BAT (CCGT/USC) in 2030
(Assuming 0.333 for 2020, 0.666 for 2030 with ñ30 years lifetimeò)

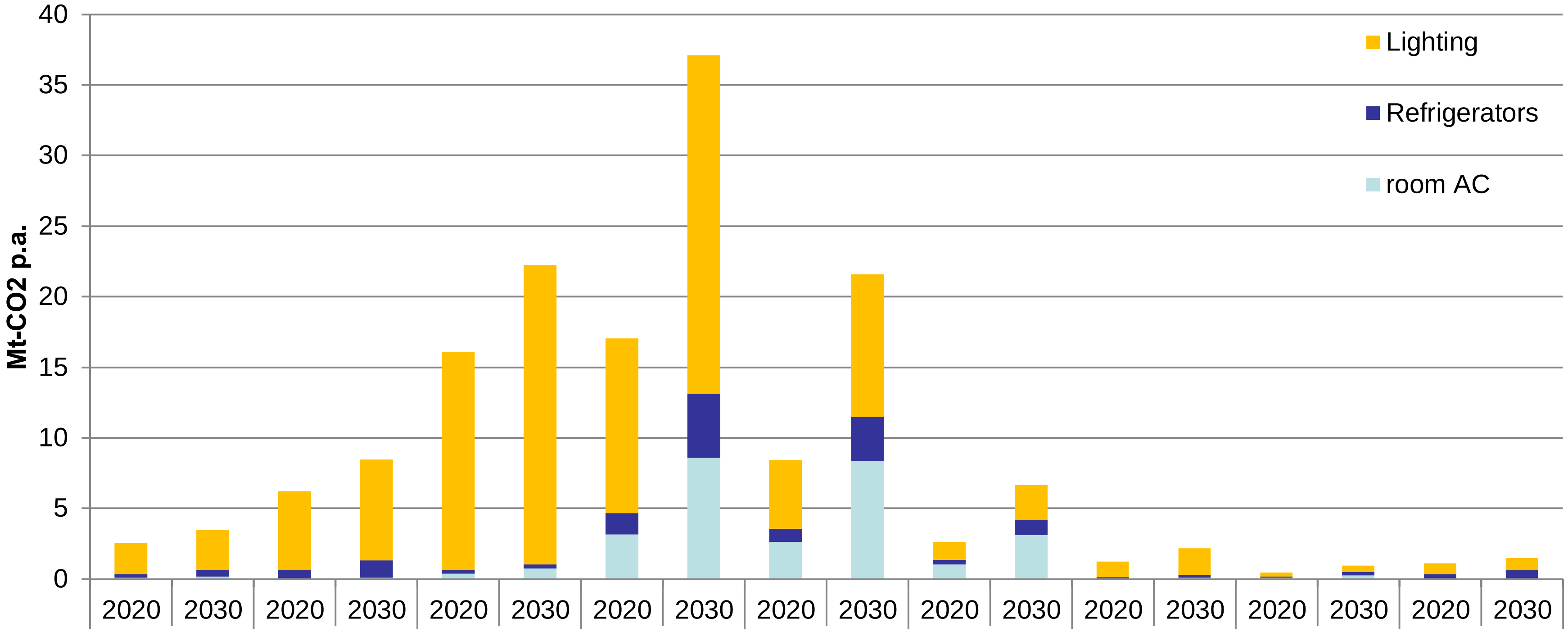
BAT = 0.593 for gas (CCGT) or 0.476 for coal (USC)

EF = Emission factor for gas/coal

Estimated CO_2 emission reduction potential in 2020 and 2030: Domestic and commercial sectors

Å Enormous reduction potentials are estimated in lighting over the world

Å Room AC and fridge have also large potential in developing countries



	Japan	EU27	US	China	India	Indonesia	South Africa	Brazil	Russia
Room AC 2020/2030	**0.1/0.2**	**0.1/0.1**	**0.4/0.7**	**3.1/8.6**	**2.6/8.4**	**1.0/3.1**	**0.0/0.1**	**0.1/0.2**	**0.0/0.1**
Refrigerators 2020/2030	**0.2/0.5**	**0.6/1.2**	**0.3/0.3**	**1.5/4.6**	**0.9/3.1**	**0.3/1.0**	**0.1/0.2**	**0.1/0.3**	**0.3/0.3**
Lighting 2020/2030	**2.2/2.8**	**5.6/7.2**	**15.4/21.2**	**12.4/24.0**	**4.9/10.1**	**1.3/2.5**	**1.1/1.9**	**0.3/0.4**	**0.8/0.8**

($Mt\text{-}CO_2$ p.a.)

