The Development of BET-GLUE model - An integrated Assessment Model and a Land Use Model-

Hiromi Yamamoto and Junichi Tsutsui

Central Research Institute of Electric Power Industry (CRIEPI), Tokyo

December 14, 2016, Tokyo

Outline of the BET model

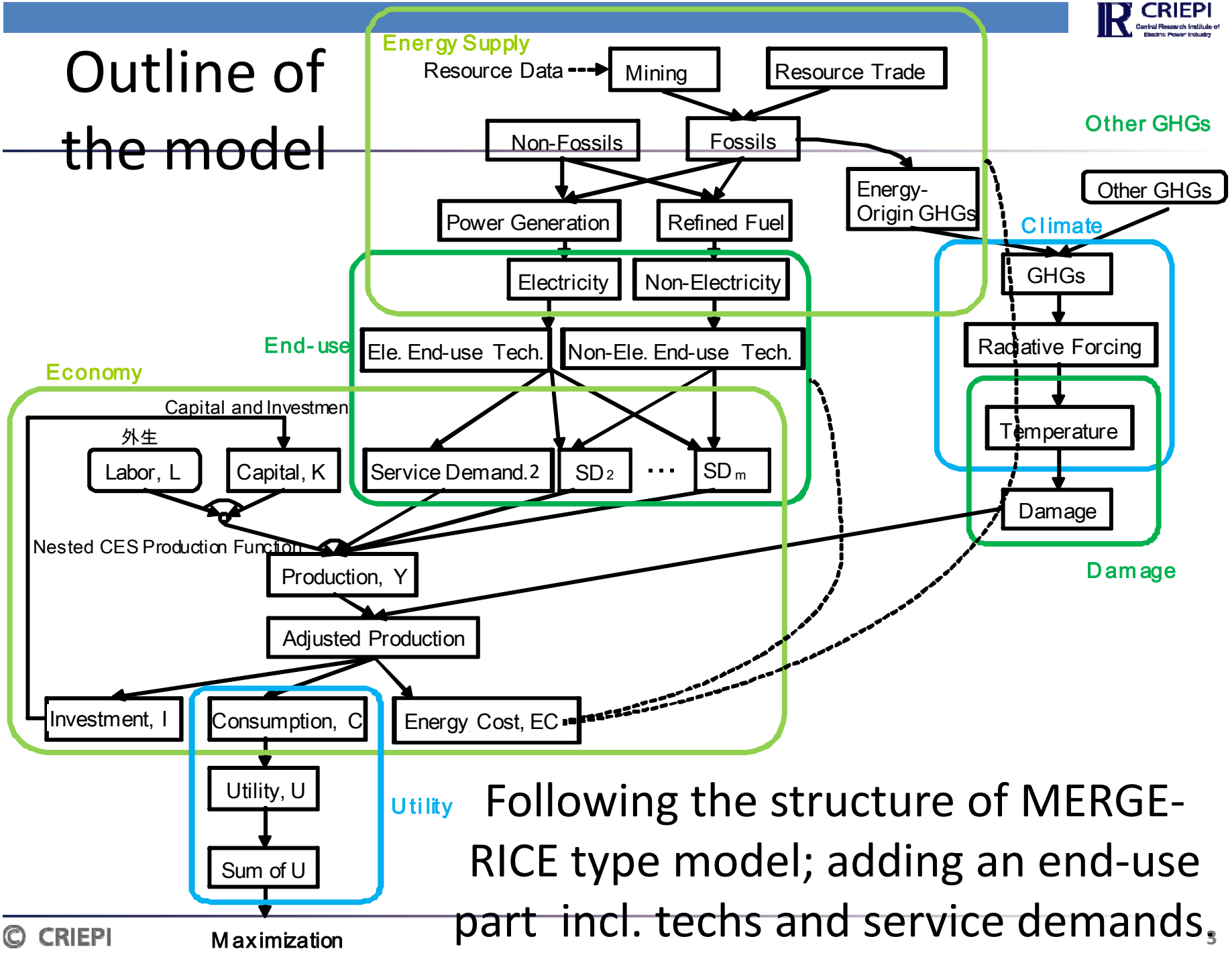
- •The BET model: MERGE-RICE type global model hard-linked with enduse technologies like MARKAL.
- •The production function is one sector and nested CES.

$$YN_{t,r} = \left\{ a_{t,r} \left(KN\right)^{\rho\times\kappa} \left(LN\right)^{\rho\times(1-\kappa)} + \sum b_{i,t,r} DN_{i,t,r}^{\rho} \right\}^{\frac{1}{\rho}}$$

KN: capital, LN: population, DN: 20 kinds of energy services.

