

# Guidelines for Effective and Sustainable Recycling of Construction and Demolition Waste



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**Abstract** Directive 2008/98/EC on waste (WFD) provides that, within 2020, the preparing for re-use and recycling of non-hazardous construction and demolition waste shall be increased to a minimum of 70% by weight. Beginning from a screening of the current percentage of reuse and recycling, type of recycling (types of waste and destinations) and incentive policies in Member States of European Union-28, the research aims to evaluate the effectiveness of the Directive and possible ways of improvement through a Life Cycle based approach. In this paper the incentive policies and some critical issues regarding current regulations are analysed. Further ways to improve legislation are proposed as well as guidelines, which would have an effect on a local level and are aimed at making the recycling of CDW management more effective and sustainable through Life Cycle Management.

## 1 Introduction

Construction and demolition waste is receiving more attention recently following new circular economy policies [1, 2]. Action plans primarily move towards reduction of waste by recycling, promoting the by-products exchange among companies and supporting digital technology platforms in order to stimulate business opportunities. In this situation, the Waste Framework Directive (2008/98/EC) [3] regains a vital role. It establishes the waste hierarchy, defines the meaning of by-product and the consequent cessation of waste classification. Furthermore, the WFD sets the target for reuse and recycling of non-hazardous construction and demolition waste by 70% in terms of weight, within 2020. In order to define the main critical aspect of the Directive, it is important to highlight that the Article 11 set out, does not include stone and soil. Moreover the percentage of recycling includes backfilling operations, which use waste to substitute other material.

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In the following section, at first, limitations in the statistical database are shown, causing difficulties in monitoring waste management. In spite of the diversity of data, in the second section, this paper gives an overall review of the amount of construction and demolition waste in EU-28 and the material composition of waste, based on the more recent available statistical data, such as Eurostat data. Then, the third part analyses Member States' recycling and recovery rates. This information is based on data provided by Bio Intelligence Services investigations [4] and the research "Resource Efficient Use of Mixed Waste" [5]. These sources give articulated data and information already analysed and corrected, in comparison with Eurostat data that are not so much detailed. Moreover, the destination of waste in recycling processes is analysed. The fourth section analyses policies and incentives of some Member State, with regards to legislative instrument and non-legislative instrument. Finally, in the last section, this paper discusses the main strategies to improve the effect of WDF in order to make it more effective and sustainable within the circular economy vision. The application of Life Cycle Management is the strategy toward sustainability.

## 2 Sources and Data Quality on CDW

In the countries of EU-28, to manage waste recycling and reuse, it's necessary to know CDW flows, but the first critical issue is that it isn't monitored well. Indeed, in the reports published by European Commission and each Member State [4, 5] and in statistical data (e.g. Eurostat, ISPRA, etc.), it has been always reported that the data based on waste flow is uncertain and sometimes needs adjustments and estimations. For example, in Italy, data collection is difficult: the national production of special waste has been quantified from the information contained in the MUD statements (Modello Unico di Dichiarazione ambientale), specifically the data presented in the ISPRA Report [7]. It should be noted that Legislative Decree 152/2006 provides for several exemptions from the obligation to declare, therefore, MUD database processing cannot provide complete information on the production of waste [6]. In addition, the reprehensible practice of the abandonment of waste is not possible to estimate. Production data must therefore be correctly estimated and this constitutes a major limitation of the analysis [7].

Another limit of the available data is that construction part and demolition part are not separated, even if demolition waste stream is larger by weight than construction waste stream, they are different. Construction waste (originated from new construction) is less mixed, less contaminated and its recovery potential is higher than demolition waste because of these characteristics. Demolition waste stream is more contaminated (with painting, adhesives etc.) and more mixed due to the integration of different elements. Furthermore, there is very little information on waste material type. CDW are composed by different quantities of concrete, cement, bricks, gypsum products (e.g. plasterboard, building plaster and gypsum block), ceramic products (e.g. tiles and consumer products), glass and asphalt, each

one with different recycling potential. Finally, the inclusion of excavated material does not seem to be systematic in national reporting. As this flow represents a big quantity in respect of the total amount in construction, demolition and excavation waste (e.g. 80% in France): uncertainty about their inclusion in national CDW statistic is a major source of doubt in the data on CDW. Data limitations make it difficult and complex to compare the amount of waste made by the Member States, and it is the first obstacle to identify efficient waste management.

