Supplementary Table S1. Economic and climatic equations in the model. The interpretation and the rationality or the method of calibration are provided for equations in the main text (Eqs. 1–22) and Supplementary Information (Eqs. S1–17).

Equation	Formulation	Economic or physical interpretations	Rationality or method of calibration
Eq. 1	$\max_{i_{s,t},i_{e,t},i_{g,t},j_{e,t},j_{g,t}} W=\sum_{t=1}^{\infty}\frac{1}{(1+\rho)^{t-1}}\cdot\frac{L_t}{1-\delta}\cdot\left(\frac{C_t}{L_t}\right)^{1-\delta}$	Using this equation, the saving rate ($i_{s,t}$) and the allocation of investment ($i_{e,t}$ and $i_{g,t}$) and labor ($j_{e,t}$ and $j_{g,t}$) are optimized simultaneously over time to maximize the welfare (W).	This equation is developed under the principal of welfare maximization [1].
Eq. 2	$Y_t=\left[B_t^{\frac{\sigma_Y-1}{\sigma_Y}}+(\eta_{e,t}\cdot E_t)^{\frac{\sigma_Y-1}{\sigma_Y}}\right]^{\frac{\sigma_Y}{\sigma_Y-1}}$	Using this equation, output (Y_t) is produced by taking energy (E_t) and non-energy products (B_t) as inputs, where the elasticity of substitution between energy and non-energy products is prescribed.	This function is developed by modifying the original function initiated by Solow [2] to represent a broad range of the elasticity of substitution between energy and non-energy products.
Eq. 3	$E_t=\left(F_t^{\frac{\sigma_E-1}{\sigma_E}}+G_t^{\frac{\sigma_E-1}{\sigma_E}}\right)^{\frac{\sigma_E}{\sigma_E-1}}$	Using this equation, energy (E_t) is produced by taking fossil fuel (F_t) and renewable energy (G_t) as inputs, where the elasticity of substitution between fossil fuel and renewable energy is prescribed.	This function is developed by modifying the original function initiated by Solow [2] to represent a broad range of the elasticity of substitution between fossil fuel and renewable energy.
Eq. 4	$F_t=\beta_{d,t}\cdot K_{d,t}^{\gamma}\cdot L_{d,t}^{1-\gamma}$	Using this equation, fossil fuel (F_t) is produced by taking capital ($K_{d,t}$) and labor ($L_{d,t}$) as inputs, where capital and labor are substitutable to each other.	This function is developed by modifying the original function initiated by Cobb and Douglas [3] to represent a perfect substitution between capital and labor in the sector producing fossil fuel.
Eq. 5	$G_t=\beta_{g,t}\cdot K_{g,t}^{\gamma}\cdot L_{g,t}^{1-\gamma}$	Using this equation, renewable energy (G_t) is produced by taking capital ($K_{g,t}$) and labor ($L_{g,t}$) as inputs, where capital and labor are substitutable to each other.	This function is developed by modifying the original function initiated by Cobb and Douglas [3] to represent a perfect substitution between capital and labor in the sector producing renewable energy.

Eq. 6	$B_t=\beta_{b,t}\cdot K_{b,t}^{\gamma}\cdot L_{b,t}^{1-\gamma}$	Using this equation, non-energy products (B_t) is produced by taking capital ($K_{b,t}$) and labor ($L_{b,t}$) as inputs, where capital and labor are substitutable to each other.	This function is developed by modifying the original function initiated by Cobb and Douglas [3] to represent a perfect substitution between capital and labor in the sector producing non-energy products.
Eq. 7	$C_t=[1-d_t(\Delta T_t)]\cdot Y_t-I_t$	The output minus the damage caused by climate change and investment is used for consumption.	This equation is obtained by applying Ramey's model of economic growth [2].
Eq. 8	$I_t=i_{s,t}\cdot[1-d_t(\Delta T_t)]\cdot Y_t$	Investment is a product of the net output and the optimal saving rate.	This equation is obtained by applying Ramey's model of economic growth [2].
Eq. 9	$d_t=d_c-\frac{d_c}{1+\lambda_w\cdot\Delta T_t^{\,2}+\left(\frac{\Delta T_t}{T_{50}}\right)^k}$	As global warming (ΔT_t) rises, the growth of damage caused by climate change is accelerated until ΔT_t surpasses a threshold, and then the growth of damage caused by climate change is decelerated after crossing critical climate tipping points.	I calibrate the coefficient (λ_w) to achieve a low damage (0.2%) in 2000 [4]. I calibrate the maximal damage (d_c=25–75%) and the characteristic temperature (T_{50}=2±0.5°C) based on the projected impacts of crossing catastrophic tipping points in the climate system [5-7]. I adopt the power coefficient from a previous study (k=6±1) [8].