- •Advanced end-use technologies such as heat-pump water- heater.
- •13 regions in the world. Calculation period is to 2230.
- •Yamamoto, Sugiyama, and Tsutsui . Climatic Change (2014).

Outline of the model



Following the structure of MERGE-RICE type model; adding an end-use part incl. techs and service demands.

Energy services and end-use technologies

: Advanced end-use technologies

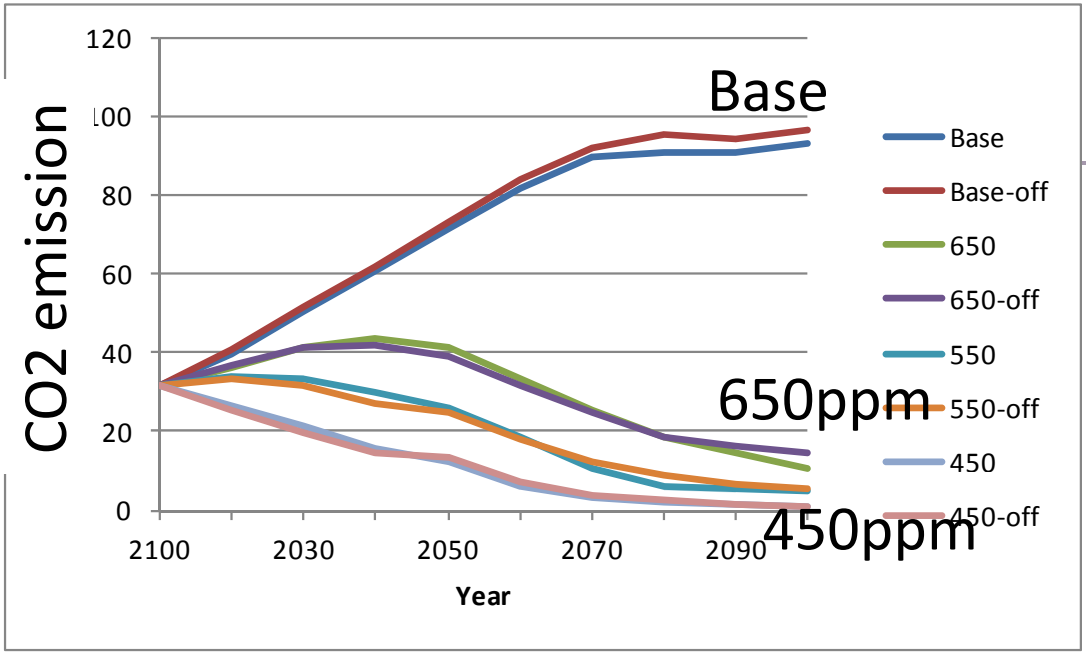
Sector	Sub-sector	Electricity	Solid fuel	Liquid fuel	Gaseous fuel
Industry	*High-temp. heating*	*Electric heating / Inductive heating*	*Solid boiler*	*Liquid boiler*	*Gas boiler*
	Low-temp. heating	*Electric heating / Heat pump*	*Solid boiler*	*Liquid boiler*	*Gas boiler*
	Other electricity	Electricity	N/A	N/A	N/A
	Other solid fuel	N/A	Solid fuel	N/A	N/A
	Other liquid fuel	N/A	N/A	Liquid fuel	N/A
	Other gaseous fuel	N/A	N/A	N/A	Gaseous fuel
Commercial	Lighting	Electricity	N/A	Oil lamp	N/A
	Space cooling	Ele. air con.	N/A	N/A	N/A
	Cooking	Ele. cooker	Solid cooker	Liquid cooker	Gas cooker
	Hot water	*Electric heating / Heat pump*	N/A	*Liquid*	*Gas*
	Space heating	*Ele. Heat pump*	*Solid stove*	*Liquid stove*	*Gas stove*
	Other	Electricity	N/A	N/A	N/A
Household	Lighting	Electricity	N/A	Oil lamp	N/A
	Space cooling	Ele. air con.	N/A	N/A	N/A
	Hot water	*Electric heating / Heat pump*	*Solid*	*Liquid*	*Gas*
	Cooking	Ele. cooker	Solid cooker	Liquid cooker	Gas cooker
	Space heating	*Ele. Heat pump*	*Solid stove*	*Liquid stove*	*Gas stove*
	Other	Electricity	N/A	N/A	N/A
Transportation	*Road freight*	N/A	N/A	*Conv. vehicle / Hybrid vehicle*	N/A
	Road passenger	*Electric vehicle*	*Conv. vehicle*	N/A	N/A
	Railroad	Electricity	N/A	Liquid	N/A
	Aviation and shipping	N/A	N/A	Liquid	N/A

