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Climate Adaptation Finance Mechanisms: New Frontiers For Familiar Tools

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1. CLIMATE ADAPTATION FINANCE MECHANISMS: NEW FRONTIERS FOR FAMILIAR TOOLS

In the framing article of this Special Issue, Colgan (2016) has argued, as others have in recent work (Wagner and Weitzman, 2015; Stern, 2015) that funding adaptive responses to climate impacts presents special, if not unique, economic challenges and demands. These include perverse capital valuations in which negative interest rates imply limitless ceilings on expenditures, problematic intertemporal cost and benefit transfers across generations, and rampant uncertainty. Nonetheless, local and state governments collectively face daily investment and construction decisions about sustaining infrastructure and managing the built environment that will have a decades-long effect. These decisions both affect and will be affected by future conditions, but we must address how to pay for them today. Hence, regardless of whether vexing aspects of climate adaptation have been recognized, let alone coped with, the decisions about it are already in play.

2. SCOPE OF THIS ARTICLE

The purpose of this article is to ground the complexities of adaptation finance for public infrastructure and risk management in a discussion of the tools and strategies available to pay for it, largely as it affects the local government level in the U.S., where much investment and construction must take place. There are emerging lessons about how to use such mechanisms and how to approach such decisions. Existing tools used in new applications and combinations present useful opportunities.

Although not a theoretical discussion, we address several relevant principles—mainly the rational nexus test of who benefits and who pays—that strongly influence public acceptability of such funding schemes. Colgan (2016) uses a variant of the well-known public goods definition matrix to identify possible finance mechanisms by who benefits and who pays, following the logic of what is a public versus private good or service. The discussion and examples herein will show that those boundaries are not only quite permeable but that successful development of adaptation finance mechanisms will often require careful navigation of mixed public and private goods and burdens to achieve needed

results. Although mixed goods and services are a well-known phenomenon in economics, hybridizing such goods and services means paying for them is not likely to be a defect, but rather a virtue, in adaptation. Examples here come from civil infrastructure, particularly stormwater management. Adaptation takes many forms and must address both coastal and inland hazards including those from water and weather, heat, disease and impacts on safety, public health, and all aspects of the economy. We will focus on water and weather-borne hazards and the adaptation of the human-settled environment to manage growing impacts. The financing strategies at local and state scales discussed here can apply across the landscape, especially when not limiting the sources of funds to limited federal programs, which is exactly the point here. Some examples of innovative financing are also drawn from the energy conversion arena (e.g. adding solar electric capacity locally), but that is not the focus.

The growing and still recent local government experience with stormwater management funding is an opportunity to learn about aspects of adaptation finance necessary to effectively utilize money streams that will come from multiple sources including new bond market utilizations, which will be discussed in part, as well as local tax and fee revenues. Finally, the focus is on the United States situation in the necessary context of its institutions and the boundaries of action those entail. Other nations' situations must be considered on their own terms.

3. THE U.S. INFRASTRUCTURE CLIMATE FUNDING DILEMMA

It is no revelation that aging infrastructure in the United States already presents a financing challenge that has yet to elicit a comprehensive framework for response at any level of government. By many estimates the entire potable water supply system will need to be replaced over the next few decades—a problem highlighted for the public by the 2016 lead emergency in the water system of Flint, Michigan. More systematically the American Society of Civil Engineers (ASCE) 2013 Report Card on America's Infrastructure gave the nation's physical plant a grade of D+, with $3.6 trillion in overall infrastructure needs by 2020 of which $633 billion is for water and wastewater systems and another $150 billion potentially for new stormwater demands, (ASCE, 2013).

3.1 The Limits of Federal Financing

The U.S. Environmental Protection Agency (EPA) recognizes stormwater as the nation's most significant water pollution control challenge because of urbanization and increasing impacts of the changing climate (Milly et al., 2008). Where sea level rise (SLR) and larger future storms are added factors, coastal communities and landscapes face even greater impacts, such as the unexpected $65 billion worth of damage caused by Hurricane Sandy in the New York City region in 2012. Thus U.S. localities are faced with large needs to maintain, replace and further adapt fixed water and wastewater treatment facilities *and* to manage the distributed, multi-actor stormwater problem for both public and private property, which is growing. To illustrate the shortfall in meeting this need, Canada is spending 10 times more money per capita on stormwater at mid-decade than the United States. Thus, a very modest estimate of what the U.S. should be spending at present would boost the current $8 billion U.S. annual expenditure to $80 billion as a comparable proportion of GDP.

Limited federal funds fall far short of these needs. A principal federal vehicle for funding domestic water infrastructure, the State Revolving Funds (SRFs) created under the Clean Water Act, have provided an important tool for states and their localities to primarily address wastewater and water supply facility needs. SRFs provide low-interest loans for investments in water and wastewater infrastructure and have recently begun to slowly add funds for nonpoint source pollution control (stormwater). An SRF receives its initial capital from federal grants and state appropriation contributions then issues bonds guaranteed by this capital. It then "revolves" via repayment of principal and payment of interest on outstanding loans. The SRFs lack funds to meet known needs and this "gap" has recently been addressed by Congress with the passage of Title V of the Water Resources Reform and Development Act (WRRDA) of 2013, which provides an additional source of funds for large (i.e. $20 million or greater) facility projects primarily for water supply and wastewater fixed facility needs but not for stormwater management. The approach leverages federal funds by providing new low-interest underwriting of loans for such projects, and can supplement SRF projects.

This new program is still being deployed and it is unknown if it can bridge the funding gap for primary water supply and wastewater facilities alone. As of this writing it was still not in full operation. Managing stormwater is also vulnerable to climate change and has only slightly been addressed with SRF funds. The US EPA

has begun vigorously promoting public-private partnerships (known as P3s) to address water infrastructure needs, primarily in terms of operating agreements and newer design-build-operate projects involving private firms. In a P3, providers responsible for public water supply and sanitation systems can be owned, financed, operated and maintained by either a public entity, a private company, or both, and can share these responsibilities through public-private partnerships. As the rest of this article argues, this is not the only mechanism to tap more funds for addressing adaptation needs that are dispersed and highly influenced by climate change, such as stormwater.