Domestic and commercial sector: Methodology and data

Å ñCO_2 emissions reduction potential in 2030ò=

ñPredicted demand for Room AC/refrigerator/lighting in 2030òx

ñ(Efficiency level in 2010 ï Efficiency level in 2030)òx

ñGrid emission factorò

Å ñPredicted demand for AC/refrigerator/lighting in 2030òis estimated based on the predicted GDP growth rates taken from WEO2012

Å ñEfficiency level in 2030òfor AC/refrigerator/lighting is estimated based on LBNL (2012)

Å BAU for lighting: CFL diffusion rates are assumed to be 75% in 2020 and 100% in 2030

Conclusions

Å Substantial amounts of CO_2 emission reduction potential in 2020 and 2030 are estimated (around 3,700 Mill.t-CO_2 p.a. in 2020 and 6,000 Mill.t-CO_2 p.a. in 2030)

Å The largest reduction potential is seen in the power sector being accounted for 65% of the total reduction in 2030 followed by the transportation sector of 22% of the total

Å The methodology and the data employed in this study can be further improved via international cooperation

Issues for further consideration

- Adequacy of BAU assumptions
  - Technological level at 2010 remains constant up to 2030?
- Adequacy of BAT assumptions
  - The 2010 BAT can be spread over in 2020/2030?
  - No progress made for BAT after 2020?
  - 1/3 of the existing power plants are replaced by BAT within 10 years due to ñ30 years lifetimeò?
- Expansion of covered sectors and countries
- Policies and measures as well as financial arrangement to realise the potential of the emission reduction

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Annex:
Detailed information on the estimation and data used for each sector

Iron & steel sector

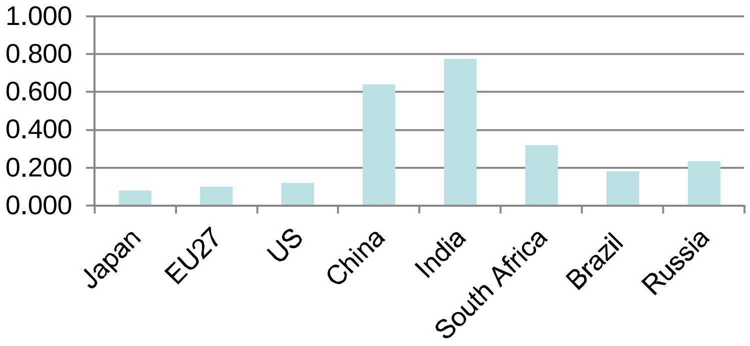
Data source:

1. Energy Saving Potential for production	t-CO2	International Energy Agency, Energy Technology Perspectives 2012
2. Production (Actual and Outlook)	t-steel	EU27, US, China, India, South Africa, Brazil, Russia: IEA-ETP2012 Low demand scenario is used for actual and outlook production.
		Japan: 2010 Actual : World Steel "Steel statistical yearbookñ 2011-2030: The steel production growth rate for OECD Asia Oceania of IEA-ETP2012 is multiplied by actual production data of 2010.
	t-cement	EU27, US, China, India, South Africa, Brazil, Russia: IEA-ETP2012 Low demand scenario is used for actual and outlook production
		Japan: 2010 Actual : USGS "Minerals Information" 2011-2030: The cement production growth rate for OECD Asia Oceania of IEA-ETP2012 is multiplied by actual production data of 2010.