Eq. 10	$\Delta T_t=\Delta T_{2020}+\varphi\cdot\sum_{\iota=2020}^{t-\tau_R}\varrho_F\cdot F_t\cdot e^{\frac{t-\tau_R-\iota}{\tau_L}}$	The rise of global annual mean surface temperature relative to 2020 depends on the cumulative global CO_2 emissions from fossil fuel since 2020.	I calibrate the response of global warming to cumulative CO_2 emissions (φ) based on the observed global warming and historical CO_2 emissions with a lagging time (τ_R) of 10±10 years [9] and a lifetime (τ_L) of 400±200 years for CO_2 in the atmosphere [10].
Eq. 11	$L_{d,t}=j_{e,t}\cdot(1-j_{g,t})\cdot L_t$	Using this equation, the labor allocated to the sector of producing fossil fuels ($L_{d,t}$) is optimized to maximize welfare.	This equation is developed under the principal of welfare maximization [1].
Eq. 12	$L_{g,t}=j_{e,t}\cdot j_{g,t}\cdot L_t$	Using this equation, the labor allocated to the sector of producing renewable energy ($L_{g,t}$) is optimized to maximize welfare.	This equation is developed under the principal of welfare maximization [1].

Eq. 13	$L_{b,t}=(1-j_{e,t})\cdot L_t$	Using this equation, the labor allocated to the sector of producing non-energy product ($L_{b,t}$) is optimized to maximize welfare.	This equation is developed under the principal of welfare maximization [1].
Eq. 14	$\frac{dK_{d,t}}{dt}=I_t\cdot i_{e,t}\cdot(1-i_{g,t})-\theta\cdot K_{d,t}$	Using this equation, the capital allocated to the sector of producing fossil fuels ($K_{d,t}$) is optimized to maximize the welfare.	Accumulation of capital in the sector of producing fossil fuel is obtained by applying Ramey's model of economic growth [1].
Eq. 15	$\frac{dK_{g,t}}{dt}=I_t\cdot i_{e,t}\cdot i_{g,t}-\theta\cdot K_{g,t}$	Using this equation, the capital allocated to the sector of producing renewable energy ($K_{g,t}$) is optimized to maximize the economic welfare.	Accumulation of capital in the sector of producing renewable energy is obtained by applying Ramey's model of economic growth [1].
Eq. 16	$\frac{dK_{b,t}}{dt}=I_t\cdot(1-i_{e,t})-\theta\cdot K_{b,t}$	Using this equation, the capital allocated to the sector of producing non-energy products ($K_{b,t}$) is optimized to maximize the economic welfare.	Accumulation of capital in the sector of producing non-energy products is obtained by applying Ramey's model of economic growth [1].
Eq. 17	$\frac{1}{\beta_{d,t}}\frac{d\beta_{d,t}}{dt}=k_p$	The impact of a delayed deployment of renewable energy is examined by keeping the efficiency of producing fossil fuel ($\beta_{d,t}$) unchanged.	I calibrate the rate of growth in the efficiency of producing fossil fuel (k_p=1±0.5% per year) based on the rate of economic growth in the Shared Socioeconomic Pathway (SSP) scenarios [11].
Eq. 18	$\frac{1}{\beta_{b,t}}\frac{d\beta_{b,t}}{dt}=k_p$	The impact of a delayed deployment of renewable energy is examined by keeping the efficiency of producing non-energy products ($\beta_{d,t}$) unchanged.	I calibrate the rate of growth in the efficiency of producing non-energy products (k_p=1±0.5% per year) based on the rate of economic growth in the Shared Socioeconomic Pathway (SSP) scenarios [11].
Eq. 19	$\frac{1}{\eta_{e,t}}\frac{d\eta_{e,t}}{dt}=k_u$	The impact of a delayed deployment of renewable energy is examined by keeping the efficiency of using energy ($\eta_{e,t}$) unchanged.	I calibrate the rate of growth in the efficiency of using energy (k_u=1–5% per year based on the rate of change in energy intensity in the Shared Socioeconomic Pathway (SSP) scenarios [11].

Eq. 20	$$\frac{1}{\beta_{g,t}}\frac{d\beta_{g,t}}{dt}=k_p-\frac{1}{G_t}\cdot\frac{dG_t}{dt}\cdot\log_2(1-L_R)$$	The rate of growth in the efficiency of producing renewable energy depends on the rate of growth in the production of renewable energy.	The Wright's law is applied to predict the rate of growth in the efficiency of producing renewable energy ($\beta_{g,t}$) by calibrating the rate of learning (L_R) based on observations [12].