### 3 Amount of Waste and Material Composition of Waste

The most recent data regarding the amount of waste production in EU-28 and each Member States, is represented by Eurostat Data (Construction—Code F—that includes general construction and specialized construction activities for buildings and civil engineering works). According to the statistical data in EU-28, construction is the main activity that produces waste, contributing to 33.5% of the total waste generated by all economic activities and households in 2014 in the EU-28. The construction sector creates the biggest amount of waste followed by mining and quarrying (29.8%), manufacturing (9.8%), households (8.1%) and energy (3.7%) and other economic activities (15%) mainly including waste and water services and services [8]. It is important to highlight that the value specified for the construction sector includes the quantity of soil. On a European level, the 98% of CDW is non-hazardous waste, that represents the percentage pointed out by WFD.

By observing the statistical data from Eurostat (Fig. 1), there are big differences in total CDW yearly produced among the Member States: France (224 million tons), Germany (199 million tons) and United Kingdom (119 million tons) are the major producers of CDW, followed by Netherland (88 million tons) and Italy (51 million tons). Greece (479 thousand tons), Latvia (453 thousand tons) and Lithuania (425 thousand tons) are the minor producers.

From the total CDW generated, 51% is divided into soil waste and 32% mineral waste. Metal waste is almost 2%, and wood waste around 1%. Other types of waste (such as glass, paper and cardboard, rubber wastes) are less than 1%. The 13% missing from the total CDW represents heterogeneous, mixed and undifferentiated wastes. By making a comparison with other research data, it is shown that when excluding the soil portion, 60–70% (by weight) of CDW is composed of concrete and masonry, followed by minor percentages of asphalt, wood, metal, gypsum and plastic [4]. Aggregates, therefore, are the largest amount of CDW. Asphalt constitutes another major share of the stream but it is usually treated separately, as this fraction is largely collected unmixed with other CDW and it is often recovered immediately on-site.

Country	source 1											source 2
	Total Waste	Metal wastes, ferrous	Metal wastes, non-ferrous	Metal wastes, mixed ferrous and non-ferrous	Glass wastes	Paper and cardboard wastes	Rubber wastes	Plastic wastes	Wood wastes	Mineral waste from construction and demolition	Soil	percentage of recycling and other recovery (soil excluded)
EU 28	851 750 000	14 610 000	1 650 000	3 170 000	850 000	700 000	30 000	930 000	6 610 000	273 300 000	436 930 000	87% *
Austria	40 037 896	83 258	6 973	0	3 122	10 047	654	4 504	108 843	8 933 873	30 320 155	--
Belgium	26 162 103	132 306	5 790	33 257	77 231	80 161	2 715	36 925	588 599	3 228 856	968 457	--
Bulgaria	1 340 281	11 893	315	768	3	8 866	1 146	110	1 721	491 341	137 289	--
Croatia	609 697	128 446	11 623	1 296	1 679	708	276	367	3 274	163 397	262 361	35,0%
Cyprus	632 922	2 298	206	295	0	271	273	186	47	148 384	474 423	58,0%
Czech Rep.	9 335 225	78 463	1 491	1 379	2 173	2 552	217	3 974	12 628	2 190 245	6 874 512	95,0%
Denmark	9 447 823	249 010	24 037	71 156	14 642	3 893	139	7 362	121 772	3 177 114	5 484 991	86,0%
Estonia	660 481	15 095	296	2 909	287	439	173	188	8 036	317 903	276 917	72% **
Finland	16 234 079	42 219	6 887	65 027	109	4 498	7	13 237	379 348	767 934	14 924 200	--
France	224 793 291	1 042 645	138 482	1 725 381	236 926	519 184	14 540	586 498	1 615 120	59 961 711	152 312 797	63,0%
Germany	199 342 097	6 565 925	453 360	186 793	268 349	10	0	99 953	3 043 005	74 111 931	112 661 328	96,0%
Greece	479 846	39 898	0	0	8 698	0	0	29 575	46 504	355 171	0	0,3%
Hungary	3 412 060	40 493	2 317	685	590	3 920	297	3 513	1 986	1 884 933	1 271 028	81% *
Ireland	1 880 330	4 063	0	3 068	17 360	2 075	70	450	14 560	130 677	1 681 877	97% **
Italy	51 332 938	3 620 960	397 084	151 861	72 265	4 456	0	28 366	181 760	34 017 820	11 653 704	76,0%
Latvia	453 688	326	4	153	17	17	43	43	30	452 236	0	--
Lithuania	425 908	17 231	288	355	77	211	784	211	1 724	392 113	1 387	88,5%
Luxembourg	5 879 862	2 238	280	518	1 867	5 075	522	2 035	7 264	501 560	5 342 572	88,0%
Malta	1 240 548	19 162	3 337	13 419	0	29	0	19	521	983 933	0	--
Netherlands	88 171 823	840 968	193 205	125 539	52 367	12 290	0	26 576	1 355 160	18 146 732	5 425 074	98,0%
Poland	16 867 671	183 390	2 961	6 943	960	3 900	1 697	17 134	42 553	3 271 767	12 013 217	92,0%
Portugal	1 495 526	39 425	3 146	19 737	4 464	3 115	884	4 804	33 049	751 301	582 572	--
Romania	1 047 749	5 286	30	617	28	912	187	85	3 919	200 716	603 101	--
Slovakia	1 379 876	17 421	180	162	215	67	213	349	1 667	318 119	275 282	37% ***
Slovenia	812 645	3 825	251	254	3 418	0	221	189	1 231	98 172	445 306	--
Spain	20 357 742	18 648	15 830	18 737	120	5 454	165	6 395	58 641	5 104 107	14 765 894	84,0%
Sweden	8 265 015	50 000	10 000	270 000	500	5 000	300	500	200 000	1 500 000	5 000 000	50,0%
UK	119 646 735	1 356 963	374 094	468 043	86 976	18 553	1 176	58 599	768 833	51 700 882	53 175 861	86,5%