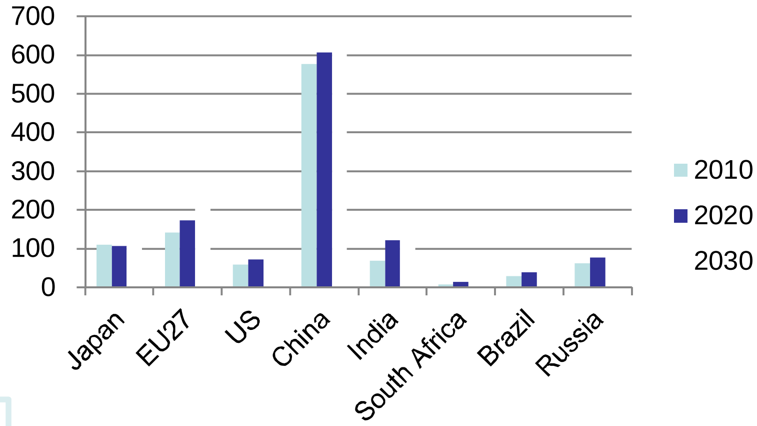
Iron & steel sector

Reduction potential intensity and predicted amount of production

CO2 reduction potential per unit of production with the 2010 BAT
（t-CO2/t-steel）



Predicted Iron and Steel Production
（thousand tons）



Technology and deployment milestones

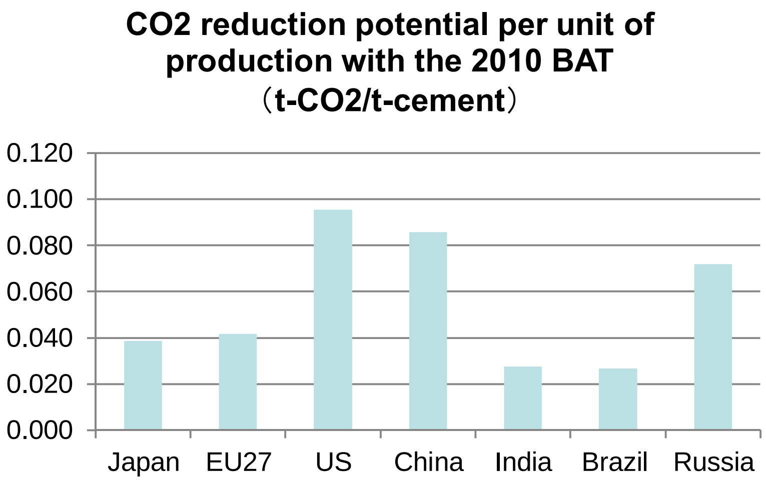
Table 12.2 Main technology options for the iron and steel sector for the 2DS