3.2 Public Private Partnerships as Remedy to Federal Shortfalls

Public-private partnerships, in which the government contracts private entities to perform different functions, have garnered a great deal of federal attention. Such contracts have long been part and parcel of construction projects, including that of the Pentagon in 1942. The Miller Act of 1935 reformed federal use of private contractors by requiring performance bonds to protect the public. Modern public-private can be used to finance, build and operate projects, such as public transportation, wastewater facilities, parks and convention centers by providing private capital especially where timely public funds are unavailable (e.g. due to indebtedness levels). The private entity can also operate a service under such agreements, which typically have a functional lifetime of 20 to 30 years. The contractor earns operating revenue by a "concession," either through payments from the public entity or direct service charges to the users. A variety of Internal Revenue Service and Securities and Exchange Commission regulations determine how these agreements can be configured.

These arrangements have mainly involved physical public facilities. A celebrated (among specialized circles) and recent innovation has been the 30-year, $100 million agreement between Prince George's County, Maryland and the private firm Corvias Solutions of the Corvias Group, Inc. to fully operate this rapidly growing, heavily urbanized county's stormwater management program as an enterprise (Corvias Group, 2014). Other major urban counties in the Chesapeake Bay watershed are likely to follow suit (University of Maryland Environmental Finance Center 2016—hereafter UMD EFC). In such arrangements, the government entity pays the operator for this service. Like a growing number of localities, the county has instituted a stormwater utility fee—a money-raising

mechanism to be discussed below and elsewhere in this article as an example of a conventional tool (user fees and surcharges) extended to new problems and situations (dispersed stormwater management rather than a facility usage fee like a water supply or a park).

The significance of stormwater utilities is that, rather than charging users for a metered service (such as a water supply, toll road or entrance to a sports facility), this arrangement involves a broad system that is both a private and public good. Such fees are based on measures of each property's contribution to storm runoff, but also contribute to a systemic level of management of the environment, which, as it has non-excludable benefits, cannot be considered private goods. This represents an innovation in that stormwater utilities, as we will argue in the following sections, represent an expansion of existing public fiscal latitude and options for funding environmental services.

4. PROPOSED AND DEVELOPING FINANCIAL INNOVATIONS

Whether coastal or inland, the local and state levels are the necessary context to examine emerging tools to pay for adaptive action to respond to climate impacts. Though existing tools provide many opportunities for novel deployment to fund adaptation, there are also needs for institutional innovation at both state and federal levels to facilitate leveraging and combining funds in new ways—for example through more such arrangements as that in Prince George's County. There is also growing high-level interest in market-based funding mechanisms including trading schemes and catastrophe, resiliency and green bonds. Nonetheless, in further discussing those new schemes here and in later sections, it is also important to recognize how the local project scale remains a critical element in utilizing any such funds and how existing tools represent innovations when configured for new purposes.

Stormwater control funding and management schemes as an area of everyday innovation have become a major applied industry as well as a key local government function. It is a prosaic arena that perhaps has not received the attention deserved in adaptation economics. Complex and still sparsely implemented mechanisms—trading markets and new bond products—do not tell the whole story of how local governments are pursuing approaches that may integrate public and private resources in projects and programs. This trend might be further represented here by

Figure 1, an alternative to the classification of finance mechanisms strictly in terms of who pays and who benefits, because those boundaries are permeable and dynamic.

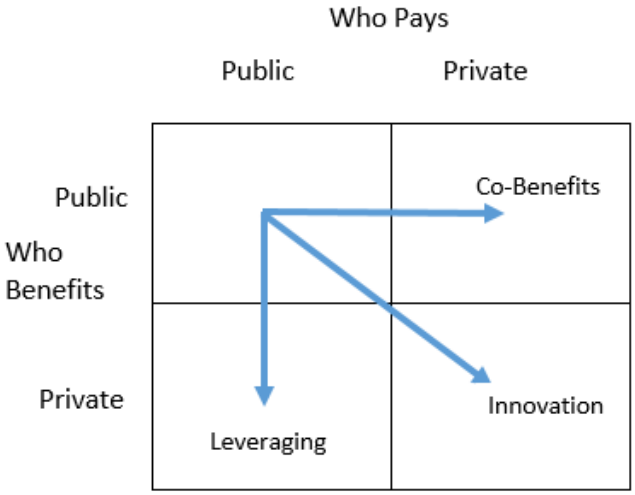

Figure 1. Desirable dynamics in public-private resilience finance

Here the role of public investments and organization is to leverage and facilitate private participation as well, and innovation that creates multiple co-benefits which allows for the leveraging. Each of these finance arenas—new bond products, market trading schemes and lessons from stormwater finance—will be discussed as well as some of the institutional demands involved.

4.1 Catastrophe and Resilience Bonds

In the face of federal resource limits, both tapping private resources more effectively and the pursuit of more effective project approaches are growing directions for local financing strategies. Catastrophe bonds have thus received new attention as one means to raise private funds for post-disaster recovery in an innovative manner. The Rockefeller Foundation-funded re:focus Partners group has proposed a framework for better promoting such catastrophe-bond-like investments and possibly to tie variable investment returns to risk reduction resulting from the local use of the bond funds (re:focus Partners, 2015a).

The catastrophe bond as insurance strategy does not, however, address the need for proactive investment to transition to resilient infrastructure in the first place. Resilience bonds, another new bond product receiving attention in specialized circles, are a potential means to fund such action. Green bonds, a term for the type of social and economic benefits to be funded, have emerged to be applied largely to energy efficiency and renewable energy projects with readily identifiable benefits over time. There are lessons about the use of such bonds for distributed (i.e., multiple household or business sector) energy conversion projects that are useful to consider and are discussed later in this section. But resilience bonding for long-term hazard reduction actions will require more challenging specification and monetization of benefits of avoided costs or damages. Moreover, pre-emptive adaptation is still an immediate local responsibility. That is the level where benefits are created and thus become trans-actable through the inventive design of the projects to be funded.

The frontier for true resiliency bonds may be "assetizing" risk-reducing adaptation actions. For example, investors would provide funds for such actions within a defined area such as a city or county or regional feature like an area of coastline. The resiliency-bond-as-insurance concept being promoted by the re:focus Partners LLC REBOUND project is a step towards this as shown on the following page in their Figure 2 (re:focus Partners LLC, 2015a). As bond funds are used to make investments that reduce risk, the insured local government entity would receive a rebate which is a reduction in the bond repayment based on the presumed better-protected capital investment by the bond buyers (i.e., a lesser chance of triggering the damage loss level that requires paying out capital to the insured).

