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## *DEMAND PROJECTIONS FOR VIET NAM WATER POLICY*

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Asian Development Bank

## ABBREVIATIONS

| | | |
|---|---|---|
| ADB | – | Asian Development Bank |
| DMC | – | developing member country |
| FAO | – | Food and Agriculture Organization |
| GW | – | gigawatt |
| Lao PDR | – | Lao People's Democratic Republic |
| MWh | – | megawatt-hour |
| PRC | – | People's Republic of China |
| VEC | - | Veitnam Enterprise Census |

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# CONTENTS

## EXECUTIVE SUMMARY

1. This report presents long-term estimates of water requirements to support economic growth in Viet Nam. As a dynamic Asian exporter, Viet Nam is undergoing continued agrifood expansion combined with a reform and modernization transition, intensifying of industrial activity and expanding service sector growth. All this has been accompanied by sustained income growth and demographic transition from rural to urban majority populations. Such dynamics portend significant increases in water demand and changing patterns of primary and conjunctive use across a complex, rapidly changing economy.

2. Our forecasts for growth over the next two decades indicate that aggregate water demand will grow more slowly than real output, primarily because agriculture, the dominant user of water, will grow more slowly than manufacturing or services. Despite this fact, total water use is estimated to nearly double by 2030. As indicated in the Baseline scenario of Figure ES1 below, this demand growth will present water capacity challenges, especially at certain times of year, for some important river basins in the country, making essential more determined policies to promote water use efficiency, in addition to storage and conveyance investments. Moreover, policies that promote more extensive conjunctive water use, water recycling, and market-oriented approaches to spatial and seasonal water scarcity probably need more emphasis.

3. The good news is that, because of its prominence in national water use, efficiency measures in one sector alone, agriculture; hold the potential for more sustainable water policy. Vietnam's modernization process will continue to shift human, land, and other resources toward non-agricultural activities, value added, and employment creation. If agricultural policy can support this with more active intervention to improve farm-level water use efficiency, Vietnam could complete this transition without severe water bottlenecks and the disruptions they cause Figures ES1 and ES2 illustrate the challenges of spatial and temporal heterogeneity in water supply and demand. Vietnam has a relatively ample nationwide and annual envelope of water resources, but these are unequally allocated over the country and annual seasons. For this reason, serious water constraints appear in the dry season (ES2) that would not be apparent from examining annual data (ES1). The good news is that promoting water use efficiency can mitigate these problems. In many cases, however, significant commitments to storage and conveyance may be needed to overcome local and seasonal water scarcity.

4. Indeed, the results of our scenario analysis suggest that agricultural water use efficiency could accommodate even higher economywide growth rates, particularly if these are part of an integrated approach to agrifood modernization and productivity growth. Thus we see that the growth potential of Vietnam's economy may be led by industrialization, but its sustainability can be secured by improved practices in the rural sector.

5. Viet Nam households will achieve substantially higher real incomes if expected growth rates can be sustained, but this prosperity could be accompanied by rapidly accelerating per capita water use. While this is a common feature of so-called middle class emergence, it also suggests that residential water use efficiency should be a high priority for policy attention. Of particular concern in this context, although it is not directly addressed in this study, will be water quality considerations. The scope of water treatment investment requires continued expansion in the coming years, and expanded conjunctive use will also necessitate this.

6. In summary, Viet Nam's expectations for economic growth are ambitious, and their resource management policies should be correspondingly so, particularly in the context of sustainability. This economy can continue to confer significant livelihood improvements on its population, but to do so it must avert scarcity in a resource critical to every economic activity, indeed to life itself.

