Institutions Beyond Quality: How Legislation and Execution Shape the Global Energy Transition

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Abstract

Institutions are widely acknowledged as critical to the energy transition, yet most studies rely on broad governance indicators and aggregate renewable energy shares. Here we introduce two new indices of renewable energy governance legislation and execution—based on 7,310 policy documents across 196 UNFCCC member states (1976–2024). Using annual installation data and a long-difference panel model covering 178 countries between 2000 and 2023, we show that credible legislation and rigorous execution are both necessary to accelerate renewable capacity expansion. Legislative frameworks establish long-term credibility, while execution policies generate operational momentum, though both may involve transitional frictions. Effects are strongest in the long run and differ systematically between developed and developing economies. These results demonstrate that national governance arrangements, when reinforced by international commitments such as the Paris Agreement, are decisive for scaling renewables and provide actionable guidance for strengthening both domestic and global governance of clean energy.

Keywords: Energy Legislation; Execution; Energy Capacity; Long Difference Method

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Introduction:

Within the conventional *market-clearing* paradigm, renewable-energy technologies are often perceived as comparatively disadvantaged because incumbent fossil-fuel generators can appear more cost-efficient when only short-run marginal costs are considered[1]. Relying solely on price signals, therefore, is unlikely to produce the scale and timing of investment necessary to meet internationally agreed-upon decarbonization targets. Government action is essential for both to redress market failures (carbon externalities, network effects, technological learning curves) and to compensate for the global, rather than purely national, character of climate risk. Precisely for this reason, the Intergovernmental Panel on Climate Change (IPCC) was established to coordinate analysis and policy guidance across jurisdictions. In this context, a critical research question arises: How do institutions established and fostered by governments and organizations contribute to the shift toward renewable energy sources during the process of transitioning to a low-carbon economic model? A multitude of impetuses underpins the inquiry into this matter:

A growing body of research has explored how "general" institutional quality—typically proxied by indicators such as rule of law, corruption control, and regulatory effectiveness—shapes renewable energy deployment. The evidence, however, remains strikingly mixed. Some scholars argue that improvements in these institutional dimensions substantially enhance the adoption and consumption of renewable energy by attracting investment and facilitating the implementation of clean energy projects[2-13]. Others, however, find little evidence of a statistically significant link between general institutional quality and renewable energy transition, and in some cases even report adverse effects[14-17]. These divergent findings suggest that the quality of broad institutional frameworks may not, on its own, be a decisive factor in driving renewable energy expansion. Instead, we contend that accelerating the uptake of renewables requires governance arrangements specifically designed to address the unique challenges and opportunities of the energy sector.

Secondly, a clear gap exists in the literature, as most studies focus on broad institutional metrics rather than the specific mechanisms driving the transformation of energy sectors. The most direct and effective way for states to advance renewable energy is through regulatory action, establishing frameworks and implementing targeted policies at the national level to promote widespread adoption. Such regulatory initiatives employ a diverse set of instruments, including

economic tools (e.g., tax deductions, subsidies, emissions trading), regulatory standards (e.g., norms, moratoriums), direct investments (e.g., climate funds, green procurement), governance measures (e.g., capacity building, institutional mandates), and informational mechanisms (e.g., education, training, research and development, knowledge dissemination). Evidence shows that countries with relatively weak overall governance scores, such as China and Brazil[43-45], have achieved rapid renewable energy growth through strong sector-specific regulation, while others with stronger generic institutions have recorded only modest progress. This disparity underscores that energy governance constitutes a distinct domain, one that conventional institutional indicators cannot fully capture. It explains why findings often diverge across countries with different governance models.

To address this gap, we argue that the substantive content and credibility of energy-specific legislation, together with the rigour of its execution, are decisive for accelerating the global energy transition. To capture these dynamics, we construct two novel composite indicators: (i) a Renewable-Energy Legislation Index (LEGI_RE)**,** measuring the legal commitment to clean-energy promotion, and (ii) a Renewable-Energy Execution Index (EXE_RE)**,** capturing the administrative capacity to implement those commitments. By empirically testing their effects on new renewable energy installation capacity, we aim to identify the governance channels most relevant for renewable energy diffusion, reconcile contradictory findings in the existing literature, and provide policymakers with actionable diagnostics for strengthening national and international energy governance frameworks. Methodologically, we employ a long-difference regression design with multiple fixed effects, which allows us to control unobserved heterogeneity while examining interactions across short-term, transitional, and long-term horizons[18]. Our analysis draws on a comprehensive panel of 178 countries spanning the period from 2000 to 2023, enabling a global assessment of policy effectiveness. The results clearly demonstrate that credible legislation, reinforced by rigorous implementation, has a significant positive impact on renewable energy deployment. These findings highlight the central role of legislation as the foundation upon which effective execution can operate and underline the importance of aligning regulatory design with implementation capacity. For policymakers, the results provide critical insights into the effectiveness of existing measures, offering guidance for designing coherent strategies to foster a

low-carbon economy and accelerate the transition to sustainable energy systems across multiple planning horizons.

In doing so, our study contributes to both the governance and energy economics literatures, offering insights for governments striving to meet the ambitious targets of the Paris Agreement and subsequent COP negotiations. First**,** we develop novel indicators of renewable energy legislation and execution that directly capture government actions, rather than relying on generic institutional quality metrics. Second**,** we employ a long-difference approach that enables us to disentangle institutional effects across short-, transitional, and long-term horizons. Third**,** we provide evidence that credible legislation and rigorous execution exert a substantial positive impact on renewable energy deployment, while also revealing systematic differences between developed and developing economies.