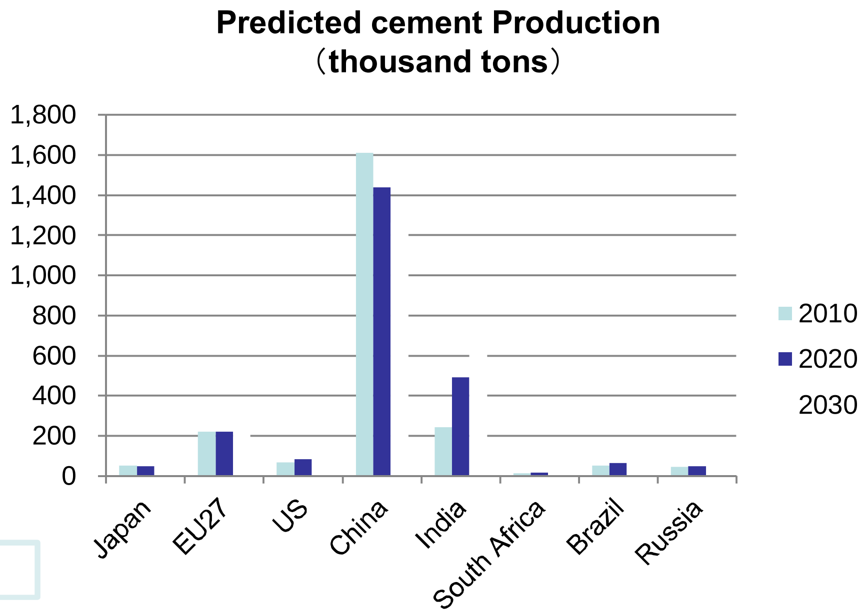
Technology	Research and development needs	Demonstration needs	Deployment milestones
Smelting reduction	Improve heat exchange in FINEX. New configuration of HIsmelt to lower coal consumption. Integrate HIsmelt and Isarna processes (Hisarna). Pair straight hearth furnaces.	Demonstration plants are already operational for FINEX and HIsmelt. Demonstration plant for producing reduced iron oxide pellets is operational by 2015. Demonstration plant with smelter is operational by 2020.	Share of crude steel production from smelting reduction rises to between 128 Mt and 237 Mt in 2050.
Top-gas recycling blast furnace	Trial of existing experimental furnace was successful.	Commercial-scale demonstration of a small blast furnace is operational by 2014. Full-scale demonstration plant is operational by 2016.	Deploys in 2020. Contributes to a 20% decrease in coke needs by 2050.
Use of highly reactive materials	Development of innovative agglomerate to lower reducing agent in blast furnaces.	Demonstration plants already operational for ferro-coke.	Deployment after 2020.
Use of charcoal and waste plastic	Proven technologies are available. Focus research on improving the mechanical stability of charcoal.		Between 1.8 EJ and 3.3 EJ of charcoal and waste plastic is used globally in 2050.
Production of iron by molten oxide electrolysis	Assess technical feasibility and optimum operating parameters.	If the laboratory-scale project is successful, demonstration starts in the next 10 to 15 years.	Deploys after 2030. Reaches marginal market share by 2050.
Hydrogen smelting	Assess technical feasibility and optimum operating parameters.	If the laboratory-scale project is successful, demonstration starts in the next 15 to 20 years.	Deploys after 2040. Reaches marginal market share by 2050.
CCS for blast furnaces	Focus research on reducing the energy used in capture.	Demonstration plant already operational.	Equip 75% to 90% of all new plants built between 2030 and 2050 with CCS. Equip 50% to 80% of refurbished plants between 2030 and 2050 with CCS.
CCS for DRI		2015-20	Equip 75% to 90% of all new plants built between 2030 and 2050 with CCS. Equip 50% to 80% of refurbished plants between 2030 and 2050 with CCS.
CCS for smelting reduction		2020-30	Equip 75% to 90% of all new plants built between 2030 and 2050 with CCS. Equip 50% to 80% of refurbished plants between 2030 and 2050 with CCS.

Notes: FINEX is a smelting reduction process developed by Pohang Iron and Steel Company (POSCO) that consists of a melting furnace with a liquid iron bath, in which coal is injected and iron fines are pre-reduced in a series of fluidised bed reactors.
HIsmelt (high-intensity smelting) is an iron bath reactor process.
Isarna is a smelting-reduction technology under development by the Ultra-Low CO_2 Steelmaking (ULCOS) consortium. It is a highly energy efficient iron-making process based on direct smelting of iron-ore fines, using a smelting cyclone in combination with a coal-based smelter. All process steps are directly hot-coupled, avoiding energy losses from intermediate treatment of materials and process gases.