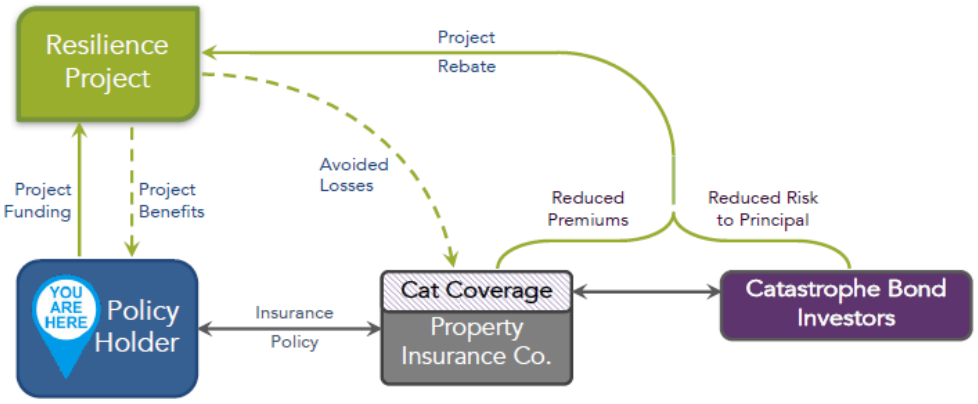

Figure 2. Resilience bond concept (re:focus Partners, 2015a)

However, this value capture scheme for adaptive risk reduction is currently only a prototype and would have to be implemented at a scale large enough to create a market. Localities may need to incrementally improve risk reduction until the conventional bond market responds with preferential rates for further infrastructure investment. Nonetheless, for more than 50 years the natural hazards community has barely achieved necessary progress in risk reduction (See Mileti, 1999).

State infrastructure banks can play a larger role in public adaptation finance. They are an essential conduit for local project funding and are being extended in new ways via local project and program design to climate-relevant adaptation and to private actors. But the institutional configurations vary from state to state and larger industrial states have more to offer. For example, in Pennsylvania the state's 2013 General Assembly session innovatively expanded the authority of PENNVEST—the Pennsylvania Infrastructure Investment Authority—to include stormwater and nonpoint pollution projects, including private as well as public borrowers. PENNVEST has also underwritten some of the construction of Lancaster's green infrastructure projects discussed in a later section.

The terrain of state infrastructure loan and bond underwriting agencies is complex: for example, the Pennsylvania Infrastructure Bank (PIB) and PENNVEST are two different authorities, the former of which deals with funding for all modes of transportation works (road, rail, air, sea) in the state. Explaining the institutional landscape nationwide is beyond the scope of this article. State underwriting authorities will play a major role in any effective solutions to funding

climate adaptation at the local level and in utilizing private capital markets, but alignment with those purposes must be developed on a state by state basis.

The energy conversion arena provides a useful example of how the existing bond market, together with local fiscal revenue tools, can propel innovation in local adaptation. These efforts contribute to the arena of climate change mitigation (greenhouse gas reduction), which aims to achieve de-carbonization. Attention should be paid to the translatable lessons from one use of such fiscal mechanisms to other arenas, e.g. from the local-scale energy conversion setting to other local adaptation project situations.

Energy projects for de-carbonization at both large (e.g., power utility) and smaller (household or business property) scales have financing advantages that hazard reduction does not. For example, the creation of energy efficiency savings and actual power generation are goods for which there is indeed a market. City and statewide adoption of official goals for climate mitigation has led to financing programs to spur distributed household and business installation of solar electric panels.

In 2007, the city of Berkeley, CA created a citywide Sustainable Energy Financing District to enable use of a pilot-scale revenue bond to provide funding to residential and commercial building owners to install solar electric systems. The upfront costs of solar conversion can be prohibitive for individual owners but through this approach the bond funds are repaid through an additional property tax increment over 20 years, like a mortgage. Palm Springs, CA soon followed suit with this model that Berkeley named FIRST—Financing Initiative for Renewable and Solar Technology. Nonetheless, Berkeley's program faced federal challenges regarding bond management.

The Federal Housing Finance Agency (FHFA) questioned the acceptability of the bond provisions and borrower qualifying procedures involved in Berkeley's agreement with their bond purchaser, a small venture firm called Renewable Financing, created by a former Berkeley mayor's office staff member who was one of the champions of the concept. Among the issues was the incompatibility of the lender's requirements for lien superiority (first call on borrower defaults) with the expectations of the underwriters of most home mortgage loans—Freddie Mac and Fannie Mae (Lord, 2010). Berkeley's pioneering program eventually disbursed its small initial bond fund to local property owners and went fallow for a time. Climate

Solutions, an organization promoting energy conversion, has argued that this is one of the prime examples of how "… local government has a critical role to play in climate leadership galvanizing stakeholders, bringing focus to zones, and leveraging public financing" as well as creating financial innovation (Tucker 2009).

Berkeley's experiment has served as a model for state-managed Property Assessed Clean Energy (PACE) programs in 21 states. These programs continue to evolve as individual states take action. For example, at this writing the proposed commercial and residential PACE programs in Connecticut are expected to provide access to private financing, with, significantly, a senior lien for qualifying resiliency investments—including hurricane and flood-proofing—that can be repaid via a benefit assessment on the owner's property tax (French et al., *in press*).

The supply of such green bonds worldwide grew by twenty percent between 2014-2015, but an International Energy Agency 2014 analysis estimated that $53 trillion U.S. are needed globally to meet greenhouse gas mitigation targets adopted by signatory nations. While adaptation funding is a different matter, this gives an idea of the scale of capital needs for dealing with the future. The director of the nonprofit Clean Bond Initiative (CBI) noted that while investment banks and other international investors are raising funds for energy investing, "they just can't find places to put their money." At the same time, CBI has also complained that "the U.S. corporate market is a big market, so the fact that it's not playing its part is worrying for us all" (Douglass 2015). Thus, bonds as a financing solution will require attractive and viable projects and programs to be conceived to mobilize capital markets sufficiently, an interactive race that has hardly begun for adaptation.