Results:

At the first stage, we estimate the dynamic response of new renewable energy installation capacity across the short, medium, and long run to three key regressors: the Renewable Energy Legislation Index (*LEGIS_RE*), financial market development (*FMD*), and economic development (*GDPC*). Table 1 presents the results. We specify six models (M1–M6). Models 1–3 use the dependent variable defined as new renewable energy installation capacity excluding hydropower and marine energy, estimated for the full sample of 178 countries (M1), the subsample of 32 developed countries (M2), and the subsample of 178 developing countries (M3). Models 4–6 extend the dependent variable to include hydropower and marine energy, again estimated for the full global sample (M4), the developed-country subsample (M5), and the developing-country subsample (M6). Our rationale for constructing two alternative dependent variables, new renewable energy installation capacity excluding and including hydropower and marine energy, is that hydroelectricity remains a relatively low-cost energy source in many countries. Its widespread adoption often reflects economic affordability rather than a genuine policy commitment to advancing the transition toward a more sustainable energy system[19].

The long-run coefficients of renewable energy legislation ($LEGIS_RE_{t-1}$) are consistently positive and statistically significant across all model specifications (M1–M6). This finding suggests that the enactment of new renewable energy laws has a robust and sustained impact on

promoting the expansion of renewable energy installation capacity, both globally and within the developed- and developing-country subsamples. With respect to the short-run coefficients, $\Delta LEGIS_RE$ is statistically significant only in the global model (M1) and the developing-country subsample (M3) when hydropower and marine energy are excluded. By contrast, the coefficients in M2 and M4–M6 are insignificant, suggesting that the contemporaneous enactment of renewable energy legislation does not immediately translate into additional installation capacity within the same year. This pattern implies that legislative measures typically require time to materialize in new capacity, particularly in developed countries, where the policy-to-implementation process is often protracted due to extended parliamentary deliberations and institutional checks[20,21]. By contrast, developing countries may demonstrate a more immediate response, as legislation is often implemented more rapidly in contexts characterized by centralized decision-making, fewer institutional veto points, or more urgent energy security and sustainability imperatives[22,23]. These findings align with the broader literature, which emphasizes that institutional capacity and governance structures condition the effectiveness and speed with which renewable energy policies are translated into tangible capacity expansion. However, the interaction coefficients of $(\Delta LEGIS_RE * LEGIS_RE_{t-1})$ are negative and statistically significant in the global model (M1) and in the developing-country subsample (M3), while they remain insignificant in the other specifications. The rationale is that newly enacted renewable energy legislation may initially impose adjustment costs or generate policy uncertainty, thereby slowing the pace of new installations before long-run benefits are realized. Such transitional frictions have been documented in the literature on renewable energy policy implementation, where regulatory changes create temporary uncertainty until enforcement mechanisms and market responses stabilize[20,21,24]. Our dynamic framework, therefore, allows us to capture both the short-run adjustment costs and the long-run credibility effects of legislation, providing a more comprehensive assessment of policy impacts.

With respect to financial market development, the short-run effects of ΔFMD are heterogeneous across model specifications. In several cases, particularly for developed economies (M2 & M5), the coefficients are insignificant or even negative, indicating that well-established financial systems may initially reinforce investment patterns dominated by fossil fuels, which are already well-established. During the transitional phase, the interaction term captures

adjustment frictions, reflecting the difficulty of reallocating capital from conventional energy assets toward renewable infrastructure without sufficient policy incentives or risk-mitigating instruments. In the long run, however, FMD exerts a more supportive influence in developing countries (M3, M6), where the deepening of financial institutions broadens access to credit, lowers the cost of capital, and mobilizes private investment into renewables. By contrast, the long-run coefficients in developed economies remain weaker or negative, suggesting that in the absence of targeted green finance mechanisms, mature financial markets may continue to favour high-return conventional assets rather than redirecting capital flows toward the renewable sector [8, 25].

Regarding economic development, in the short term, the coefficients of ΔGDPC are generally positive but modest in magnitude, indicating that immediate increases in per capita income stimulate incremental expansion of renewable energy capacity, likely by boosting short-term investment demand. However, the effect strengthens over the long run, where GDPC consistently emerges as a significant driver across all models (M1–M6). This suggests that economic prosperity generates the structural conditions—such as fiscal resources, technological upgrading, and consumer demand—that underpin sustained renewable adoption. During the transitional period, the interaction term occasionally weakens or becomes insignificant, reflecting the adjustment costs associated with reorienting growth trajectories toward renewables. This is consistent with prior evidence that income growth alone does not automatically translate into cleaner energy systems until complementary policy and institutional frameworks are established [7,8].

Table 1| Renewable energy legislations and annual change in renewable energy installation capacity

	M1	M2	M3	M4	M5	M6
DV: RE Installation Capacity $\Delta REIC$	*Full Sample*	*Developed*	*Developing*	*Full Sample*	*Developed*	*Developing*
	DV: excluding hydropower and marine energy			DV: including hydropower and marine energy		
$REIC_{t-1}$	-0.1140***	-0.0277**	-0.1320***	-0.0866***	0.0192*	-0.105***
	(0.0086)	(0.0123)	(0.0102)	(0.00705)	(0.00981)	(0.0083)
$\Delta LEGIS_RE$	0.0052**	0.0014	0.0071**	0.00220	0.0006	0.0023
	(0.0021)	(0.0017)	(0.0030)	(0.0013)	(0.0010)	(0.0019)

$LEGIS_RE_{t-1}$	0.0043***	0.0022***	0.0043***	0.0030***	0.0010***	0.0029***
	(0.0005)	(0.0004)	(0.0008)	(0.0003)	(0.0002)	(0.0005)
$\Delta LEGIS_RE * LEGIS_RE_{t-1}$	-0.0006*	-9.71e-05	-0.0012*	-0.0001	-5.37e-05	-0.0001
	(0.0003)	(0.0002)	(0.0006)	(0.0002)	(0.0001)	(0.0003)
ΔFMD	0.0592	-0.2680**	0.1830	0.0010	-0.1350*	0.0463
	(0.0814)	(0.1330)	(0.1180)	(0.0515)	(0.0796)	(0.0743)
FMD_{t-1}	0.0201	-0.0460**	0.0682**	-0.0130	-0.0053	0.0032
	(0.0228)	(0.0220)	(0.0301)	(0.0145)	(0.0134)	(0.0191)
$\Delta FMD * FMD_{t-1}$	-0.1590	0.2600	-0.4320	-0.0462	0.1510	-0.1330
	(0.1540)	(0.1870)	(0.3080)	(0.0978)	(0.112)	(0.1950)
$\Delta GDPC$	0.1040	0.0386	0.1170	0.00312	0.114	0.0118
	(0.1120)	(0.3100)	(0.1340)	(0.0709)	(0.187)	(0.0850)
$GDPC_{t-1}$	0.0206***	0.0172**	0.0173***	0.00640**	0.0148***	0.0039
	(0.0050)	(0.0086)	(0.0059)	(0.0031)	(0.0050)	(0.0037)
$\Delta GDPC * GDPC_{t-1}$	-0.0090	-0.0024	-0.0108	0.000494	-0.01000	-0.0008
	(0.0128)	(0.0306)	(0.0157)	(0.00816)	(0.0184)	(0.0099)
Constant	-0.1710***	-0.1380	-0.1440***	-0.0244	-0.151***	-0.0003
	(0.0404)	(0.0872)	(0.0454)	(0.0252)	(0.0512)	(0.0284)
Observations	4272	768	3504	3,694	735	2,959
R-squared	0.095	0.137	0.094	0.131	0.296	0.121
N	178	32	95	178	32	95