Cement sector

Reduction potential intensity and predicted amount of production





Technology and deployment milestones

Table 12.5 Main technology options for the cement sector for the 2DS

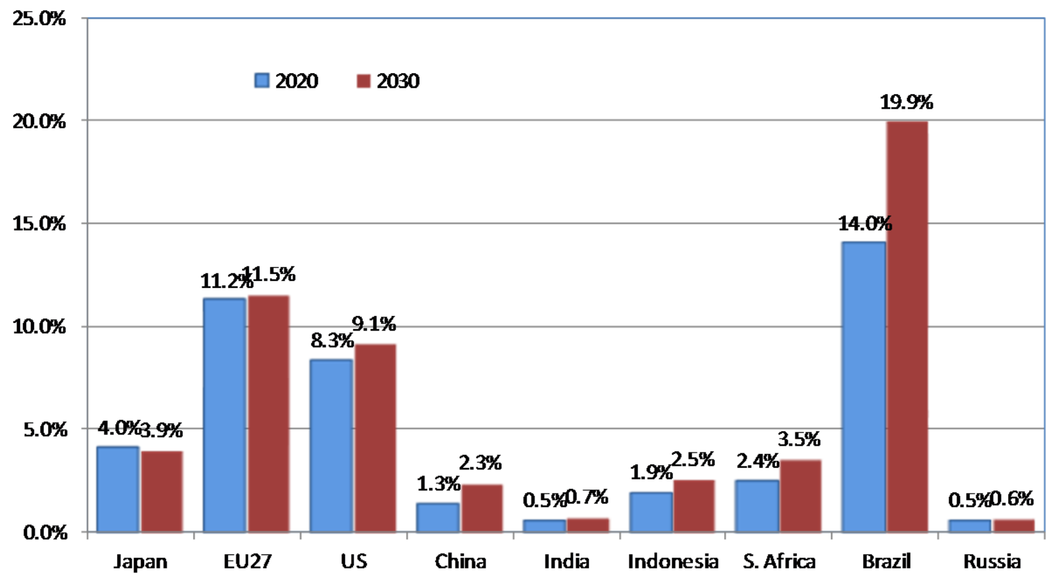
Technology	Research and development needs	Demonstration needs	Deployment milestones
Energy efficiency and shift to BATs	Ongoing further improvements of BAT. Fluidised bed technology.		Phase-out of inefficient wet kilns in small cement plants. International standard for new kilns.
Alternative fuels	Ongoing identification and classification of suitable alternative fuels.		Global shares increase from 4% in 2010 to about 30% in 2050.
Clinker substitutes	Analyse substitution material properties and evaluate regional availability. Develop and implement international standards for blended cements.		Global average clinker-to-cement ratio to reach between 0.66 and 0.67 by 2050.
CCS post-combustion	Pilot plant needed by 2013. Gas cleaning.	2015-20	About 50% to 70% of all new large plants and 30% to 45% of retrofitted plants equipped with CCS by 2050.
CCS oxy-fuelling		2020-30	

Transportation sector

Estimated results

	2010 Fuel Efficiency l/100Km (GFEI)	Mileage km/car (SMP/IEA)	CO2 Coef co2-t/kl	2020 BAT Efficiency l/100Km (Prius1.8)	Vehicle Ownership thousand	CO2 Reduction Mt-CO2	2030 BAT Efficiency l/100Km (Prius1.8)	Vehicle Ownership thousand	CO2 Reduction Mt-CO2
Japan	6.7	8,938	2.32166	3.1	61,603	46.4	3.1	60,197	45.4
EU27	7.0	12,500	2.32166	3.1	349,702	399.1	3.1	359,343	410.1
US	9.7	17,600	2.32166	3.1	164,851	446.8	3.1	180,749	489.9
China	7.7	10,000	2.32166	3.1	90,371	97.2	3.1	161,395	173.6
India	5.6	8,000	2.32166	3.1	17,780	8.4	3.1	24,715	11.6
Indonesia	7.2	10,000	2.32166	3.1	7,572	7.3	3.1	10,278	9.9
S. Africa	7.7	10,000	2.32166	3.1	7,867	8.5	3.1	11,311	12.2
Brazil	7.3	12,000	2.32166	3.1	45,059	53.1	3.1	64,041	75.5
Russia	8.3	13000	2.32166	3.1	40,672	64.2	3.1	47,080	74.4
Total					785,475	1,131		919,111	1,302