4.2 Trading Market Schemes

There is also growing interest in market-based strategies such as trading schemes. While much debate surrounds national-market strategies such as carbon trading, which could influence large scale energy supply, product design, manufacturing and other major systems if fully implemented, localized market strategies for nutrient reduction credits for pollution control have begun to emerge in a few places with the most extreme needs and capacity to innovate, such as the states and localities of Chesapeake Bay, at the local government and watershed scales (Chesapeake Bay Program, 2016). Nutrient trading is a new mechanism and requires a framework to establish a marketplace for transactions, again with a role for state government to reach scale. A recent Chesapeake Bay Forum on

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Environmental Finance conducted by the EPA Region 3 Environmental Finance Center at the University of Maryland reported that:[1]

> While Maryland's Nutrient Credit Trading Program has not yet seen much trading activity, its web-based Marketplace and Trading Registry is a good model of well-conceived market infrastructure. The portal includes a tool for estimating credits generated by BMPs, and it serves as a central place for buyers and sellers to make transactions (UMD EFC 2016:17).

Such pollution trading is driven and defined by pollution control requirements of the Clean Water Act (e.g. TMDL limits—Total Maximum Daily Loads of specified pollutants such as nitrogen and phosphorous). This has tended to emerge so far only where there is a well-defined resource—for example Chesapeake Bay—in which many actors including local governments and property owners all play a role in creating impacts.

Trading schemes to engage in adaptive and proactive risk reduction for infrastructure and communities present greater challenges in terms of defining benefits and how to distribute those benefits to the receiving traders in relation to the costs of actions assumed by the sending traders. For example, why should some property owners choose to buy credits from other property owners who have raised a road to avoid storm surges? There is not a clearly tradable benefit in and of itself by which the former can utilize the value in avoided proximate area damages of the latter's action. Yet there is a demonstrable need to raise, harden or move many such roads across coastlines to adapt to sea level rise and storm surge impacts. There is a community benefit to risk reduction even beyond that which benefits the property location, but it is dispersed as an externality beyond the transaction. Trading schemes at all levels remain controversial in that there is an implicit if not explicit

[1] The Environmental Finance Centers (EFCs) are a nationwide network of university-based teams sponsored by USEPA in its 10 regions since the 1990s to address the question of "how to pay" for environmental improvements. Following the heightened need for innovation, the EFCs in EPA Region 4 (University of North Carolina at Chapel Hill) and Region 3 (University of Maryland) have held recent expert regional forums on emerging trends in environmental finance, in 2014 and 2016 respectively (UNC EFC 2014; UMD EFC 2016). Both forums, attended by public and private leaders representing all three levels of government, utilities, and the finance sector, focus on the need for and conditions that will foster greater private engagement in environmental resilience projects.

acceptance of some level of pollution, for example. That has been the basis of lawsuits by environmental activists protecting the State of Maryland's nutrient trading scheme for Chesapeake Bay, although it was unsuccessful (Wheeler, 2013). The same questions will arise even more so in trading schemes for adaptive risk reduction: how much risk is acceptable and what are the implications of the variable distribution of exposure within the trading area?

Credit rather than trading schemes have so far been based on regulatory mandates which force the externality back into the picture in a manner to be explained here. There are some systems called "credits" like the Lake Tahoe Lake Clarity Credit Program (Lahontan Regional Water Quality Control Board, 2011), in which the term "credit" simply refers to a technical metric of how much each nonpoint (nutrient and runoff) pollution control measure is likely to contribute to meeting the required TMDL benchmark. This should not be confused with credits that have a monetized transfer value in terms of off-setting a fee, as with stormwater utility credit systems. Many questions remain about how trading schemes can work to enable distributed (many-site) private investment in adaptive risk reduction. The experience with stormwater fees and credits provides some potential insights.

4.3 Stormwater Utilities, Credit Systems and Adaptive Action

Credit systems are already playing a substantive role in the stormwater management arena and being translated into adaptive investments by ratepayers. Stormwater utility fees have set an important precedent for expanding the legitimacy of public service charges to a generalized, systemic environmental impact—too much water, too little of it controlled. It is important to note that the mechanism has often met with public resistance, being called a "rain tax" as a term of political derision implying that the government outrageously wants to charge for a natural process. Yet nothing could better characterize likely funding disputes on the even greater challenge of climate adaptation.

Stormwater utilities provide an opportunity to go beyond simply raising capital and operating funds to spurring the engagement of private parties in adaptation actions in new ways through the offering of credits that offset fees. For a homeowner, that may mean decoupling from street sewers and capturing runoff in a lawn area that has been modified to allow water to percolate into the soil or have slow release after storms. For a commercial or industrial structure, it may mean modifying parking lots or creating artificial wetlands or green roofs. Such practices

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(often bundled under the terms green infrastructure or low impact development) are not entirely new but must emerge at a very wide scale from many smaller actions to create significant resilience. These efforts go beyond the "Minimum Control Measures" for stormwater required by existing regulation of states and localities under Phase 2 of the Clean Water Act National Pollution Discharge Elimination System (NPDES Phase 2) since 1996. But a growing number of communities are pursuing such systemic efforts because the increases in stormwater runoff in some regions due to climate change are causing problems with performance of other Clean Water Act-required pollution control infrastructure (e.g., central wastewater treatment) as well as more flooding. Multi-actor private investment and innovation (use of new green infrastructure on properties) that reduces impacts and adapts to emerging environmental conditions is as much needed for adaptation as are larger-scale public infrastructure investments.

The following credit illustration is drawn from the City of Richmond, Virginia's stormwater utility (another Chesapeake Bay community) using a residential single-family-homeowner's case. Other details apply to multi-family and commercial ratepayers but it is not the intent here to review all such details (City of Richmond, 2013). A homeowner could receive a maximum of a fifty percent fee reduction for installation of a combination of on-site runoff storage, on-site infiltration or other measures that keep excess water from entering and stressing city storm sewerage and waste treatment systems or contribute to flooding. Storage control of the entire housing unit's roof through rain barrels and creating infiltration for the driveways with permeable pavement could earn that half-fee reduction level in Richmond. This system converts part of a transfer payment (the fee) into private investment in actions that have co-benefits on several levels: property improvement, a contribution to risk reduction over time, resiliency and a lessening of the expensive load on public water infrastructure are only some of those *mixed* benefits.