  

type of material %	1,72	0,19	0,37	0,10	0,08	0,00	0,11	1,01	32,09	51,30
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**Fig. 1** Amount of waste, material composition and recovery and recycled rate. Sources Eurostat (source 1) data and Resource Efficient Use of Mixed Waste, Member State factsheet (source 2). Note Table represents the total construction waste, and the main portion of material waste. The table does not report 13% of heterogeneous, mixed and undifferentiated wastes. The percentages of recycling to each Member States are related to year 2012. Percentages with \*are related to 2013, with \*\*are related to 2011, and with \*\*\*are related to 2009. Data in grey cells in last column may contain soil parts

### 4 Recovery and Recycling Rate and Destination of Waste

The recovery and recycling rate of CDW is an important piece of data to define the current state of Member States, with regards to the 70% recovery goal and recycling rates set by the WFD. Nevertheless, this information is very difficult to find and the associated data are not reliable yet. The European “Resource Efficient Use of Mixed Waste” research program [5] tried to fill the gaps and inconsistencies by collecting data from each Member State, based on statistics provided by national agencies. This paper gives an overview of the collected data in Table 1 last column (Fig. 1).

It is possible to observe that the objective of the WFD is already abundantly achieved by many European countries and can be easily reached by many other (Table 1). In the Netherlands around 98% of CDW is recovered (recycling, energy recovery and other recovery), of which 95% is recycled. The amount of landfilled CDW corresponds to only 2% of all CDW. In Germany 96% of CDW are recovered or recycled, and the percentage of landfilled waste is only 4%. Less advanced is the construction and demolition waste management in Italy, where in 2012 the recovery operations accounted for 76% (even if recycling rate has been steadily growing

from 2010, when it stood at 68.4%) and landfilling remains 24% (however, recovered is over than 70%). However, according to WFD, the recycling rate includes reuse, recycling (and other forms of material recovery), as well as backfilling.

Moreover, there are still differences in national calculations: some countries' percentage still contains soil; others do not distinguish between hazardous and non-hazardous CDW and consider total amount. One other main point is the destination of waste recycled to understand if the practices follow measures to promote high quality recycling, as promoted by WFD.