DV = annual change in renewable energy installation capacity (MW); $LEGIS_RE$ = cumulative count of renewable energy laws enacted by the legislative branch in a given year. FMD = IMF financial market development index; GDPC = log of GDP per capita (World Bank). Country, year, and regional fixed effects are included. Robust standard errors (clustered at the country level) are in parentheses.***, **, * denote significance at the 1%, 5%, and 10% levels.

In Table 2, we examine the effect of renewable energy execution policies on new installation capacity. The long-run coefficients of $EXEC_RE_{t-1}$ are consistently positive and statistically significant across all six models (M1–M6). This robust pattern highlights the critical importance of execution measures such as targeted strategies, subsidies, action plans, and regulatory programs in sustaining the expansion of renewable energy capacity. Whereas legislation establishes long-term credibility and signals a country's commitment to decarbonization, execution policies operate at the implementation level, channeling resources, coordinating institutions, and reducing barriers for investors and firms. The results therefore suggest that execution policies serve as the operational backbone of the energy transition, translating legal frameworks into concrete project activities, accelerating the market uptake of renewables, and ensuring that the intentions of legislation are realized through measurable capacity growth.

With respect to the short-run effects of renewable energy execution policies (ΔEXEC_RE), the coefficients are positive and statistically significant in Models M1, M2, and M4, while they remain insignificant in the other specifications. This pattern suggests that execution measures can generate an immediate boost to renewable installations at the global level (M1), within developed countries (M2), and when hydropower and marine energy are included (M4). In these contexts, subsidies, action plans, and targeted investment programs appear effective in stimulating rapid project activity. By contrast, the absence of significance in the other models—particularly in developing countries—implies that execution policies often require longer gestation periods, complementary financing, or stronger institutional capacity before their benefits materialize in measurable capacity gains. These findings are consistent with prior evidence that policy instruments emphasizing direct incentives tend to have faster payoffs in mature governance environments, whereas their effectiveness in emerging markets depends on overcoming institutional bottlenecks and financing constraints[7, 8, 25].

Table 2 further shows that the transitional effects ($\Delta\text{EXEC_RE} * EXEC_RE_{t-1}$), are negative and statistically significant in Models M1, M2, and M4, while the coefficients for the other models remain insignificant. This suggests that in the global sample, in developed economies, and when hydropower and marine energy are included, execution policies may initially slow down the pace of new renewable installations during the transitional period. Such negative effects are consistent with the literature on policy adjustment and institutional learning, which emphasizes that newly introduced execution measures can create temporary uncertainty for investors, raise compliance and transaction costs, or require reallocation of resources away from ongoing projects before their long-term benefits materialize[20,21,24]. The insignificance of coefficients in the remaining models, particularly for developing countries, indicates that in contexts with weaker institutional capacity or financing constraints, the transitional effects of execution policies may be muted until implementation frameworks are more fully established.

Table 2| Renewable energy execution and annual change in renewable energy installation capacity

	M1	M2	M3	M4	M5	M6
DV: RE Installation Capacity $\Delta REIC$	*Full Sample*	*Developed*	*Developing*	*Full Sample*	*Developed*	*Developing*

	DV: excluding hydropower and marine energy			DV: including hydropower and marine energy		
$REIC_{t-1}$	-0.111***	-0.0149	-0.133***	-0.0777***	0.0225**	-0.102***
	(0.0085)	(0.0120)	(0.0102)	(0.0069)	(0.0092)	(0.0082)
ΔEXEC_RE	0.0027***	0.00132*	0.00189	0.00172**	0.0005	0.0014
	(0.0010)	(0.0007)	(0.0020)	(0.000675)	(0.0004)	(0.0012)
$EXEC_RE_{t-1}$	0.0028***	0.0016***	0.00241***	0.00177***	0.0010***	0.00131***
	(0.0004)	(0.0005)	(0.0005)	(0.000279)	(0.0002)	(0.0003)
ΔEXEC_RE $* EXEC_RE_{t-1}$	-0.0002*	-0.0001*	-0.00005	-0.00013*	-0.00008	-0.0001
	(0.0001)	(8.75e-05)	(0.0002)	(0.00007)	(0.00005)	(0.0002)
ΔFMD	0.0510	-0.242*	0.1580	-0.00365	-0.1300	0.0329
	(0.0816)	(0.134)	(0.1180)	(0.0518)	(0.0796)	(0.0746)
FMD_{t-1}	0.0247	-0.0361	0.0741**	-0.00777	-0.000370	0.0112
	(0.0228)	(0.0220)	(0.0301)	(0.0146)	(0.0132)	(0.0191)
ΔFMD $* FMD_{t-1}$	-0.1400	0.2320	-0.3520	-0.0348	0.1500	-0.0902
	(0.1550)	(0.1890)	(0.309)	(0.0984)	(0.1120)	(0.196)
$\Delta GDPC$	0.1450	0.0735	0.1340	0.0324	0.1300	0.0211
	(0.1120)	(0.3120)	(0.1340)	(0.0712)	(0.1860)	(0.0853)
$GDPC_{t-1}$	0.0156***	0.0164*	0.0135**	0.00418	0.0137***	0.00322
	(0.0053)	(0.0087)	(0.0063)	(0.0033)	(0.0051)	(0.0039)
$\Delta GDPC$ $* GDPC_{t-1}$	-0.0137	-0.0072	-0.0126	-0.0028	-0.0123	-0.0017
	(0.0129)	(0.0308)	(0.0157)	(0.0081)	(0.0183)	(0.0100)
Constant	-0.1270***	-0.1320	-0.1130**	-0.0077	-0.141***	0.0038
	(0.0432)	(0.0891)	(0.0485)	(0.0272)	(0.0521)	(0.0306)
Observations	3,687	735	2,952	3,694	735	2,959
R-squared	0.090	0.124	0.092	0.122	0.297	0.115