Scenarios

Greenhouse gas constraints: Base(without GHG constraints) , 650 ppm-eq, 550 ppm-eq, and 450 ppm-eq (CO_2 equivalent).

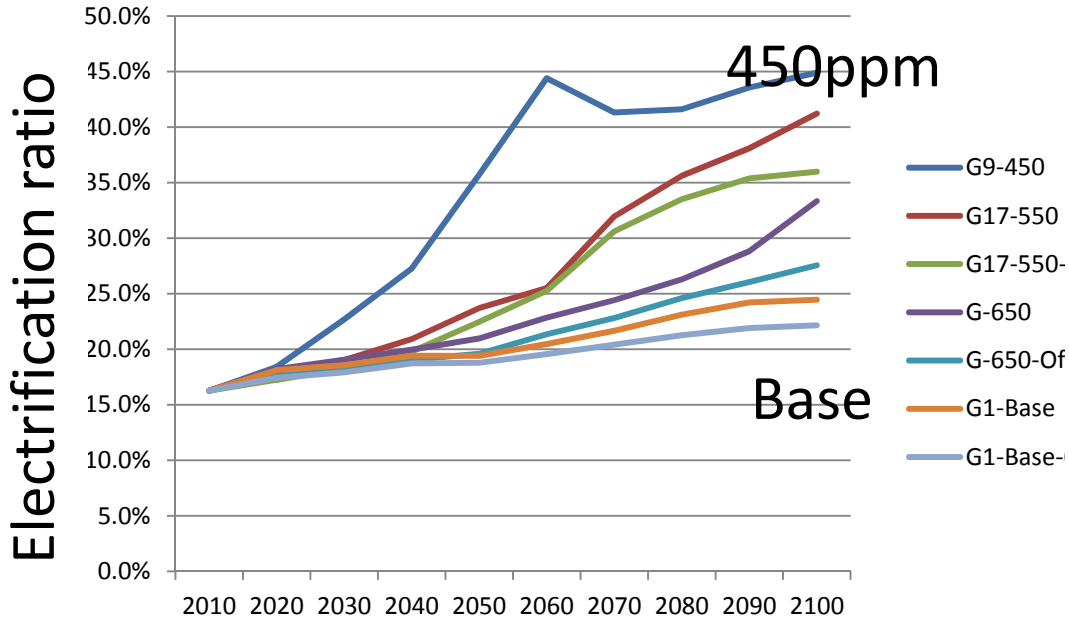
Advanced end-use technologies such electric heat pump water heater, industrial inductive heater, electric passenger vehicles, and hybrid freight vehicles: Turning on or off.

To analyze the role of the advance end-use technologies under the greenhouse gas constraints.