An important overview of the trade market of CDW and hence the destination of waste is given by the final report of European Commission, written by IDEA Consult [9]. This report shows the general situation of waste trade in the EU, in particular the main stream of mineral waste, completed on collected data from many sources (Eurostat 2010, Koumpanis 2008, EAPA 2010, ANPAR 2011, UEPG 2014). The 10% of waste is from new construction, 75% from demolition and 15% from road construction. The IDEA Consult report [9] demonstrates that after collection, around 11% of CDW is sent to backfilling, and 18% is brought to a landfill. The remaining 71% is separated into different materials. Metal, plastic and wood, which are a small percentage with respect to the total amount, come out of the process as recyclable material or energy recoverable. The remaining big amount of inert is recycled (on-site, in order to produce secondary aggregates that are used again in the production of new construction materials, or off-site in stationary recycling plants, where it is separated and crushed) or, when the waste is not contaminated, it is reused, after the cleaning or transforming operation. The 71% includes either reused, recycling, recovery and backfilling activities, such as the use of recycled aggregates (secondary material) to restore mining works. The secondary material goes to the industries in a small portion and the remaining goes to the backfilling (the percentage is unknown).

Concrete, masonry, and mixed demolition debris, after crushing (and certifying the quality) become recycled aggregates, constituting: Recycled Concrete Aggregates (with a large concrete content), Recycled Masonry Aggregates (with a large bricks and mortar content) or Mixed Recycled Aggregates [10].

All of the recycled aggregates types can be used as low performance application in sub-base layers in roads, ground improvements and building foundations. Aggregate use in concrete production requires high density and cleaner fraction, and the use of recycled aggregates in asphalt is limited due to mechanical characteristics, as regulated by standards (e.g. EN 12,620, Aggregates for concrete; EN 13,043 Aggregate for bituminous mixtures and surface treatments for roads, air-fields and other trafficked areas). In fact, in civil construction and industrial product (such as gypsum, concrete, ceramic and bricks productions) only 6% of material used is from recycled material, while 94% come from virgin materials [9]. It is possible to understand that the major applications of recycling aggregate are downcycling. This issue is also favoured by the fact that in most countries the production of natural aggregates dominates [9]. In the Flemish Region, the main CDW are recycled granulates, mainly used for road construction and similar

activities. In Italy, ANPAR (National Association of Recycled Aggregates) reports the recovery percentages about the portion of recycled aggregates: these secondary materials are widely used in roadworks for substrates and fillings (almost 60% of the total recycled in 2013); the remaining is used for pavements and backfilling [11]. In Italy the use of recycled aggregates into new concrete production is not widely practiced, due to the regulations (DM January 14, 2008). This regulation indicates the maximum percentage use of recycled aggregates into new concrete, compared to “concrete strength classes”. For example, concrete class C30/37 allows a maximum 30% of inert derived from concrete or reinforced concrete waste. Buildings demolition rubble are only allowed for non-structural concrete C8/10 [12]. In addition, the regulation imposes mandatory laboratory tests about aggregates compliance. Through interviews obtained, ANCE (National Association of Builders) states that the tests are too expensive and require too much time.

Price is another point that obstructs the use of secondary materials in new industrial products. A defining factor is transport costs. Secondary materials are, in general, not much cheaper than primary resources and can even be more expensive. The distances among natural aggregates buyers, suppliers, sellers and consumer cannot be too large. Interviews evidence that the costs of transport could double for every additional 30 kilometres travelled [9]. As a result, this characteristic makes the markets for mineral CDW very local.

## 5 Policies and Incentives

Waste prevention and sustainable recovery strategy is achieved through a defined legislative framework, favouring conditions for a sustainable management of CDW among operators and consumers (designers, planning supervisors, public administration, construction companies). Overall policies that incentive the recycling and recovery rate growth are related to waste disposal (landfill taxes) and exploitation of natural resources reduction (aggregates levies or taxes). Each of these actions can enhance price differences between recycled materials and virgin materials, towards the economic attractiveness of secondary materials. The largest obstacles for recycling CDW is cheap availability of low cost raw materials. Therefore, there is not a large economic incentive for business. A solution could be to increase (through taxation) the price of raw material goods [13]. Aggregates levies or taxes is considered more effective to make economically advantageous secondary materials. It concerns a direct relation with the price of virgin aggregates, instead landfill taxes could implicate illegal disposal risks [12]. The final report of Bio Intelligence Service [14] provides an overview between the CDW tax rate and the percentage of CDW recycled. It shows that there is no significant relationship between the tax rate and the amount of waste recycled. To reduce significantly illegal traffic, Belgium (Flanders) introduced a mandatory pre-demolition inventory of the types/quantities of materials present in

buildings (for non-residential buildings with an enclosed volume over 1000 m<sup>3</sup>) to identify hazardous and other waste fractions [15].