There are also possible pecuniary benefits to the property owner from such "green infrastructure" (GI) improvements. For example, the earliest adopters of such efforts such as Seattle and other Washington State localities and the Toronto metropolitan region have found that GI investments add value to real property (Ontario Ministry of the Environment, 2003). With increasing and expensive water-driven impacts on a variety of local infrastructure from a changing climate—transportation and critical facilities as well as primary waste treatment plants—local governments are going beyond minimum regulatory requirements to engage

the private sector in adaptation at the basic level of home and business properties as this will help reduce combined sewer overflows that impact large, expensive central systems and reduce some levels of flooding.

For example, the Lancaster, PA fee-and-credit system in its first two years (2013-2015) received 47 private property owner applications for credits for green infrastructure private investments, of which over 40 were approved for the exchange. The city has also assisted owners with tapping construction funding from the state's infrastructure bank, PENNVEST (Katzenmoyer, 2015). Lancaster's adopted strategy intends to cover 25 years of progressive stormwater actions, so these credits and resulting private improvements are just a beginning.

Stormwater utilities as enabled by each state's legislation are a matter of local choice. Thus, the option to develop expanded local funding systems that provide credit systems for proportional exchange of private investments that increase resilience is demonstrated by these growing local practices. Whether local governments and state enablers choose to widen such practices to risk reduction, for example, has yet to be seen. Some of the factors that will influence this development are discussed in following sections.

5. PRINCIPLES SUPPORTING THE NEW FINANCE

Figure 1 suggests that we see adaptation finance strategies and tools not as strictly public goods-private goods categories, but as a dynamic process. The principles in Figure 1 describe practical design characteristics of financing mechanisms in terms of three ideas: combing private and public investment where possible; promoting distributed innovation by private actors through multiple means; and supporting both aims by designing uses of resources that aim for co-benefits. A fourth principle—not new to anyone involved in the struggle for more flood and storm hazard mitigation that long pre-dates concern with climate change—is to pursue finance mechanisms that move from post-impact disaster recovery funding to proactive risk reduction and increased resilience.

One of the vital and at times hard-won lessons in winning public approval for the new stormwater utility fees just discussed has been the need to engage the public, from the earliest phases of the effort to create the new financing mechanism, in learning how better management will benefit the community (Office of Policy, USEPA 2013). Acceptance must also be gained for the specific means of funding.

To be acceptable, emerging approaches must confront and satisfy the long-standing boundaries placed on American public finance. These are grounded in the utilitarian foundations of the U.S. economic-legal system and are the basis for public finance theory and actual everyday practice. Local governments have two major categories of revenue-raising mechanisms for public purposes. First are general revenue sources in the form of various taxes, especially those on real property for local government actions. Nonetheless, in some states local governments share sales tax revenues directly or indirectly with their states and in a few states, larger localities may impose income taxes.

Traditional local property tax revenues for public goods and services must comply with the constitutional requirement for equal protection and the utilitarian principle of tax benefit equity (Musgrave and Musgrave, 1973). This allows for compulsory taxation to raise a general fund without a specific inventory of everyone's consumption of those goods and services. An important modification to the real property tax mechanism has been the specific enabling by many state legislatures of tax increment financing (TIF) districts in which revenue from the new real estate tax base in a defined area can be sequestered for public improvements that benefit the public but may be used to enable specific development projects. This is but one example of how the tax benefit equity dictum has been loosened, how new value is leveraged and how public and private benefits are mixed.

The second major revenue category includes fees or service charges for public goods and services, such as water supply and sewer utilities. But many other kinds of charges have been devised in recent times, limited only by new needs, inventiveness and success at meeting another type of test: the rational benefit nexus for incurred burden. This rational nexus test has become even more important as local governments have faced new needs to pay for the capital and service costs of growth starting in the 1970s and '80s by inventing many kinds of development impact fees (Nelson and Moody, 2003). Such fees can be successfully accumulated and used for future public improvements, beyond month-to-month or annual service, if the rational nexus between the charges and the needs for infrastructure investment generated by those who are charged (even though they are only part of the constituent population) is present. This ability to charge for prospective public goods will be important to the discussion here and represents the context for development of stormwater utility fees—a later development. We argue that

stormwater utility fees point to part of the future of climate adaptation financing as resiliency fees.

Finally, local government borrowing for capital improvements such as infrastructure and other service facilities that can accrue revenue, such as stadiums and parks, allows for large expenditures to be paid for over time, given state legal enabling, a consenting public and a willing bond or loan market. Funds collected from taxation or fees can be used to amortize payments. Federal funds, such as those available through the State Revolving Funds (SRFs) and other state infrastructure finance banks mentioned earlier for water infrastructure, play a role in contributing to such projects but are limited in dollars and scope. Opportunities to use limited public funds to leverage additional bond investment from private markets is of intensifying interest, as already noted.

5.1 Meeting the Rational Nexus Test with New Mechanisms

Although the principle of uniform taxation or tax benefit equity has been stretched in practice, with both progressive and regressive effects, it has a strong practical influence on everything done in state and local finance. A test is needed to determine legitimate public benefit and equitable imposition of costs.

Taking action to adapt to future risks or to address risk reduction that benefits some areas or groups more than others, and at different times, raises new challenges to funding. Deyle and Smith (2000) noted that the hazards research community has long made arguments that private decisions resulting in more risky locations of real property due to the environment should be taxed more to secure funds for the likely public costs of disaster response and recovery in the future (Burby et al., 1991). Deyle and Smith proposed a system of indices for a risk-based property assessment system for the future public burden generated by hurricane-vulnerable properties on Florida's coast, but no such system has been devised.

Benefit from taxes or fees that are imposed to adapt to future hazards of climate change may appear to violate the tax equity or rational nexus test. The acceptability of special benefit districts as a staple of local fiscal mechanisms still depends on this test. As Deyle and Smith (2000):

> The efficiency of a separate tax or fee for specific services depends on the ability to base the tax rate or fee structure on a measure of

> differential consumption by individual beneficiaries. Special benefit taxes [sic or fees] accomplish this to varying degrees (2000: 425).

The following example from recent research on public preferences for funding coastal adaptation illustrates that local tax and ratepayers' perception of benefits is essential to acceptability of new schemes for adaptation finance.