Reduction potential against actual 2010 emissions by region

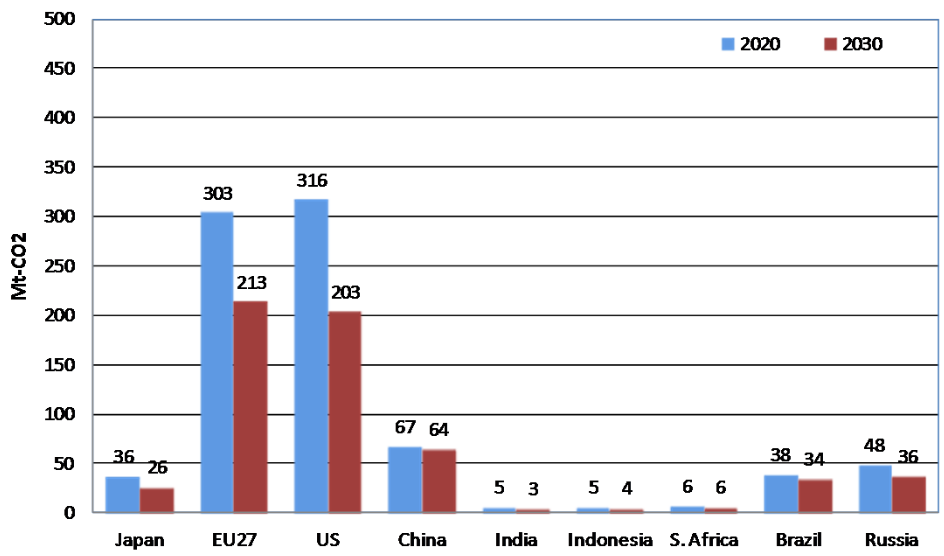


Transportation sector

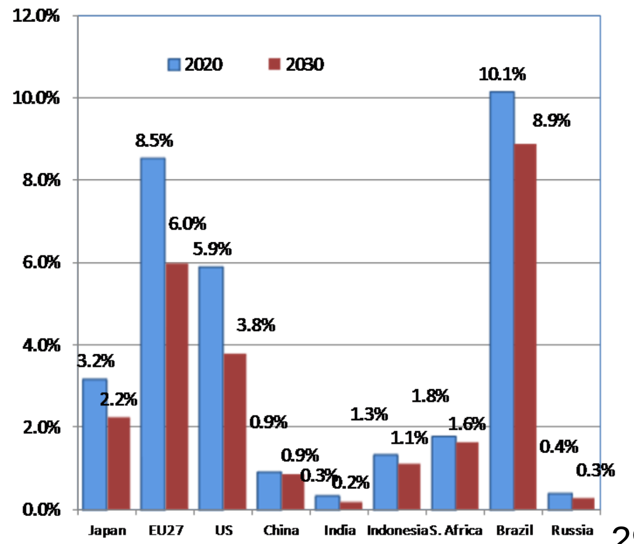
Estimates of BAU based on fuel efficiency Standards

	Have Fuel Economy Standards'	Improvments under Fuel Economy Standards (		Fuel Economy of BAU l/100Km		CO_2 Reduction Potential Mt-CO2		Compared with Fixed BAU Reduction (%)	
		2020	2030	2020	2030	2020	2030	2020	2030
Japan	Yes	12%	24%	5.9	5.1	36	26	78%	57%
EU27	Yes	14%	27%	6.1	5.1	303	213	76%	52%
US	Yes	20%	40%	7.8	5.8	316	203	71%	42%
China	Yes	19%	38%	6.2	4.8	67	64	68%	37%
India	Scheduled	16%	32%	4.7	3.8	5	3	64%	29%
Indonesia	No	16%	32%	6.0	4.9	5	4	72%	44%
S. Africa	Scheduled	16%	32%	6.5	5.2	6	6	73%	47%
Brazil	No	16%	32%	6.1	5.0	38	34	72%	45%
Russia	No	16%	32%	7.0	5.6	48	36	75%	49%

Reduction potential



against actual 2010 emissions by



Power Sector

Details of formula and assumptions	Data	Data sources
1. Power generation efficiency by fuel Power generation efficiency of existing facilities = Electricity generated by gas or coal / Electricity generated by gas or coal with CHP adjustment* *Power generation efficiency lowered in CHP plant due to simultaneous supply of heat	power generated, fuel input, CO_2 emissions CHP adjustment value	ÅIEA Energy Balances、IEA CO_2 Emissions ÅEcofys (2011) International comparison of fossil power efficiency
2. BAT: USC（47.6%）、CCGT（59.3%） * Constant value assumed for efficiency of oil-fired thermal power generation due to limited number of newly built plants	USC efficiency CCGT efficiency	ETP2008
3. Electricity portfolio of each country (installed capacity for each fossil fuel source 2010 (actual value), 2020, 2030) *Based on actual installed capacity in 2010 and 30-year life, one-third of installed capacity and increased capacity assumed to be replaced by BAT every ten years. *Reductions in fuel input by fuel calculated by assuming replacements with BAT. Reduction potential = reduced amount of fuel input by fuel * CO_2 emission coefficient	Installed capacity (actual value, forecasts) CO_2 emission coefficient	WEO2012 Current Policies Scenario, national forecasts, Electric Power Development Plan, etc. IPCC 2006 Guidelines