DV = annual change in renewable energy installation capacity (MW); EXEC_RE= cumulative count of renewable energy laws enacted by the executive branch in a given year. FMD = IMF financial market development index; GDPC = log of GDP per capita (World Bank). Country, year, and regional fixed effects are included. Robust standard errors (clustered at the country level) are in parentheses. ***, **, * denote significance at the 1%, 5%, and 10% levels.

Table 3 presents the effects of the composite index, which integrates both legislative and executive measures of renewable energy policy. The long-run coefficients are consistently positive and statistically significant across all six models (M1–M6), confirming that the simultaneous presence of credible legislation and effective execution substantially strengthens renewable energy capacity expansion. Compared to the results of Table 1 (legislation alone) and Table 2 (execution alone), the effects observed in Table 3 are more pronounced, suggesting that the interaction of these two policy dimensions produces a reinforcing effect. Legislation provides long-term credibility, stability, and investor confidence, while execution ensures that these commitments are

translated into tangible actions such as subsidies, implementation programs, and administrative enforcement[20,21]. When combined, they deliver greater capacity expansion than either policy instrument in isolation.

In the short run, the coefficients are positive but smaller in magnitude, indicating that combined policy action can yield immediate results; however, the majority of the effect materializes over time as institutions and markets adapt. Transitional effects, however, are negative and significant in selected specifications, suggesting that scaling up legislation and execution simultaneously may introduce temporary adjustment costs, policy overlap, or investor uncertainty before the long-run benefits fully manifest[24]. Taken together, the results highlight that renewable energy transitions are most effectively accelerated when legislative credibility is coupled with robust execution capacity, amplifying the effects documented in Tables 1 and 2, while also emphasizing the need for policymakers to anticipate and mitigate transitional frictions during the implementation phase.

Table 3| Renewable energy legislations and execution, and annual change in renewable energy installation capacity

	M1	M2	M3	M4	M5	M6
DV: RE Installation Capacity $\Delta REIC$	*Full Sample*	*Developed*	*Developing*	*Full Sample*	*Developed*	*Developing*
	DV: excluding hydropower and marine energy			DV: including hydropower and marine energy		
$REIC_{t-1}$	-0.122***	-0.0430***	-0.136***	-0.0867***	0.0071	-0.1040***
	(0.0087)	(0.0135)	(0.0102)	(0.0070)	(0.0103)	(0.0082)
ΔLEXC_RE	0.0037***	0.00243**	0.00327*	0.00197***	0.0012**	0.0016
	(0.0011)	(0.0009)	(0.0017)	(0.0007)	(0.0005)	(0.0011)
$LEXC_RE_{t-1}$	0.0027***	0.0017***	0.0023***	0.00172***	0.0009***	0.0014***
	(0.0003)	(0.0003)	(0.0004)	(0.0001)	(0.000181)	(0.000273)
ΔLEXC_RE $* LEXC_RE_{t-1}$	-0.0002***	-0.0001***	-0.00019	-0.0001**	-0.00008**	-0.00011
	(7.88e-05)	(5.76e-05)	(0.0001)	(0.00005)	(0.00003)	(0.0001)
ΔFMD	0.0524	-0.2620**	0.1640	-0.0038	-0.1330*	0.0339
	(0.0812)	(0.1320)	(0.1180)	(0.0514)	(0.0791)	(0.0744)
FMD_{t-1}	0.0137	-0.0426*	0.0582*	-0.0166	-0.00529	-0.000138
	(0.0228)	(0.0218)	(0.0303)	(0.0145)	(0.0132)	(0.0192)
$\Delta FMD * FMD_{t-1}$	-0.1380	0.2630	-0.3770	-0.0316	0.1540	-0.0970
	(0.1540)	(0.1870)	(0.3080)	(0.0977)	(0.1110)	(0.1950)
$\Delta GDPC$	0.1300	0.0192	0.1290	0.0218	0.0822	0.0184

	(0.1110)	(0.308)	(0.134)	(0.0707)	(0.185)	(0.0850)
$GDPC_{t-1}$	0.0104*	0.0112	0.0092	0.0002	0.0104**	-0.0001
	(0.0053)	(0.0087)	(0.0063)	(0.0033)	(0.0052)	(0.0040)
$\Delta GDPC * GDPC_{t-1}$	-0.0122	-0.0018	-0.0121	-0.0017	-0.0074	-0.0014
	(0.0128)	(0.0304)	(0.0157)	(0.00814)	(0.0182)	(0.0099)
Constant	-0.0834*	-0.0775	-0.0784	0.0278	-0.1030*	0.0323
	(0.0432)	(0.0890)	(0.0489)	(0.0273)	(0.0527)	(0.0308)
Observations	3,687	735	2,952	3,694	735	2,959
R-squared	0.100	0.147	0.096	0.133	0.309	0.120

DV = annual change in renewable energy installation capacity (MW); LEXC_RE= cumulative count of renewable energy laws enacted by the legislative and executive branch in a given year. FMD = IMF financial market development index; GDPC = log of GDP per capita (World Bank). Country, year, and regional fixed effects are included. Robust standard errors (clustered at the country level) are in parentheses. ***, **, * denote significance at the 1%, 5%, and 10% levels.