Eq. 21	$$\frac{\partial Y_t}{\partial G_t}=\frac{\partial Y_t}{\partial E_t}\cdot\frac{\partial E_t}{\partial G_t}=\left(\frac{Y_t}{E_t}\right)^{\frac{1}{\sigma_Y}}\cdot\left(\frac{E_t}{G_t}\right)^{\frac{1}{\sigma_E}}\cdot\eta_{e,t}^{\frac{\sigma_Y-1}{\sigma_Y}}$$	The price of renewable energy depends on energy intensity, the share of renewable energy in total energy, and the efficiency of producing renewable energy.	This equation is derived from the first-order derivative of output to the production of renewable energy [2].
Eq. 22	$$SCC_t=\frac{\frac{1}{\varrho_F}\cdot\frac{\partial W}{\partial F_t}}{\frac{\partial W}{\partial C_t}}=\frac{1}{\varrho_F}\cdot\left(\frac{C_t}{L_t}\right)^{\delta}\cdot\frac{\partial W}{\partial F_t}$$	The social cost of carbon (SCC_t) depends on the ratio of CO_2 emissions to the consumption of fossil fuel (ϱ_F), per capita consumption (C_t/L_t), and the marginal change in welfare with respect to CO_2 emissions ($\partial W/\partial F_t$).	The social cost of carbon is derived as the discounted economic damage caused by an incremental tonne of CO_2 emissions at present [4].
Eq. S1	$$y=\left[v^{\frac{\sigma-1}{\sigma}}+c^{\frac{\sigma-1}{\sigma}}\cdot(1-v)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}$$	The output depends on the fraction of labor or investment allocated to the sector producing one input.	This function is developed by modifying the function initiated by Solow [2] to represent a broad range of the elasticity of substitution between two inputs.
Eq. S2	$$\frac{\partial y}{\partial v}=y^{\frac{1}{\sigma}}\cdot\left[v^{-\frac{1}{\sigma}}-c^{\frac{\sigma-1}{\sigma}}\cdot(1-v)^{-\frac{1}{\sigma}}\right]=0$$	The optimal fraction of labor or investment allocated to a sector producing an input is determined by the principal of output maximization.	This equation is derived from the first-order derivative of output under the principal of output maximization [1].
Eq. S3	$$v_o=\frac{1}{1+c^{\sigma-1}}$$	The optimal fraction of labor or investment allocated to a sector producing an input depends on the efficiency of producing one input relative to producing another input.	This equation is derived from the first-order derivative of output under the principal of output maximization [1].
Eq. S4	$$y_{max}=\left[v_o^{\frac{\sigma-1}{\sigma}}+c^{\frac{\sigma-1}{\sigma}}\cdot(1-v_o)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}=\left(v_o^{-\frac{1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}=v_o^{\frac{1}{1-\sigma}}$$	The final output depends on the optimal fraction of labor or investment allocated to the sector producing an input.	This equation is derived from the first-order derivative of output under the principal of output maximization [1].

Eq. S5	$Y_0^{\frac{\sigma_Y-1}{\sigma_Y}}=B_0^{\frac{\sigma_Y-1}{\sigma_Y}}+\left(\eta_{e,0}\cdot E_0\right)^{\frac{\sigma_Y-1}{\sigma_Y}}= \left\{\beta_{b,0}\cdot\left[K_0\cdot(1\text{-}i_{e,0})\right]^{\gamma}\cdot\left[L_0\cdot(1\text{-}j_{e,0})\right]^{1\text{-}\gamma}\right\}^{\frac{\sigma_Y-1}{\sigma_Y}}+ \left(\eta_{e,0}\cdot K_0^{\gamma}\cdot i_{e,0}^{\gamma}\cdot L_0^{1\text{-}\gamma}\cdot j_{e,0}^{1\text{-}\gamma}\right)^{\frac{\sigma_Y-1}{\sigma_Y}}\cdot \left\{\left[\beta_{d,0}\cdot(1\text{-}i_{g,0})^{\gamma}\cdot(1\text{-}j_{g,0})^{1\text{-}\gamma}\right]^{\frac{\sigma_E-1}{\sigma_E}}+\left(\beta_{g,0}\cdot i_{g,0}^{\gamma}\cdot j_{g,0}^{1\text{-}\gamma}\right)^{\frac{\sigma_E-1}{\sigma_E}}\right\}^{\frac{\sigma_E}{\sigma_E-1}\cdot\frac{\sigma_Y-1}{\sigma_Y}}$	The final output depends on the optimal fraction of labor or investment allocated to the sector producing an input, which is a function of the efficiencies of producing various inputs.	This equation is derived from the first-order derivative of output under the principal of output maximization [1].