To explore other main guidelines to incentive the recycling percentage, it is interesting to analyse the countries that have the highest percentage of recycling, based on the country screening factsheet of the research “Resource Efficient Use of Mixed Waste”. Analysing Germany and The Netherlands’ policies, it is noted that both countries had waste regulation before the WFD.

Germany took the initiative in 1996 through a voluntary commitment to cut in half the amounts of CDW landfilled. The high recycling rates were achieved although there is no national ban on landfilling of CDW material. The initiative “Kreislaufwirtschaft Bau” (Circular Economy in Building) has been documenting mineral construction and demolition waste arising and treatment since 1995, setting waste reduction targets. It can be seen as one of the main reasons for the high recovery rates that are observed today (96%).

With regard to The Netherlands, since January 1st, 1994, the Dutch legislation on waste can be found primarily in the Environmental Management Act (Wet Milieubeheer; Wm), which already sets the waste hierarchy (used before the WFD). However, a large number of issues was not in the law itself, but was regulated at local level: provincial environmental regulations or municipal waste regulations (such as landfills and waste bans).

Furthermore, these countries have many legislative instruments that follow the WFD. In Germany the Ordinance on the Management of Municipal Wastes (Gewerbeabfallverordnung) contains national obligations for selective demolition. It defines on a national level, separation and requirements regarding the pre-treatment of CDW.

In The Netherlands, in order to implement Directive 2008/98, the Minister of the Environment submitted a proposal in 2010 to amend the Environmental Protection Act (Wm), the Law on environmental taxes and the Law on economic offenses.

The main strategies present in the countries with high level of recycling, (differently to country with low level of recycling) are non-legislative instruments. They contribute to create good conditions for the management of CDW recycling. In Germany several municipalities already integrate the preferred use of recycled construction material in their calls for tenders (even if this is not a standard). Demolition has to be performed by authorized companies, which need to be certified (Regional level). Moreover, different regional standards for recycled CDW exist and are defined in the respective waste management plans. In Germany, Sustainable Building Certificate is an important driver. A voluntary scheme run by the German Sustainable Building Council (DGNB) encourages the practice of recycling. It sets particular criteria regarding CDW.

Also in The Netherlands, the role of non-legislative instruments is strong. Relating to pre-demolition audits, it is mandatory to have a demolition license for every demolition with more than 10 m<sup>3</sup> of waste (Model Bouwverordening MBV). Selective demolition (Kaderrichtlijn Afvalstoffen) companies must be registered in order to carry, collecting or trade waste. Moreover, a “passport” for buildings was developed which contains what substances are in the materials of the building.



Tools are used to understand what is possible to do in construction and demolition in order to be sustainable. Eventually it leads to obtaining the BREEAM certificate. The Netherlands promotes initiatives focused on trying to get the quality of reusable concrete as high as possible and offering sustainable wood.

In Italy, there is the legislative instrument Decree 205/2010 as implementation of WFD. In legislative framework the drive of Green Public Procurement (GPP) requirements, that incentive waste recovery, has important role. Indeed, the use of recycled materials becomes mandatory and strategic in the assignment of the tender. The project must contain second raw materials, at least 15% by weight on all materials used (with 5% in non-structural materials). This percentage must be documented. Moreover GPP requirements promotes the application of Environmental Product Declaration. Instead, non-legislative instruments (such as pre-demolition audit, demolition license etc.) are not so much promoted.

Overall, in countries where non-legislative instruments are not highly used, the recycling percentage is low.

## 6 Guidelines for Sustainable Strategies

Given that the Directive 2008/98/CE shows the percentage in weight, and the 60–70% (by weight) of CDW is composed of concrete and masonry, as a result the directive target is achieved in the majority of Member States. Indeed, as a result, it was found that in many countries, the target is achieved through the recycling of aggregates for road foundations, earth works and backfilling, even if these works are not “high quality recycling” as required by Article 11 of WFD (and resulting in a loss of economic value of inert).