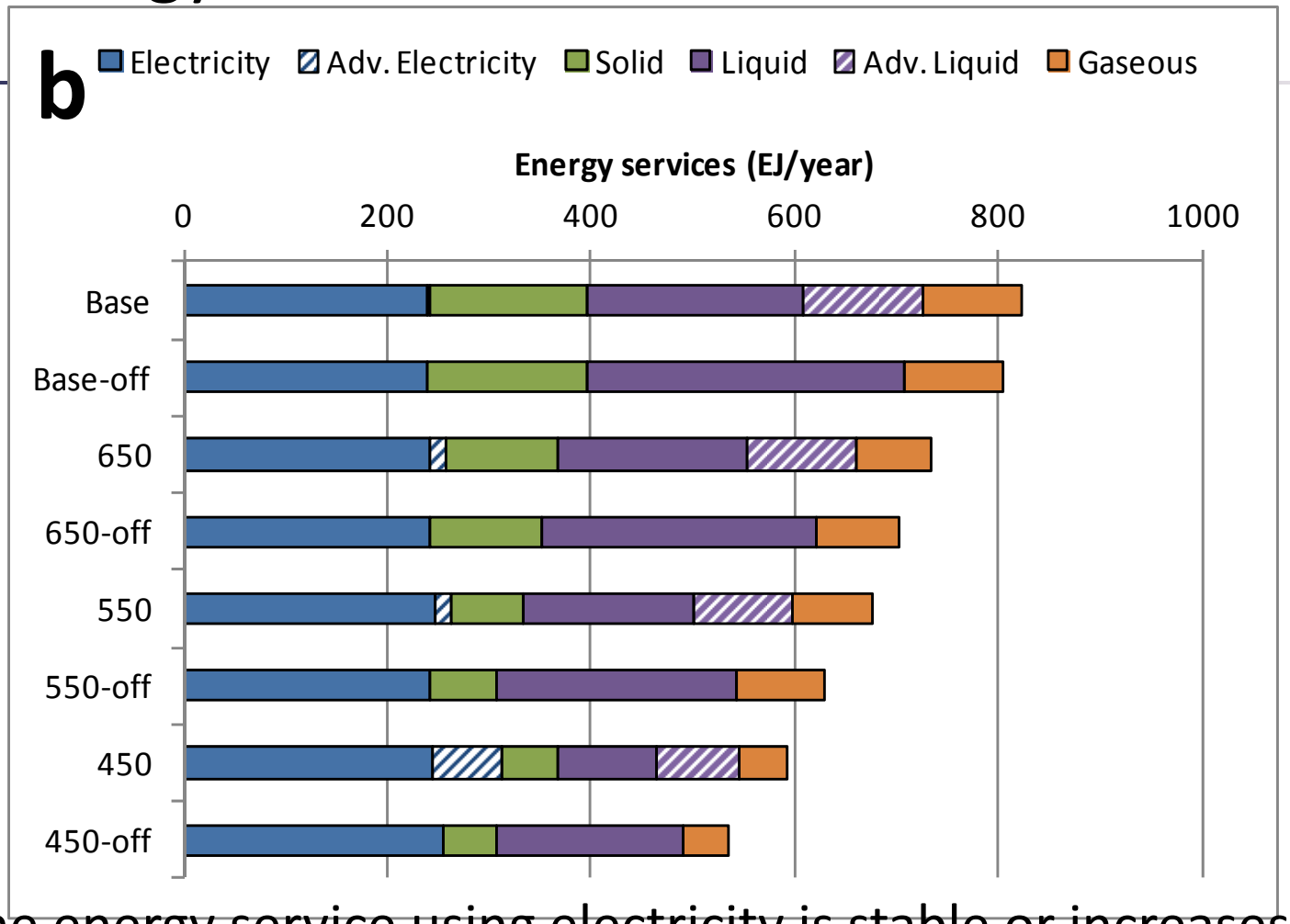
Results of the BET model

Upper Fig. : GHG constraints and CO2 emission pathways



Lower Fig.: GHG constraints and electrification ratios -> Importance of advance electric appliance technology

Energy services in the world in 2050



The energy service using electricity is stable or increases under stringent GHG constraints. Electrification increases, too. Advanced electric end-use technologies such as heat-pump water heaters play increasingly important roles.