Eq. S6	$\left(\frac{Y_0}{K_0^{\gamma}\cdot L_0^{1\text{-}\gamma}}\right)^{\frac{\sigma_Y-1}{\sigma_Y}}=\left[\beta_{b,0}\cdot(1\text{-}i_{e,0})^{\gamma}\cdot(1\text{-}j_{e,0})^{1\text{-}\gamma}\right]^{\frac{\sigma_Y-1}{\sigma_Y}}+ \left(\eta_{e,0}\cdot i_{e,0}^{\gamma}\cdot j_{e,0}^{1\text{-}\gamma}\right)^{\frac{\sigma_Y-1}{\sigma_Y}}\cdot\left\{\left[\beta_{d,0}\cdot(1\text{-}i_{g,0})^{\gamma}\cdot(1\text{-}j_{g,0})^{1\text{-}\gamma}\right]^{\frac{\sigma_E-1}{\sigma_E}}+\left(\beta_{g,0}\cdot i\right.\right.$	The total factor productivity can be expressed as a function of the efficiencies of producing various inputs.	This equation is derived from the first-order derivative of output under the principal of output maximization [1].
Eq. S7	$i_{e,t}=j_{e,t}=(L_{d,0}+L_{g,0})/(L_{d,0}+L_{g,0}+L_{b,0})= (K_{d,0}+K_{g,0})/(K_{d,0}+K_{g,0}+K_{b,0})$	Under the equilibrium state, the fraction of labor allocated to the energy sector is identical to the fraction of investment and thus capital allocated to the energy sector.	The duality of capital and labor in the economic production function leads to the same fraction of labor, investment, and the capital allocated to the energy sector [13].
Eq. S8	$i_{g,t}=j_{g,t}=L_{g,0}/(L_{d,0}+L_{g,0})=K_{g,0}/(K_{d,0}+K_{g,0})$	Under the equilibrium state, the fraction of labor in the energy sector allocated to producing renewable energy is identical to the fraction of investment and thus capital in the energy sector allocated to producing renewable energy.	The duality of capital and labor in the economic production function leads to the same fraction of labor, investment, and the capital in the energy sector allocated to producing renewable energy [13].
Eq. S9	$\frac{\partial Y_0}{\partial i_{g,0}}=\frac{\partial Y_0}{\partial j_{g,0}}=0 \Longrightarrow i_{g,0}=j_{g,0}=\frac{1}{1+\left(\frac{\beta_{d,0}}{\beta_{g,0}}\right)^{\sigma_E-1}}$	The optimal fraction of labor and investment in the energy sector allocated to producing renewable energy depends on the ratio of the efficiency of producing fossil fuel to the efficiency of producing renewable	The optimal fraction of labor and investment in the energy sector allocated to producing renewable energy is derived from the first-order derivative of output under the principal of output maximization [1].

		energy.	
Eq. S10	$\frac{G_0}{F_0}=\frac{\beta_{g,0}\cdot i_{g,0}^{\gamma}\cdot j_{g,0}^{1-\gamma}}{\beta_{d,0}\cdot(1-i_{g,0})^{\gamma}\cdot(1-j_{g,0})^{1-\gamma}}=\left(\frac{i_{g,0}}{1-i_{g,0}}\right)^{\frac{\sigma_E}{\sigma_E-1}}=\left(\frac{\beta_{g,0}}{\beta_{d,0}}\right)^{\sigma_E}$	The ratio of the production of renewable energy (G_0) to the production of fossil fuel (F_0) depends on the ratio of the efficiency of producing renewable energy to the efficiency of producing fossil fuel.	I calibrate the ratio of the efficiency of producing renewable energy to the efficiency of producing fossil fuel based on the observed ratio of the production of renewable energy to the production of fossil fuel.
Eq. S11	$E_0=(K_0\cdot i_{e,0})^{\gamma}\cdot(L_0\cdot j_{e,0})^{1-\gamma}\cdot\beta_{g,0}\cdot i_{g,0}^{\frac{1}{1-\sigma_E}}$	The total energy production depends on the total capital, total labor, the efficiency of producing renewable energy, and the allocation of investment and labor to the energy sector.	I calibrate the efficiency of producing renewable energy based on the observed total energy production, the observed total capital, the observed total labor, and the fraction of investment and labor allocated to the energy sector.