Discussion:

Our findings provide new evidence on the institutional drivers of renewable energy transitions, highlighting the differentiated and complementary roles of legislation and execution. Across Tables 1–3, several consistent patterns emerge. First, legislation exerts a robust and sustained long-run effect on renewable energy expansion. Laws provide durability and stability, reducing investor uncertainty and signalling lasting political commitment. Yet, as the short-run and transitional results indicate, the effect of legislation is rarely immediate. In many cases, especially in developed countries, new laws require extended parliamentary deliberation, regulatory alignment, and institutional adaptation before their benefits translate into capacity growth. This lag is consistent with prior work emphasizing the role of credibility and institutional learning in renewable energy policy[20,21].

Second, execution policies play a more operational role. Table 2 shows that execution measures—such as subsidies, action plans, and targeted investment programs—can generate immediate short-run boosts in renewable capacity, particularly in global and developed-country models. However, their transitional coefficients are frequently negative, underscoring the adjustment frictions associated with implementing new mechanisms. These include temporary compliance costs, bureaucratic delays, and coordination challenges. Over time, execution policies prove essential for translating legislative intent into measurable capacity expansion, in line with evidence that direct incentives are most effective in contexts with strong administrative capability[7,8].

Third, Table 3 demonstrates that the combination of legislation and execution yields the most pronounced effects. When legal credibility is coupled with robust implementation capacity, renewable adoption accelerates more strongly than under either policy dimension in isolation. Importantly, however, transitional frictions persist, suggesting that scaling up both laws and execution simultaneously may generate short-term uncertainty before the full benefits are realized. These results highlight the complementarity of institutional functions: legislation anchors long-term policy credibility, while execution provides the mechanisms through which credibility is operationalized into investment and project activity.

Taken together, these findings advance the literature on the institutional foundations of energy transitions. They suggest that policy effectiveness depends not only on the presence of legislation or execution, but also on their alignment and sequencing. In countries where legislative frameworks exist without sufficient execution capacity, the risk is symbolic regulation without tangible outcomes. Conversely, executing interventions without a strong legal foundation may result in fragmented or short-lived outcomes. The most successful transitions are therefore likely to emerge where legislative commitment and executional follow-through reinforce each other, providing both stability and immediate impact.

While our results highlight legislation and execution as crucial domestic levers, their effectiveness must also be situated within the broader architecture of global energy governance. International frameworks, such as the Paris Agreement and the Sustainable Development Goals, as well as successive COP negotiations, provide the normative and political scaffolding within which national laws and policies are conceived, implemented, and evaluated. The credibility of national legislation is often bolstered when it aligns with binding international commitments, while execution capacity may be strengthened by cross-border knowledge sharing, technical assistance, and multilateral climate finance[35,38].

At the same time, global governance remains fragmented, operating through what Keohane and Victor (2011) term a "regime complex" rather than a centralized authority. Institutions such as the UNFCCC, IRENA, IEA, and multilateral development banks perform differentiated but complementary functions: setting standards, monitoring progress, mobilizing finance, and diffusing policy innovations across jurisdictions[42]. Our findings suggest that this polycentric governance structure[41] is most effective when it supports the alignment of national legislation and

execution. For example, climate finance initiatives are most impactful when they reward not only the enactment of clean-energy laws but also demonstrable implementation outcomes.

For policymakers, the implication is that strengthening global-to-national linkages is as critical as refining domestic frameworks. International climate clubs, cross-border carbon markets, and regional integration schemes can reinforce legislative credibility and reduce transitional frictions by providing external anchors for reform[37,40]. Equally, monitoring mechanisms under the Paris Agreement could expand beyond headline targets to track the robustness of both legislative and executional functions. By situating our indices of renewable energy governance within this global framework, we demonstrate that national institutional quality is not only a domestic issue but also a cornerstone of collective progress toward a sustainable energy future one that ultimately depends on the strength of global governance linkages.

Methods

Data: we employ two dependent variables to measure renewable energy development. Using the IRENA energy capacity dataset, we calculate the share of renewable installed capacity in total installed capacity within a country for a given year. Installed capacity refers to the maximum net generating capacity of power plants and other facilities that use renewable sources to produce electricity (Fig. 1). In this specification, renewable energy includes bioenergy, geothermal energy, solar power, and wind power, while hydropower and marine energy are excluded to avoid bias from their cost advantages and widespread historical adoption. The second dependent variable extends the measure by including hydropower and marine energy alongside the other renewable sources, thereby providing a more comprehensive indicator of renewable capacity expansion (Fig 2).

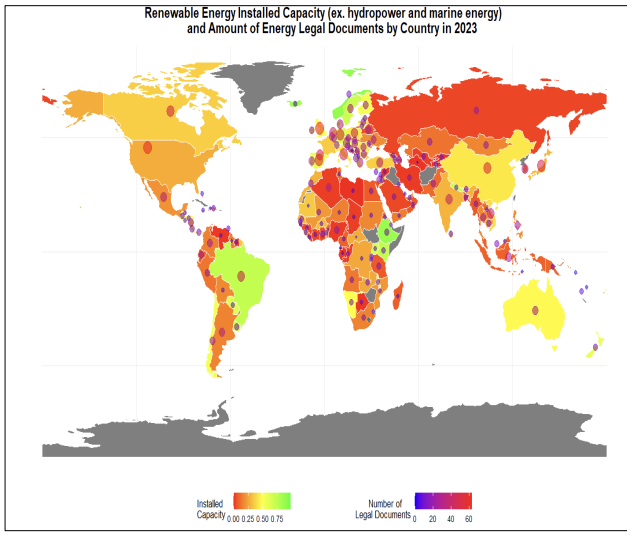


Fig. 1| Renewable energy installed capacity (excluding hydropower and marine energy) and amount of energy legal documents by country in 2023. Installed Renewable Energy Capacity (excluding hydropower and marine energy) – indicated by the background shading of each country (green → high, yellow → moderate, brown → low). Number of Legal Energy Documents – represented by the size and colour of circles (purple → few laws, red → many laws). A positive correlation is visible in many developed and emerging economies: more legal documents coincide with higher renewable energy deployment with some exceptions