5.2 Public Preferences Reflect the Rational Nexus Test

In an NSF-sponsored action research project on adaptation in Broward County/Ft. Lauderdale, Florida, community leaders and engaged citizens participated in a series of workshops in which information on expected damages from sea level rise and storm surge through 2060 was analyzed for two heavily urbanized coastal parts of the area (Merrill et. al., In Submission, 2016). The participants in 2014-2015 were engaged in choosing specifications for two alternative adaptation schemes—phased property buyouts versus elevation of properties for selected areas—and benefit-cost analyses were conducted for the avoided damages to be realized from each action versus the investments required.

Participants were asked about relative preferences for different types of local fiscal mechanisms to pay for such long-term adaptation actions. Table 1 (next page) shows a revealing pattern of rankings in the choices: general charging of the community for infrastructure and built environment adaptation—by general taxation means—is least preferred.

Respondents were unlikely to support paying for a risk that someone else has but the respondents do not—i.e., coastal versus inland properties. There were two most-frequently preferred fiscal approaches. One is to use mechanisms like the benefit-assessment district, where a line is drawn around those who will benefit from the expenditures to be made and who will then pay for it. The second is helping to leverage private investment through underwriting loan access for adaptation. (Note that this study did not specify the source of the underwriting).

The long-standing benefit district mechanism satisfies the equal taxation issue because it is based on what the courts have defined as the rational nexus between benefit and charge. But the jurisdiction-wide fees for stormwater management, for example, are a small but significant departure from and expansion of the acceptable definition of that rational nexus for funding responses to broad environmental

problems—like, potentially, climate change. In the middle with mixed acceptance in Table 1 are options for long-term amortization of investments in the future—bonding and loans. (Methods of funding both forms of borrowing—public and subsidized private—were left open). This result is cause for optimism because, as mentioned earlier, adaptation will require present spending for actions that should be amortized in the long-term.

The preferences that align with the rational benefits criterion proved very stable in this case: for example, as Table 2 (next page) shows, when participant rankings were grouped by their stated political affiliations, Republicans gave the lowest average numerical-equivalent scores for every choice, whereas Democrats gave the highest and Independents fell between the two extremes. However, the first and second ranked choices were the same across Republicans, Democrats and Independents, despite some variation among lower rankings. But what will the adaptation actions and their funding mechanisms we hope the public will accept look like?

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Table 1. Comparative Acceptability of Funding Mechanisms for Local Adaptation Action (n=48) (Project Metropole, 2015)

FUNDING METHODs	**ACCEPTABILITY (% of Responses)**						**Rank order**
	Not (1)	**Some what (2)**	**Moder-ately (3)**	**Highly (4)**	**Totally (5)**	**Mean Score[1], S.D.**	
Create a new county-wide resiliency fund based on **property taxes**	18.8	12.5	31.3	16.7	20.8	3.08, 1.4	4
Develop a **special district assessment** (on) properties in areas designated highly vulnerable	10.4	12.5	29.2	18.8	29.2	3.48, 1.3	2
Issue a **bond** (long-term borrowing) to finance public infrastructure improvements	8.3	25.0	20.8	14.6	31.3	3.35, 1.4	3
Create **a low-interest loan program** for flood proofing and elevating **residences**	4.2	10.4	20.8	35.4	29.1	3.75, 1.1	1
Add a **flood resiliency surcharge** on monthly water utility bill (ex: specific to storm water drain improvements)	31.2	20.8	10.4	16.7	20.8	2.75, 1.6	5
Raise the **local sales tax** slightly (options under the law <in FL> are either ½ cent or 1 cent per dollar)	33.3	22.9	18.8	10.4	14.6	2.50, 1.4	6

Table 2. Political Affiliation versus Funding Mechanism Ratings of Acceptability (rank order) (n=46) (Project Metropole, 2016)

Funding Mechanism/Political Affiliation	**Republican n=6**	**Democrat n=24**	**Independent N=16**
Property Tax-Based Fund	2.50 (3)	3.33 (4)	3.00 (3)
Special District Assessment	2.17 (4)	3.67 (3)	3.56 (1)
Long-Term Bonding	3.00 (2)	3.71 (2)	3.13 (2)
Low-Interest Loans for Elevation or Flood-proofing	3.17 (1)	4.08 (1)	3.56 (1)
Flood Resilience Surcharge on Water Bills	2.17 (4)	3.29 (5)	2.31 (4)
Raise Local Sales Tax $ .005 to $.01	2.17 (4)	2.79 (6)	2.31 (4)

6. DESIGNING LOCAL PROJECTS THAT INTEGRATE REVENUE GENERATION AND BENEFITS

Innovation with existing local fiscal tools, leveraging and mixing of public and private resources and creation of co-benefits are all elements of robust approaches that are emerging at the local project level with state and other non-governmental organization support to address the gap that federal funding alone cannot fill. Among other things, these projects generate multiple benefits that can also create revenue opportunities to support innovative infrastructure solutions. Projects must also meet the tests of fiscal rationality for tax and ratepayers and will depend on creative project design at the local and regional levels. Here are four examples of emerging approaches.

6.1 Miami Seawall and the re:focus Partners/Rockefeller re:invest Initiative

Miami/Dade County Florida has devised innovative mechanisms to create value from adaptation by building on local fiscal mechanisms in new ways. The project is one of nine local demonstration projects supported by the Rockefeller Foundation with oversight by re:focus Partners LLC in an infrastructure development approach called the re:invest Initiative (re:focus Partners, 2015b). The re:invest initiative—an eighteen-month experiment in re-imagining infrastructure projects using a new predevelopment process with the nine cities—aimed to generate:

> [...]projects made possible using a new framework for reimagining civic infrastructure systems to create both public value and private investment opportunities, especially for vulnerable communities. (re:focus Partners, 2015b: 3)

"Predevelopment" demonstrations in Miami and eight other cities resulted from a competitive recruitment of the participating localities and systematic implementation of holistic design of resilient infrastructure solutions that innovatively integrate engineering with finance solutions, short- and longer-term steps (much like those pioneered by the United Kingdom in its resilience plan for the River Thames) and a mix of public and private roles and benefits. This is termed a "new predevelopment approach" to infrastructure replacement and innovation (re:focus Partners, 2015b). All its details including principles and specific project

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feasibility analyses and alternatives are beyond the scope of this article but are illustrated using two project examples in Miami, FL and Hoboken, NJ.