Domestic and Commercial sector

	Efficiency levels in Air Conditioners (SEER*)			Predicted Demand for Room AC (thousand units)		
	2010	2020	2030	2010	2020	2030
Japan	5.20	6.55	7.90	8,242	8,973	10,656
EU	4.10	6.20	8.30	3,232	3,784	3,976
US	4.60	6.45	8.30	6,419	10,082	13,523
China	4.10	5.70	7.30	30,424	54,948	96,078
India	3.60	5.75	7.90	3,363	8,944	19,523
Indonesia	3.60	5.75	7.90	1,493	3,727	7,655
South Africa	3.60	5.75	7.90	153	194	264
Brazil	2.90	5.85	8.80	3,195	7,628	14,486
Russian	3.60	6.90	10.20	1,381	1,449	1,467

* Seasonal Energy Efficiency Ratio

	Assumptions of Efficiency Improvements in Refrigerators (kWh/year)			Predicted Demand for Refrigerators (thousand units)		
	2010	2020	2030	2010	2020	2030
Japan	520	390	260	4,585	4,461	4,714
EU	280	200	120	18,611	19,964	21,953
US	580	510	440	9,369	7,211	3,800
China	400	300	200	14,364	20,185	29,733
India	470	355	240	5,550	8,874	14,910
Indonesia	470	355	240	2,511	3,941	6,343
South Africa	540	330	120	413	487	604
Brazil	360	240	120	5,356	8,401	12,651
Russian	540	330	120	3,509	3,562	3,571

Assumed efficiency levels in Lighting (Lm/W)	
Incandescent	15
CFL	60
LED	100

Predicted electricity Demand for Lighting (GWh)			
	2010	2020	2030
Japan	37.8	21.6	33.3
EU	104.2	65.7	101.6
US	179.2	120.4	200.2
China	63.5	65.7	154.3
India	19.0	21.7	54.7
Indonesia	7.5	7.3	17.4
South Africa	5.0	4.9	10.0
Brazil	13.4	12.1	24.4
Russian	16.1	8.2	10.9

Source:

Å (Efficiency levels taken from) Letschert et.al, (2012). "Estimate of Cost-Effective Potential for Minimum Efficiency Performance Standards in 13 Major World Economies" LBNL-5724E

Å (Production in 2010 taken from) The Japan Electrical ManufacturersôAssociation (2013), ñSurvey on World Demand for 5 White Goods Items 2005-2011ò

Domestic and Commercial sector

Assumptions

Method of determining BAU

Å Outlook of future demand for refrigerators and AC (BAU)

- Demand outlook estimated based on GDP growth rate.

Å Outlook of future demand for electricity for lighting (BAU)

- Electricity demand for lighting estimated based on assumption of increase in proportion to GDP growth rate.
- Many countries having discontinued manufacture and sales of incandescent light bulbs, diffusion rate of 75% assumed for CFLs in 2020, and 100%, in 2030.

Assumptions of improved efficiency

- Technology: applied assumptions for efficiency improvements in Letschert et al. (2012)

Assumptions for household appliances

- Based on assumptions for 410L refrigerators and 2.8kW Room ACs
- Refrigerators assumed to operate year-round.
- Room ACs assumed to be used only for cooling purposes. Adjusted operating hours calculated by individually assuming cooling degree days for each country, based on operating hours using Japanese APF.
- Canadian figures used for air conditioning efficiency improvements in the US.

Assumptions for demand for electricity for lighting use

- Residential electricity consumption for lighting: electricity consumption for lighting estimated from electricity consumption in the residential sector in each country, based on ratio of electricity used for lighting (13.4%) to total electricity consumption in Japanôs residential sector in 2009.
- The diffusion rate of LED assumed to be 100% in 2050, with a replacement rate of 33% and 55% in 2020 and 2030. respectively.

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