Eq. S12	$\left(\frac{Y_0}{K_0^{\gamma}\cdot L_0^{1-\gamma}}\right)^{\frac{\sigma_Y-1}{\sigma_Y}}=\left[\beta_{b,0}\cdot(1-i_{e,0})^{\gamma}\cdot(1-j_{e,0})^{1-\gamma}\right]^{\frac{\sigma_Y-1}{\sigma_Y}}+\left(\eta_{e,0}\cdot i_{e,0}^{\gamma}\cdot j_{e}\right.$	The total factor productivity depends on the fraction of labor and investment allocated to the energy sector and the efficiency of producing various inputs.	I calibrate the efficiency of producing non-energy products based on the observed output, the observed total capital, the observed total labor, the fraction of investment and labor allocated to the energy sector, and the efficiency of producing renewable energy.
Eq. S13	$\frac{\partial Y_0}{\partial i_{e,0}}=\frac{\partial Y_0}{\partial j_{e,0}}=0\Longrightarrow i_{e,0}=j_{e,0}=\frac{1}{1+\left(\frac{\beta_{b,0}}{\eta_{e,0}\cdot\beta_{g,0}\cdot i_{g,0}^{\frac{1}{1-\sigma_E}}}\right)^{\sigma_Y-1}}$	The optimal fraction of labor and investment allocated to the energy sector depends on the efficiency of producing non-energy production, the efficiency of using energy, the efficiency of producing renewable energy, and the fraction of investment in the energy sector allocated to producing renewable energy.	I calibrate the efficiency of using energy and the efficiency of producing renewable energy based on the fraction of investment and labor allocated to the energy sector and the fraction of investment in the energy sector allocated to producing renewable energy.
Eq. 14	$Y_0=\left(\eta_{e,0}\cdot\beta_{g,0}\cdot i_{g,0}^{\frac{1}{1-\sigma_E}}\cdot i_{e,0}^{\frac{1}{1-\sigma_Y}}\right)\cdot K_0^{\gamma}\cdot L_0^{1-\gamma}$	The final output depends on the total capital, total labor, the efficiency of using energy, the efficiency of producing renewable energy, the fraction of investment allocated to the	I calibrate the efficiency of using energy and the efficiency of producing renewable energy based on the observed total output, total capital, total labor, the fraction of investment allocated to the energy sector,

		energy sector, and the fraction of investment in the energy sector allocated to producing renewable energy.	and the fraction of investment in the energy sector allocated to producing renewable energy.
Eq. S15	$\frac{dK_t}{dt}=I_0\text{-}\theta\cdot K_0=i_{s,0}\cdot Y_0\text{-}\theta\cdot K_0=0$	The rate of growth in total capital is zero when the economic growth reaches an equilibrium state.	Accumulation of capital is simulated by applying Ramey's model of economic growth [1].
Eq. S16	$\beta_{g,0}=E_0/\left[\left(K_0\cdot i_{e,0}\right)^{\gamma}\cdot\left(L_0\cdot j_{e,0}\right)^{1\text{-}\gamma}\cdot i_{g,0}{}^{\frac{1}{1\text{-}\sigma_E}}\right]$	The efficiency of producing renewable energy is expressed as a function of total energy, total capital, total labor, the fraction of investment and labor allocated to the energy sector, and the fraction of investment in the energy sector allocated to producing renewable energy.	I calibrate the efficiency of producing renewable energy based on the observed total energy consumption, total capital, total labor, the fraction of investment and labor allocated to the energy sector, and the fraction of investment in the energy sector allocated to producing renewable energy
Eq. S17	$\eta_{e,0}=Y_0/\left[\left(\beta_{g,0}\cdot i_{g,0}{}^{\frac{1}{1\text{-}\sigma_E}}\cdot i_{e,0}{}^{\frac{1}{1\text{-}\sigma_Y}}\right)\cdot K_0{}^{\gamma}\cdot L_0{}^{1\text{-}\gamma}\right]$	The efficiency of using energy is expressed as a function of total output, total capital, total labor, the fraction of investment allocated to the energy sector, the fraction of investment in the energy sector allocated to producing renewable energy, and the efficiency of producing renewable energy.	I calibrate the efficiency of using energ based on the observed total output, the observed total capital, the observed total labor, the fraction of investment allocated to the energy sector, the fraction of investment in the energy sector allocated to producing renewable energy, and the efficiency of producing renewable energy.

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