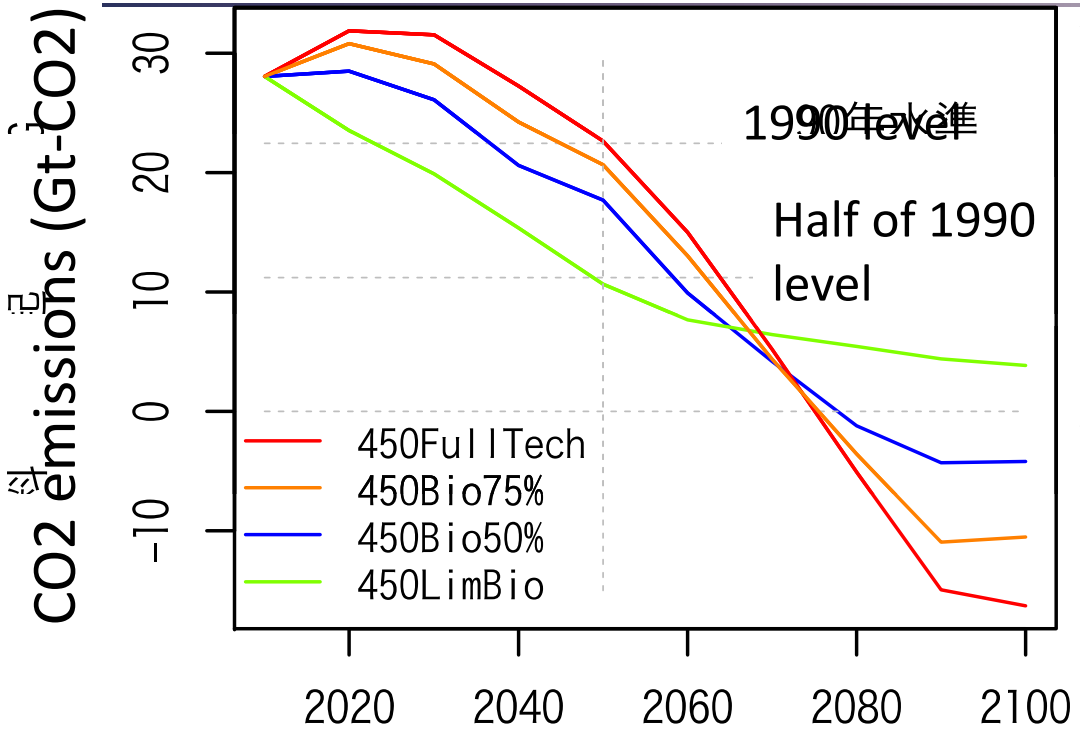
Flexibility of Emission pathways (Role of Carbon Dioxide Removal technology, BECCS)

- Examples of CDR (Carbon Dioxide Removal) options
  : BECCS (BioEnergy with Carbon Capture and Storage)
  Large scale reforestation
  DAC (Direct Air Capture).

- We evaluate BECCS and emission pathways using the BET model.

- (Sugiyama, M. et al., CRIEPI report Y13015 (2014)).

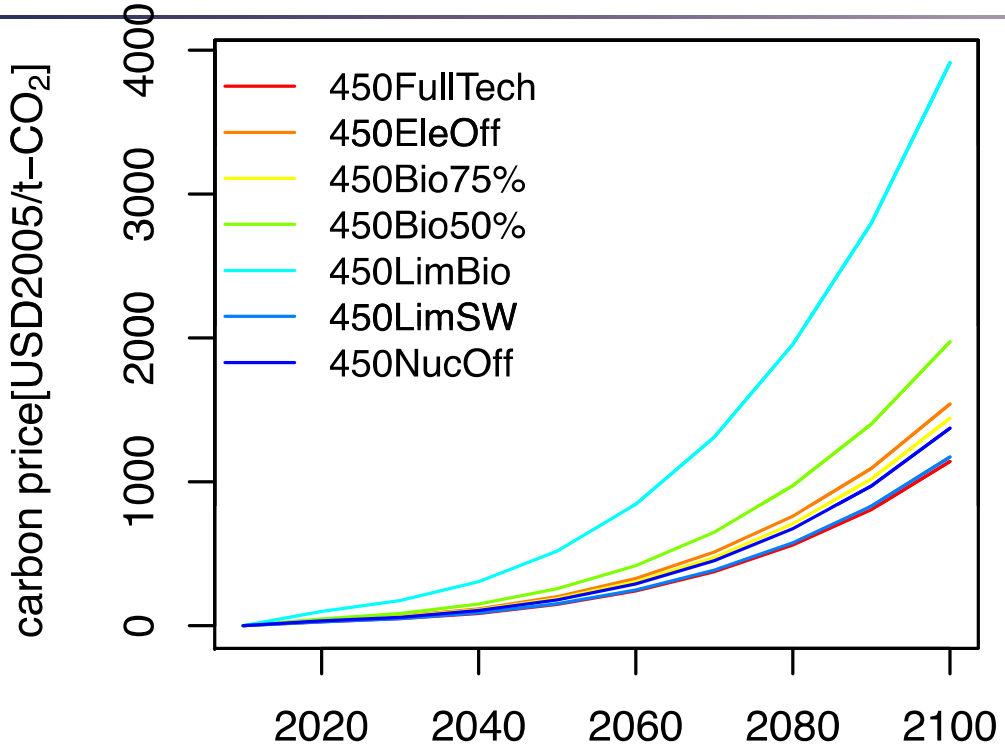
Biomass resources and emission pathways



Assumed biomass resources,
FullTech: 500EJ/year,
50%: 250EJ/year,
LimBio: 100EJ/year.