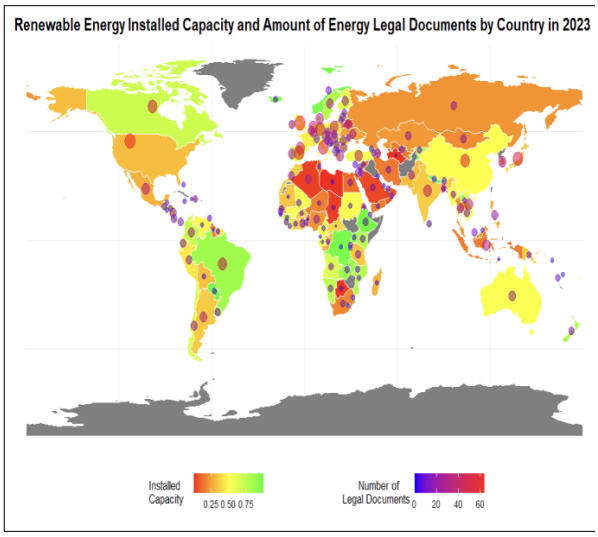


Fig 2| Renewable energy installed capacity (including hydropower and marine energy) and amount of energy legal documents by country in 2023. Installed Renewable Energy Capacity (excluding hydropower and marine energy) – indicated by the background shading of each country (green → high, yellow → moderate, brown → low). Number of Legal Energy Documents – represented by the size and colour of circles (purple → few laws, red → many laws). A positive correlation is visible in many developed and emerging economies: more legal documents coincide with higher renewable energy deployment with some exceptions

Using both measures allows us to disentangle two important dynamics. Excluding hydropower and marine energy provides a cleaner indicator of countries' policy-driven commitment to emerging renewables, since hydropower in particular often reflects historical path dependence and low-cost opportunities rather than deliberate sustainability strategies (Liu & Feng, 2023). Including these sources, by contrast, provides a broader picture of renewable adoption, capturing the full spectrum of technologies that contribute to energy transitions. This dual approach ensures robustness and enables us to test whether policy effects differ when focusing on newer, more innovation-intensive renewables versus the aggregate renewable mix.

We construct three indices to capture renewable energy legislation, execution, and their combined effects over the period 2000–2023 for 178 countries (Fig 3). The Renewable Energy Legislation Index (LEGIS_RE) is defined as the cumulative number of laws, acts, and decrees enacted by the legislative branch of government in a given year. More precisely, legislation refers

to binding legal instruments—such as statutes or parliamentary bills—that establish the overarching regulatory framework for renewable energy. The Renewable Energy Execution Index (EXEC_RE) is defined as the cumulative number of renewable energy policies, regulations, roadmaps, strategies, programs, or plans adopted by the executive branch in a given year. Execution thus reflects operational policy instruments—such as action plans, subsidy schemes, and administrative decrees—that translate legislative intent into practical measures. Finally, the Combined Index aggregates both dimensions, capturing the overall institutional commitment to renewable energy development (Appendix C).

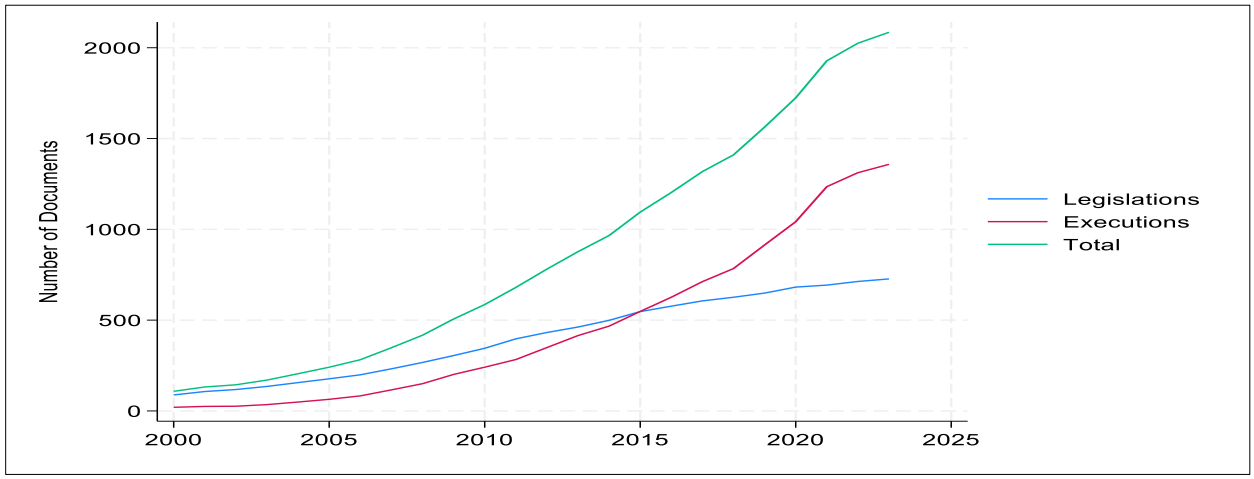


Fig. 3| Cumulative number of energy legislation, executions and total enacted by the legislative and executive branch in a given year from 2000 to 2023. This figure tracks the evolution of renewable-energy-related legal documents (legislations and executions) across 178 countries between 2000 and 2023.

The use of cumulative counts is methodologically justified because it reflects both the stock and credibility of institutional frameworks. Whereas single-year measures capture only annual changes, cumulative indices account for the accumulation of legal and policy commitments over time, thereby embodying the long-term institutional environment in which firms and investors operate. Legislation provides credibility and durability, anchoring expectations about the trajectory of the energy transition, while execution captures the operational capacity and immediacy of government action. Taken together, these indices enable us to distinguish between symbolic commitments and tangible implementation, and to assess whether alignment between legislative intent and executive follow-through amplifies renewable energy outcomes.