The Miami area's 63-miles of legacy seawall is largely owned by private individuals. It is unevenly maintained and has gaps in coverage. Some property owners along the seawall face increasing losses due coastal storms and sea level rise, in addition to skyrocketing flood insurance costs (re:focus Partners, 2015c). On the engineering side, the long-term proposal is to build a seaward skirt-wall on the flawed existing structures, thus protecting and increasing the value of the considerable and increasingly vulnerable property behind it. On the finance side, the initiative has explored redesigning the catastrophe bond and/or pooling public-private funds, both of which revolve around recouping value by reducing risks and avoiding losses in well-planned projects. One way to understand the recapture of value from risk reduction is to view the increased protection of properties as part of a new type of broad tax increment financing (TIF) district in which the increased tax base due to redevelopment/development of protected lands could be used to amortize the hazard mitigation efforts. Theoretically, the re:invest initiative would expand the scope of both TIF districts and special assessment districts to cover capital as well as O&M costs for such projects.

This is a summary of the complex ideas in the Miami city report which readers should study for detail. The value-recapture proposals discussed in this section must analyze expected costs of no-action versus avoided losses and new value as a benefit and how that benefit will be accrued to public and private actors.

Although the re:invest framework argues for "large-scale infrastructure", the initiative also maintains that localities should pursue portfolios of multiple projects "at scale". In other words, they should tailor integrated projects to local benefit and revenue opportunities of all sizes and pursue these efforts as part of an ongoing strategy rather than just specific projects (re:focus Partners, 2015b). There are three more examples that illustrate the potential role of distributed, smart project design. Two are driven by private foundation seed funding for the project ideas and design, in Hoboken, NJ and Hampton, VA, and the third is part of a community-wide, long-term strategy in Lancaster, PA.

6.2 Scaling Adaptation to Local Opportunities: Hoboken

Hoboken is a dense, urban area with an extensive 100-year floodplain, much of which was under six feet of water during Hurricane Sandy. Coupled with combined sewer overflow (CSO) problems, even small events pose serious pollution control and flood hazard problems. The State of New Jersey was awarded substantial funds as part of the U.S. Department of Housing and Urban Development's post-Sandy recovery funding competition "Rebuild by Design", Hoboken being one of three target cities. Hoboken also won involvement in the Rockefeller-funded re:invest innovative design project with re:focus partners LLC (re:focus partners, 2015d).

One of the re:invest projects in predevelopment is a combined facility that incorporates an excess rainfall vault underneath a parking garage. The garage will be topped by a four-acre green infrastructure roof that will provide open space as well as additional permeable water storage facilities. The vault under the six-acre redevelopment site will drain storm sewer overflow from a large 50-acre drainage area called a contributory area. This will both reduce flood hazard in a subarea of downtown and relieve pressure on the sewerage system during large events by pumping nearly 1.5 million gallons of water back to the hard infrastructure system when it can be accommodated. The feasibility study for this proposal examines storage combinations combined with 1, 2, 3 and 4-level commercial parking garages in comparison to the costs and benefits of either a conventional 4-level parking-only garage (with the maximum 1,200 parking spaces) or a stormwater-retention-only facility, as well as different 1- to 10-year storm loads and expected performance.

For Hoboken, a dense, growing city already stressed for parking as well as hazard vulnerability, both the public and private sectors would accrue the integrated benefits of the combination of a parking facility and stormwater management. On the public side, stress would be relieved on the combined sewer system (also lessening incidences of regulatory issues with state and federal agencies), new urban outdoor recreation space would be created and a key area of downtown would increase in resilience with economic as well as safety value. On the private side, the project improves the attractiveness of a significant downtown area for new investment and consumption. On the financing side, possible models for this project include city ownership and operation with parking revenues supporting the facility or a public-private partnership for construction and operation under a long-term agreement, also based on parking revenues.

The alignment between such innovative, project-level public-private partnering designs and existing funding sources will need to be explored and the scope of key funding sources likely clarified and expanded. The New Jersey communities slated for the USHUD Rebuild by Design post-Sandy disaster recovery investment have significant resources available to them, including the New Jersey Environmental Infrastructure Trust (NJEIT), providing investment loans for water resource needs. The first of its kind in 1986, the NJEIT represents an institutional resource that can help finance adaptation, but not necessarily in projects like those mentioned above. The NJEIT Finance Program underwrites the NJ Clean Water State Revolving Fund and other financing streams aimed at local government and regional authority (e.g. ports, public utilities) water resource project needs including water supply, wastewater and conventional hard storm sewerage systems. Loans reduce borrowing costs to those public entities by twenty-five percent (over 20 years) to up to fifty percent over 40 years, as well as providing support for IRS and SEC procedures that reduces local consultant and legal costs (Zimmer, n.d.). The re:focus report on Hoboken mentions this and a variety of other possible funding sources, but not a definitive funding plan as of this writing.

As argued here, successful use of innovative lending mechanisms will depend on smart project design integrating engineering solutions with finance and benefits at a local level. Two further examples from outside the Rockefeller programs demonstrate this.

6.3 Creating Co-Benefits through Local Opportunities: Lancaster, PA

The City of Lancaster is in the Chesapeake Bay watershed via the Conestoga River. With forty-five percent of its area in combined sewers subject to overflow and illegal discharge, and forty-eight percent impervious surfaces, the city has been involved since 1998 in trying to meet Clean Water Act and other Bay requirements (such as a sixty percent reduction in TMDLs by 2017) under a 1998 compliance plan. However, the continued high cost and limitations of controlling the stormwater pollution and flooding problems with gray (hard) infrastructure alone and the option of undertaking new integrated water resource planning with EPA and state regulators led the city to change direction. In 2010, Lancaster adopted a Green Infrastructure Plan with regulatory approval that aims to achieve what would cost $300 million in gray infrastructure construction and few other benefits with, instead, an integrated approach to their urban infrastructure that captures significant

stormwater volumes while providing many additional benefits. The plan identifies $140 million in green infrastructure opportunities for all capital projects including city streets, parking lots, public parks and green roofs that will match the performance of the previously planned $300 million in hard drainage.