- Under 450ppm constraints, the shape of the pathways depends on the quantity of bioenergy resource.
- If the biomass resource is limited, the CO2 emission in 2050 is smaller and that in 2100 is larger.
- If the biomass resource is large, the CO2 emission in 2050 is larger and that in 2100 is smaller.
- However, the steep reduction pathway is

Carbon price (450ppm-eq)



- Technology options
- EleOff: without advance enduse technolgies
- Bioenergy resources: 500EJ (default),75%, 50%, and 100EJ.

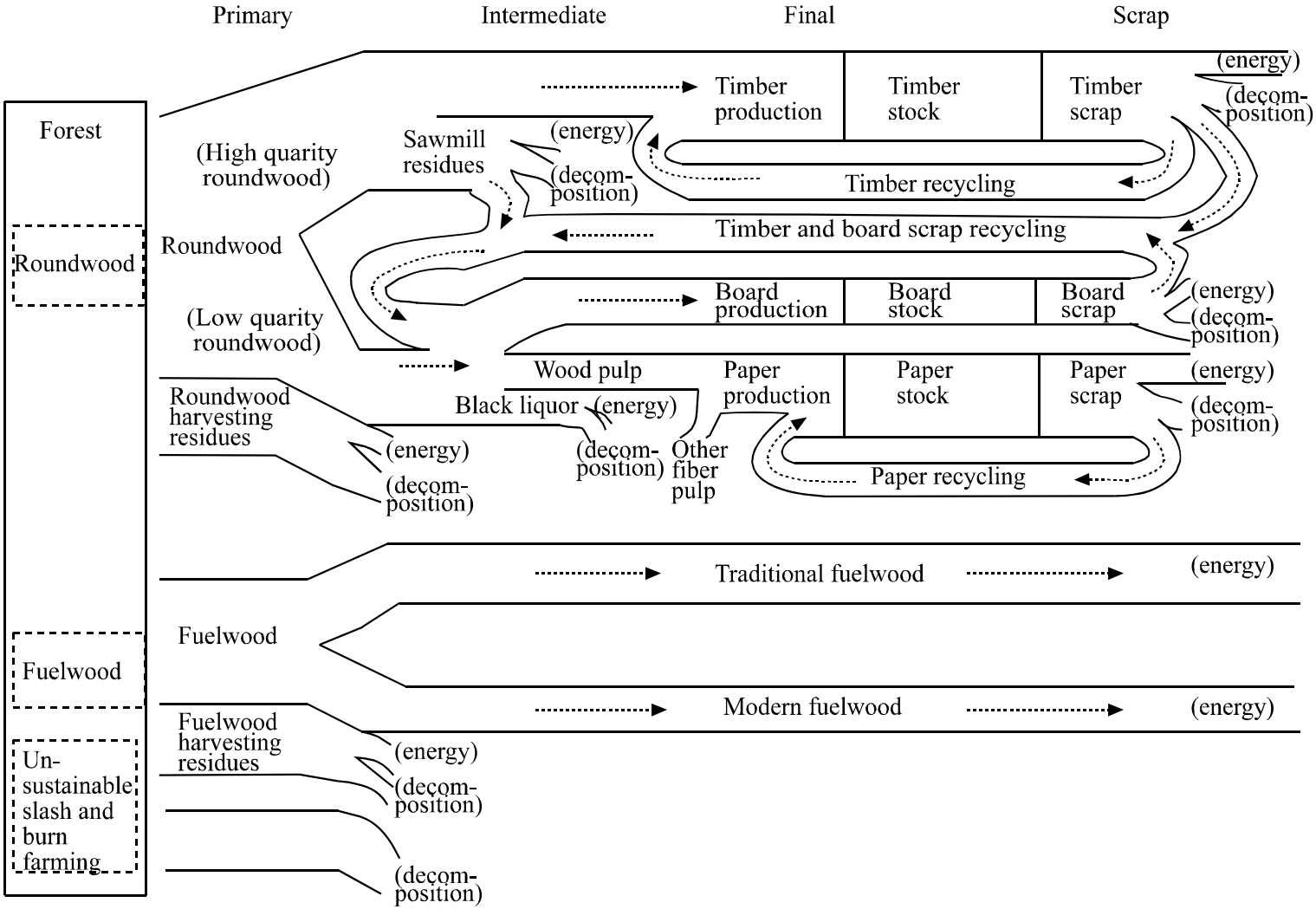
- The lowest carbon price in the cases in 2100 is USD 4000 per t-CO2 (in the case with 100 EJ of bioenergy resources.
- The highest carbon price in the cases in 2100 is USD 1000 per t-CO2 (in the case with maximum bioenergy resources, nuclear and advanced end-use technologies.