In addition, we include two control variables: financial market development (FMD) and overall economic development, the latter proxied by the logarithm of real GDP per capita (see

Table 4). Financial market development is a critical determinant of renewable energy investment, as well-functioning capital markets reduce financing costs, mobilize private investment, and facilitate the scaling of infrastructure projects. Likewise, economic development shapes both the demand and supply side of renewable adoption: higher income levels increase energy demand, fiscal capacity, and societal willingness to support clean energy transitions. Controlling for these factors ensures that the estimated effects of legislation and execution policies are not confounded by structural differences in financial depth or economic prosperity across countries.

Table 4: Description of research variables

Variable	Description	Unit of measurement	Source
REIC	Share of Renewable Installed Capacity in Total Installed Capacity within the country in the given year. Installed capacity refers to the maximum net generating capacity of power plants and other installations utilizing renewable energy sources to produce electricity. Renewable sources include bioenergy, geothermal energy, hydropower, marine energy, solar energy and wind energy.	Percentage	Calculated by author using International Renewable Energy Agency (IRENA)
LEGIS_RE	The Renewable Energy Legislation Index is a cumulative measure of energy legislation within the country in a given year. Legislation refers to a legal document that is enacted by the legislative branch of the government.	Cumulative number of documents	Calculated by author using Climate Change Laws of the World (CCLW)
EXEC_RE	The Renewable Energy Execution Index is a cumulative measure of energy policies implemented within a country in a given year. Policy refers to a legal document that is enacted by the executive branch of the government.	Cumulative number of documents	Calculated by author using Climate Change Laws of the World (CCLW)
LEXC_RE	The Renewable Energy Legislation and Execution Index is a cumulative measure of energy laws enacted within the country in a given year. Laws refer to legal documents enacted by the executive and legislative branches of the government.	Cumulative number of documents	Calculated by author using Climate Change Laws of the World (CCLW)
FMD	The Financial Development Index is evaluated based on a country's financial institutions (banks, insurance companies, mutual funds, and pension funds) and financial markets (stock and bond markets). The resulting indicator is a combination of assessments of depth (size and liquidity of markets), accessibility (the ability of individuals and companies to access financial services) and efficiency (the ability of institutions to provide financial services at low prices and with stable returns, as well as the level of capital market activity) of a country's financial institutions and markets.	Index	International Monetary Fund (IMF)
GDPC	Gross domestic product (GDP) per capita is the aggregate value of all final goods and services produced within all segments of the economy by residents of a country during a calendar year, measured at the final purchaser's price, normalized by total population. In this case, the variable represents GDP, estimated at constant 2015 prices in US dollars, divided by the mid-year population.	Logarithmic value	World Bank

Estimation Strategy: We estimate horizon-specific impacts using a long-difference panel framework with multi-way fixed effects. This approach is appropriate because new renewable energy capacity does not adjust instantaneously to policy changes. Instead, the effects unfold gradually over time, making it essential to distinguish between short-run, long-run, and transitional dynamics. Long-difference estimators are particularly well suited for this purpose, as they mitigate serial correlation and short-term noise while preserving sufficient variation to identify structural effects[18].

The specification is

$$\Delta \ln REIC_{i,t} = \ln REIC_{i,t-1} + \underbrace{\theta^{\top} X_{i,t-1}}_{Long\ Run} + \underbrace{\gamma^{\top} \Delta X_{i,t}}_{Short\ Run} + \underbrace{\delta^{\top} (X_{i,t-1} \odot \Delta X_{i,t})}_{Transitional} + \mu_i + \lambda_t + p_r + \varepsilon_{i,t}$$

$Where\ X_{i,t}$ collects $LEGIS_RE$, EXEC_RE, LEXC_RE, FMD, and GDPC. μ_i captures country fixed effects, absorbing time-invariant heterogeneity such as geography, historical energy endowments, or institutional legacies. λ_t captures year fixed effects, controlling for global shocks that affect all countries simultaneously (e.g., fuel price fluctuations, financial crises, or international climate accords). p_r captures region fixed effects, accounting for spatially correlated factors such as regional integration, policy diffusion, or shared infrastructure. The coefficient blocks identify long-run (θ) stock effects, short-run (γ) flow effects, and transitional (δ) interactions between stocks and flows. We mean-center $X_{i,t-1}$ before interactions to ease interpretation. The design follows best practice for heterogeneous panels with high-dimensional FE[32-34]. Full translog motivation and Euler constraints are provided in Appendix A & B.

Data availability: All datasets used in this study, along with detailed descriptions, are publicly accessible at https://github.com/ksohag/Green-Governance-.

Code availability: The analyses were conducted using several computational packages, including *R* and *Stata*. The corresponding codes are available at https://github.com/ksohag/Green-Governance-

References

1. Beiter, P., Guillet, J., Jansen, M., Wilson, E., & Kitzing, L. The enduring role of contracts for difference in risk management and market creation for renewables. *Nature Energy*, 9, 20-26 (2024).