To achieve a sustainable recycling management, it is important to consider material recycling with the approach of Life Cycle Management, as an integrated approach, based on technology and process defined considering LCA and LCC results.

This approach can be useful to support the waste hierarchy of WFD, to make a decision about the best way to reuse, recycle or dispose waste materials. It is clear that since the CDW has high “embodied” environmental impacts (in terms of the investment done to produce what turn into waste), the re-use or recycling can eliminate the need for further investment in primary production [16]. Obviously prevention is often the best possible solution for the environment avoiding the replacement and prolonging the service life of components.

A life cycle approach is important to move towards an upcycling of waste, to improve the economy and creating an effective sustainable market.

To make CDW recycling management more effective and sustainable it is important to apply a LCT in non-legislative instruments.

The objective of this paper is to suggest sustainable guidelines to improve work of legislative operators, and local authority action. Following, the main important



point made by analysing the best practice and the application of Life Cycle approach.

Regarding legislative improvements, it is important to suggest:

- (1) to look at quality rather than quantity: value the best material to be recycled in terms of effectiveness and sustainability, not heavier ones; through the separation of recycling targets (percentage well-defined for every type of waste material) related to the quality target;
- (2) to improve the waste hierarchy: support decisions of the type of recovery with an assessment of quality of recovery, in term of environmental and economical sustainability (support by LCA and LCC). As well as to promote upcycling directions;
- (3) to reassess the inclusion of some actions considered in the percentage (70%) of recycling rate: “backfilling” (is a low quality recycling) and “preparing for re-use” (this is only storage of material to check, clean or for repair recovery operations, until the real recovery stage).

With regard to non-legislative action of local authorities, that is useful to improve the sustainable local waste management, they should follow these guidelines:

- (1) to improve selective demolition, which helps prepare for the reuse process;
- (2) to use restrictive pre-demolition audit in order to have the information about the consistency and quality of material; to evaluate the environmental impact with LCA and the market opportunities with LCC approach before deconstruct a building. This information is important to make a decision of end-of-life stage, to drive resource efficiency and effectiveness of refurbishment and demolition projects. Thus preventing unnecessary waste and maximizing the value and sustainable use of construction and demolition waste;
- (3) to use mandatory building passport and material passport (for new construction): encouraging the use of Environmental Product Declaration (EPD) in order to facilitate the assessment of construction products and material sustainability, promoting recycled material. One of the current problems is the high application of composite materials (not recyclable at end-of-life) used due to their high thermal performance in energy-efficient buildings or due to their recycled content.
- (4) to apply mandatory environmental criteria in GPP on waste management: to improve waste recovery and sustainability of buildings through building benchmark LCA based in the assignment of public procurements.

To overcome the obstacles created by the lack of consumer and operator awareness is fundamental:

- (1) to increase skills and knowledge: to eliminate the lack of confidence in the quality of materials from recycled construction and demolition waste;
- (2) to support professional training of the operators within the demolition sector;

- (3) to use environmental labelling of recycled (and non-recycled) products to encourage awareness and stimulate a sustainable waste market.

## 7 Conclusion

In this paper, an analysis of CDW recycling and recovery was conducted, with the objective to find possible applications of a life cycle approach in support to recycling practices policies. The first obstacle to a sustainable waste flow management is the gaps in the database for monitoring CDW quantities. CDW is the main stream of waste in EU-28, and almost 60% of the weight is composed of concrete and masonry materials. It is possible to observe that many countries have already abundantly achieved the target set by WFD of 70% recycled waste. The main recycling practice focuses on inert waste. It is used as low performance application (downcycling) of sub-base layers in roads and backfilling, since aggregate is used in new concrete production or asphalt it requires high performance (following standard regulations).

Regarding the policies and incentives of some Member States, the analysis shows that the most exemplary countries have many legislative instruments and many non-legislative instruments (e.g. criteria in public tenders). Non-legislative instruments play a crucial role in the waste management target. The Life Cycle approach is needed in order to set more effective, for the environment, and more cost-efficient, for stakeholders, policy targets. Policies at regional level should be encouraged to move towards a Life Cycle Management, therefore achieving a sustainable management of waste within a new definition of circular economy.

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