Outline of the GLUE model

- A Biomass flow model (Yamamoto et al. 2001, Biomass & Bioenergy.)
- Feature of the GLUE: calculating bioenergy supply potentials of biomass residues in the biomass flows in detail.
- After determining biomass flows in detail, it calculates bioenergy potentials.

- The biomass supply potentials are used in the BET model.
- Biomass demands are set by the relation between BD per cap and GDP/cap calculated by the BET model

Wood biomass flow in the GLUE



Food biomass flow in the GLUE

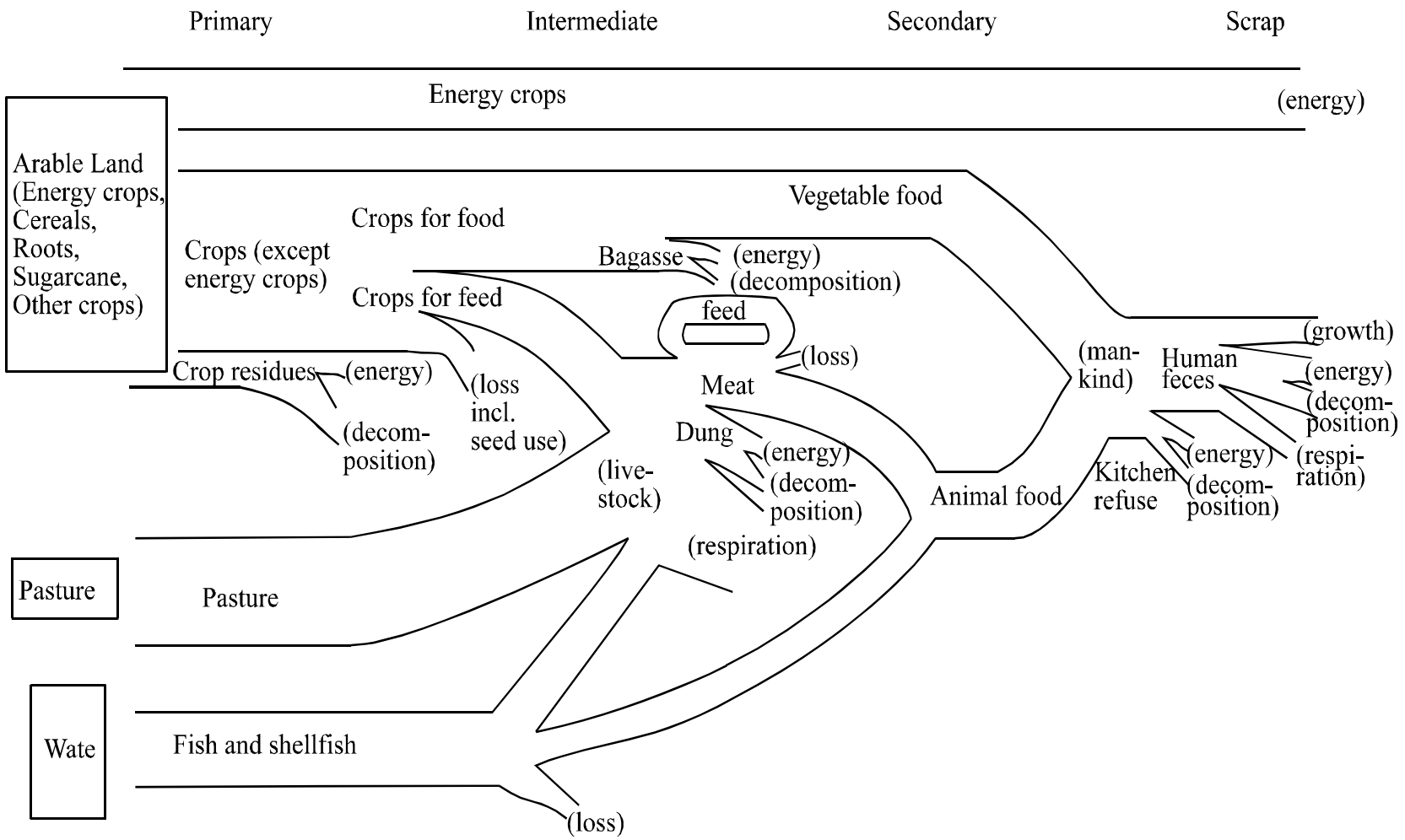
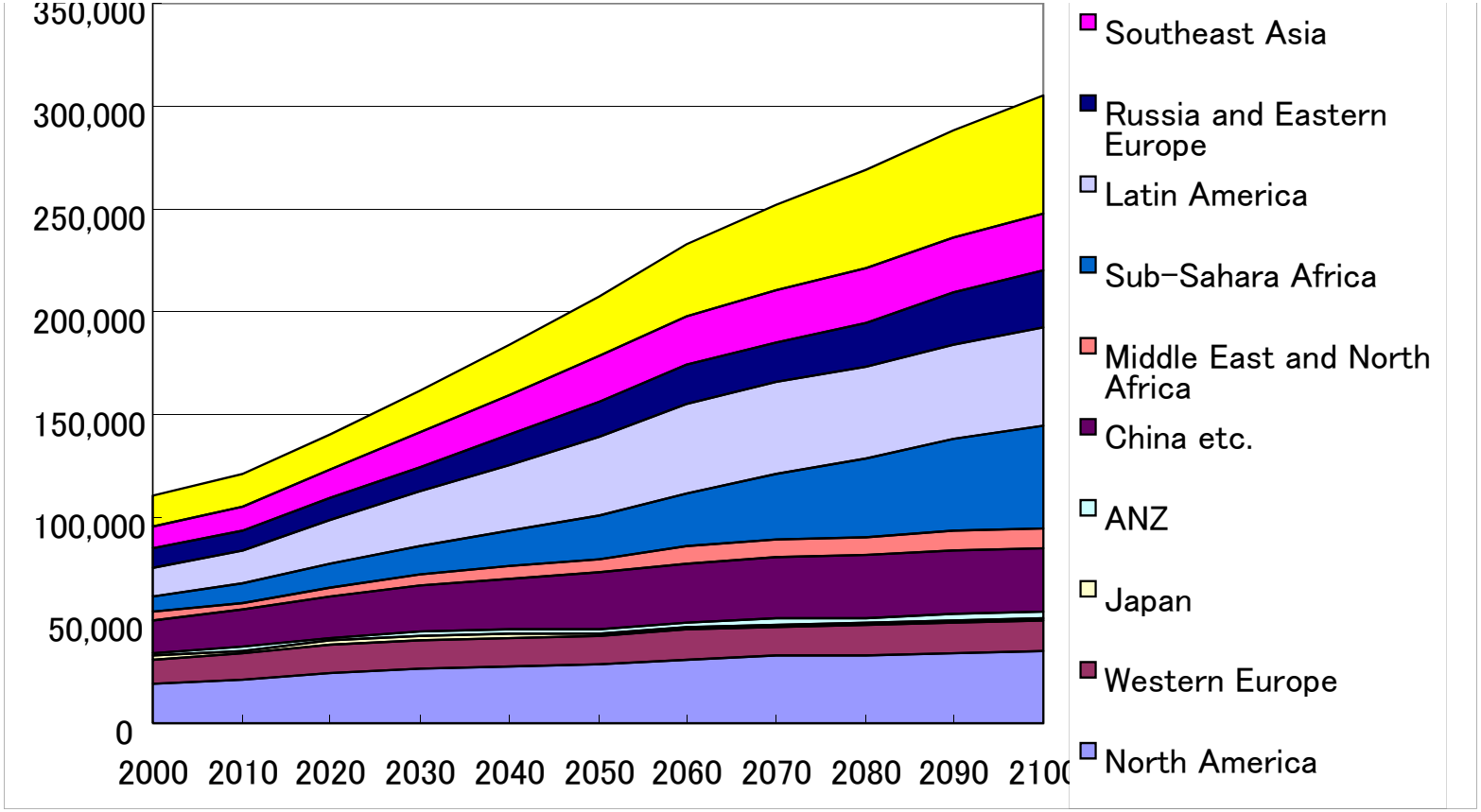


Figure Regional ultimate supply potential of biomass residues (unit: PJ/yr)



The ultimate means all discharged biomass residues minus material-recycled biomass residues.

The ultimate supply potential of biomass residues will increase from 110 EJ/yr in 2000 to 208 EJ/yr in 2050 and 305 EJ/yr in 2100.

Linkage of the BET-GLUE model (Soft-link of the two models)