2. Sinha, A., Bekiros, S., Hussain, N., Nguyen, D. K. & Khan, S. A. How social imbalance and governance quality shape policy directives for energy transition in the OECD countries? *Energy Econ.* 120, 106642 (2023).
3. Sadiq, M., Talbi, B., Ghosh, S. & Bashir, M. F. How does external debt and governance quality impact renewable energy consumption: novel policy insights from BRICS countries. *Environ. Sci. Pollut. Res.* 31, 43049–43065 (2024).
4. Wang, E., Gozgor, G., Mahalik, M. K., Patel, G. & Hu, G. Effects of institutional quality and political risk on the renewable energy consumption in the OECD countries. *Resour. Policy* 79, 103041 (2022).
5. Tabash, M. I., Farooq, U. & Ahmed, A. How does institutional quality determine energy consumption? Empirical evidence from South Asia. *Manag. Environ. Qual.* 35, 712–727 (2023).
6. Dong, Z., Tan, C., Zhang, W., Zhang, L. & Zhang, L. Are natural resources a blessing or a curse for renewable energy? Uncovering the role of regulatory quality and government effectiveness. *Resour. Policy* 98, 105346 (2024).
7. Cadoret, I. & Padovano, F. The political drivers of renewable energies policies. *Energy Econ.* 56, 261–269 (2016).
8. Wu, L. & Broadstock, D. C. Does economic, financial and institutional development matter for renewable energy consumption? Evidence from emerging economies. *Int. J. Econ. Policy Emerg. Econ.* 8, 20–39 (2015).
9. Evensen, D. & Sovacool, B. K. Political economy of low-carbon electricity: Governance effects across 198 countries. *Renew. Sustain. Energy Rev.* 189, 114016 (2024).
10. Hwang, Y. K. & Venter, A. The impact of the digital economy and institutional quality in promoting low-carbon energy transition. *Renew. Energy* 238, 121884 (2025).
11. Khan, A. M. & Wyrwa, A. Integrating machine learning and econometric models to uncover macroeconomic determinants of renewable energy production in selected European countries. *Energy* 333, 137266 (2025).
12. Khan, A., Khan, B. & Khan, G. Dynamic effects of energy aid in energy transition under the moderating role of regulatory quality. *Sustain. Futures* 8, 100247 (2024).
13. Alsaleh, M., Abdul-Rahim, A. S. & Abdulwakil, M. M. The importance of worldwide governance indicators for transitions toward sustainable bioenergy industry. *J. Environ. Manag.* 294, 112960 (2021).
14. Asongu, S. & Odhiambo, N. Governance and renewable energy consumption in Sub-Saharan Africa. *Int. J. Energy Sect. Manag.* 16, 209–223 (2022).
15. Nawaz, A. & Rahman, M. M. Renewable energy consumption in Sub-Saharan Africa: the role of human capital, FDI, financial development, and institutional quality. *Energy Rep.* 10, 3383–3393 (2023).
16. Zhao, W., Gyimah, J., Yao, X. & Ismaail, M. G. A. Investigating the role of good governance systems in renewable energy transition in China and USA. *Sustain. Futures* 10, 100943 (2025).
17. Saba, C. S. & Biyase, M. Determinants of renewable electricity development in Europe: Do governance indicators matter? *Energy Rep.* 8, 6284–6295 (2022).
18. Hahn, J., Hausman, J. & Kuersteiner, G. Long difference instrumental variables estimation for dynamic panel models with fixed effects. *J. Econom.* 140, 574–617 (2007).
19. Liu, Y. & Feng, C. Promoting renewable energy through national energy legislation. *Energy Econ.* 118, 100384 (2023).

20. Aklin, M. & Urpelainen, J. *Renewable Energy in the Developing World: Policies and Politics*. MIT Press (2018).
21. Pahle, M., Pachauri, S. & Steinbacher, K. Can the Green Economy deliver it all? Experiences of renewable energy policies with socio-economic objectives. *Appl. Energy* 179, 1331–1341 (2016).
22. Sovacool, B. K. Energy policymaking in Denmark: Implications for global renewable energy policy. *Energy Policy* 61, 829–839 (2013).
23. Zhang, S., Andrews-Speed, P. & Li, S. To what extent will China's ongoing electricity market reforms assist renewable integration? *Energy Policy* 148, 111929 (2021).
24. Stokes, L. C. The politics of renewable energy policies: The case of feed-in tariffs in Ontario. *Energy Policy* 56, 490–500 (2013).
25. Beiter, P., Guillet, J., Jansen, M., Wilson, E. & Kitzing, L. The enduring role of contracts for difference in risk management and market creation for renewables. *Nat. Energy* 9, 20–26 (2024).
26. Bourcet, C. Empirical determinants of renewable energy deployment: A systematic literature review. *Energy Econ.* 85, 104563 (2020).
27. Li, R., Hu, S. & Wang, Q. Reexamining the impact of resource rent and corruption control on environmental quality: Evidence from 152 countries. *Nat. Resour. Forum* 48, 12391 (2023).
28. IRENA. *Energy Taxonomy: Classification for the Energy Transition*. https://www.irena.org/ (2024).
29. Climate Change Laws of the World. https://climate-laws.org/ (2024).
30. International Monetary Fund. https://www.imf.org/ (2024).
31. World Bank. World Development Indicators. https://databank.worldbank.org/ (2024).
32. Wooldridge, J. M. *Econometric Analysis of Cross Section and Panel Data*. MIT Press (2010).
33. Baltagi, B. H. *Econometric Analysis of Panel Data*, 6th edn. Springer (2021).
34. Correia, S., Guimarães, P. & Zylkin, T. Fast Poisson estimation with high-dimensional fixed effects. *Stata J.* 20, 95–115 (2020).
35. Bodansky, D. The Paris Climate Change Agreement: A new hope? *Am. J. Int. Law* 110, 288–319 (2016).
36. Falkner, R. The Paris Agreement and the new logic of international climate politics. *Int. Aff.* 92, 1107–1125 (2016).
37. Green, J. *The Climate Club: How to Fix a Failing Global Effort*. MIT Press (2021).
38. Hale, T. Catalytic cooperation. *Glob. Environ. Polit.* 20, 73–98 (2020).
39. Keohane, R. O. & Victor, D. G. The regime complex for climate change. *Perspect. Polit.* 9, 7–23 (2011).
40. Nordhaus, W. Climate clubs: Overcoming free-riding in international climate policy. *Am. Econ. Rev.* 105, 1339–1370 (2015).
41. Ostrom, E. Polycentric systems for coping with collective action and global environmental change. *Glob. Environ. Change* 20, 550–557 (2010).
42. Sovacool, B. K. & Van de Graaf, T. Building or stumbling blocks? Assessing polycentric energy and climate governance. *Energy Policy* 118, 317–324 (2018).
43. Tibrewal, K. & Venkataraman, C. Climate co-benefits of air quality and clean energy policy in India. *Nat. Sustain.* 4, 305–313 (2021).

44. Klingler, M., Ameli, N., Rickman, J. et al. Large-scale green grabbing for wind and solar photovoltaic development in Brazil. *Nat. Sustain.* 7, 747–757 (2024).
45. Zhang, S., Chen, W., Zhang, Q. et al. Targeting net-zero emissions while advancing other sustainable development goals in China. *Nat. Sustain.*7, 1107–1119 (2024).

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