While not an innovative fiscal mechanism, this integrated approach is a national model for a citywide strategy that maximizes economic co-benefits not project-by-project, but on a long-term and jurisdiction-wide scale—a major change.

An example from the dozens of projects completed to date is the reconstruction of the intersection at Plum and Walnut streets. This location, a gateway to downtown with a major building on the Historic Register recently converted to a signature business—the Lancaster Brewing Company—was also an area of high storm runoff into the city sewer system contributing to overflows in violation of requirements under the Clean Water Act and the Chesapeake Bay compliance agreements. The intersection also had the highest accident rate in the city where one-way and two-way streets meet. Lancaster is integrating a Complete Streets approach to their urban transportation improvements with green infrastructure for water hazard management. The result has been a fall in accidents, a multi-modal area of the city complementing the redevelopment tasking place and the capture of 2 million gallons per year of runoff. The five funding sources used are essentially conventional public mechanisms but combined in new ways including Pennsylvania Department of Transportation funds that would traditionally focus mainly on a conventional road improvement design (from the Pennsylvania Infrastructure Bank) and the integrated drainage system funded by a green infrastructure grant program from PENNVEST.

The Plum & Walnut project won multiple state and NGO awards in 2014. A 2014 EPA analysis recognizes the citywide effort as a model for future integrated approaches. It estimates that if fully implemented the strategy will save $660,000 in reduced wastewater management costs, avoid $120 million in avoided gray infrastructure construction and produce an estimated $4 million in annual energy, air quality and climate-related benefits, for about $120 million in green infrastructure over time (Katzenmoyer, 2015). The city has also relied on the assistance of PENNVEST, that state's version of the infrastructure banks in many cases being built on but extending beyond the long-time SRF program under the Clean Water Act. PENNVEST provided the green infrastructure funding, and is also noteworthy for extending credit to nontraditional borrowers and for managing

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Pennsylvania's nascent nutrient trading market—necessary finance organization infrastructure to realize private involvement, as discussed at the 2016 Environmental Finance Forum cited earlier.

6.4 Generating Private Revenue for Adaptation: Hampton Gardens, VA

Finally, The Hampton Gardens initiative further demonstrates that the opportunistic, context-sensitive design approach to projects is at the heart of integrating adaptive solutions and creative financing on modest as well as larger scales. The Stormwater Alternatives through Green Enhancement (SAGE) program in the tidewater city of Hampton was created to offset the high cost of stormwater infrastructure projects using an innovative public/private partnership model. (The National Fish and Wildlife Foundation, 2013)

The city, in partnership with the University of Maryland EFC and two consulting firms, under a grant from the National Fish and Wildlife Foundation (NFWF), has taken up the practice among some Virginia cities of maintaining public beautification gardens along key roadways and added stormwater management. Such gardens lack the subsurface water drainage (such as cobble vaults and gradual-release mechanisms) that would allow them to capture excess rainfall in volumes significant enough to reduce nutrient pollution as well as localized flooding. Creating such systems is straightforward but requires capital investment.

A program in Lynchburg, VA has been successful in creating gardens for beautification only with business support for philanthropic and business advertising reasons. In Hampton, the model designed is aimed at combining a new city stormwater fee which businesses will be paying with a new stormwater banking market that will allow contributions to be made to offset costs of new development by reducing fees. Selling advertising through sponsorship is also an option in the approach. While facing many challenges in early stages, the National Fish and Wildlife Foundation (NFWF) is funding this pilot to extend it throughout Chesapeake Bay (NFWF, 2016).

7. CONCLUSIONS, RESEARCH AND POLICY IMPLICATIONS

While the focus of examples here has been on adaptation mainly regarding the problem of more uncertainty about water as hazard (i.e., stormwater—a major aspect of climate change for some regions) and due to sea level rise, the general issues and principles discussed all apply to other arenas for adaptation and resiliency such as energy, urban heat extremes and public health, to name a few. Many propositions are emerging from operational lessons about how to approach adaptation finance challenges that point to the need to bridge the distinction between public and private goods and fiscal mechanisms in creative ways and at multiple levels:

- Some existing local and state fiscal tools can be extended and combined in new ways to support adaptation and they can widen in purposes but still meet the necessary test of a rational nexus between burdens and benefits. The use of stormwater utilities is a case in point examined here. Existing mechanisms for drawing local benefit districts and perhaps tax increment financing districts may be others.
- Public funds, insufficient to meet needs, can be more actively used to leverage private participation through packaging of finance strategies and especially through using underwriting of preferential private borrowing for resilience to increase distributed adaptation by households and firms that complements larger-scale public projects.
- Packaging and leveraging require creative and opportunistic project design and thinking of both the solutions and the resource or revenue generation options from the earliest stages, especially regarding the co-benefits that can be created, contrary to much traditional public works and public finance practice. This emphasis on pre-development invention and choices is receiving growing attention.
- The local government level is where much invention and innovation will take place with flexible collaboration of state and federal levels, and such flexibility is essential to attracting private financial and organizational participation
- State governments have a key role to play in enabling and facilitating local as well as state level actions in financial

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markets as well as in promoting coordination and providing technical support for local government level effort.

More research is needed on emerging models such as those briefly covered herein. The work by re:focus Partners LLC under Rockefeller sponsorship is important for bringing to the fore innovations that their group is helping invent, but discussion and dissemination of these initiatives is still very limited. The characteristics of smart project design at the pre-development stage, as briefly illustrated here, need more investigation as to their economic benefits and fiscal sustainability. Most of the emerging ideas and lessons are largely only documented and disseminated in gray literature, foundation-generated reports among specialized audiences and in some industry circles. More investigation is needed on how inventive strategies can be combined with existing state authorities and local practices, as well as with the financial industry and federal regulators, as the experience with energy finance innovation has illustrated. Best practices across states need to be analyzed, as well as needed legal and organizational changes at federal and state levels. For example, in 2016 the U.S. Internal Revenue Service decision to expand safe harbors for funds in public-private utility partnerships has addressed a long-standing issue known by the financial industry, states and some local specialists. Wading through the understanding of what is needed within state as well as federal institutions is difficult given the lack of consolidated, comparative analysis. Adaptation finance forums that bring public and private sectors together, like those held by the Environmental Finance Centers in the last few years, are needed within regions and states to bring together the multiple actors as a source of comparative and detailed knowledge and to identify practical questions that need to be answered.

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