## Basin Water Capacity Use – 2030

**Figure ES1**
**Baseline Annual Average**

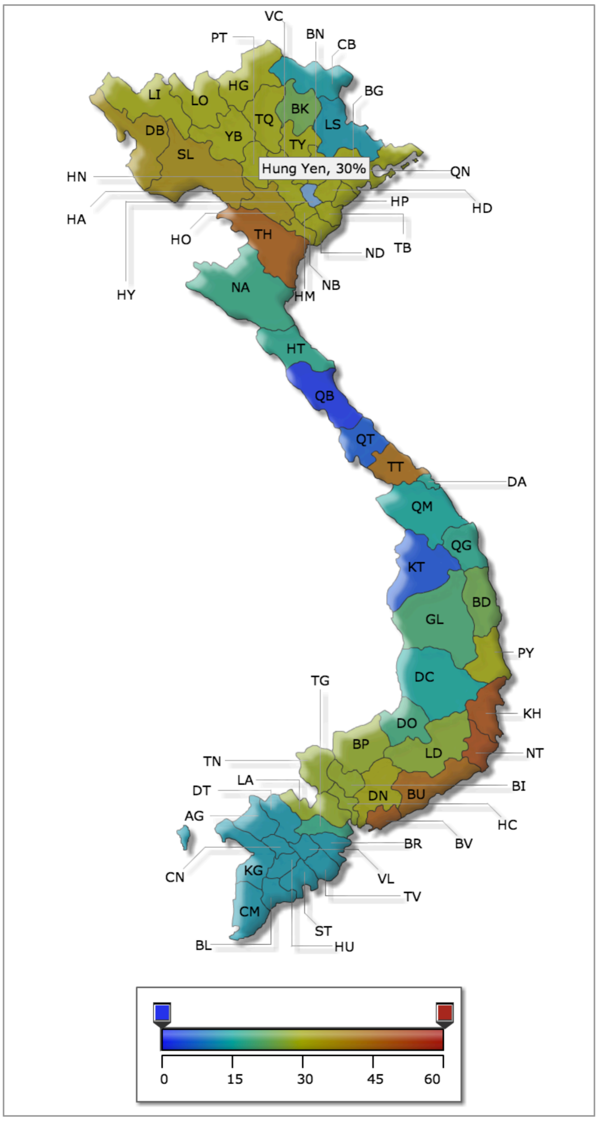
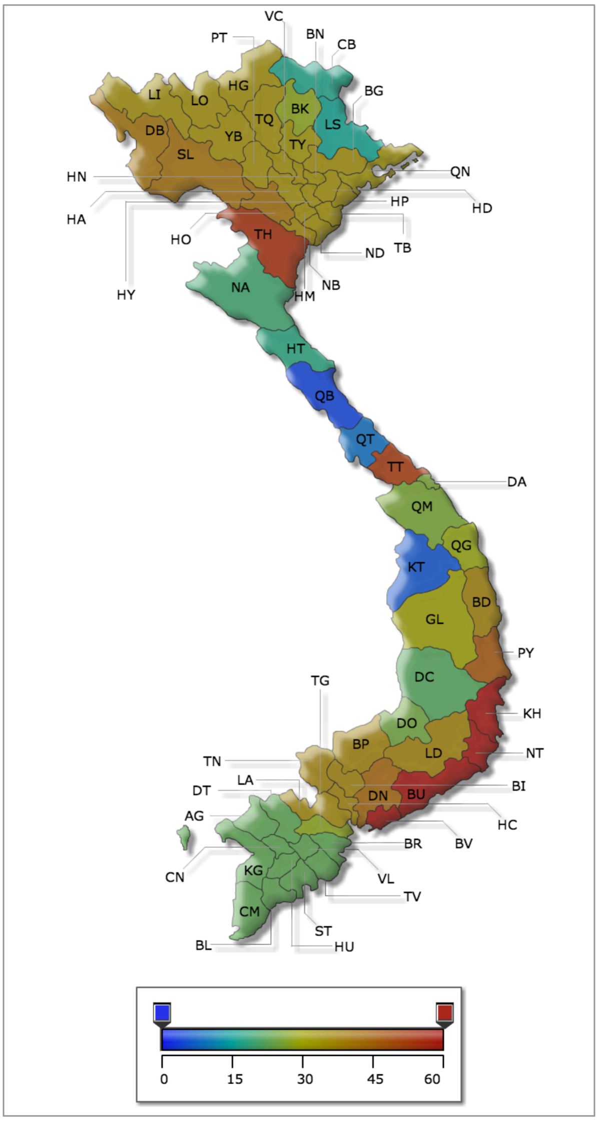



**Figure ES2**
**Baseline Dry Season**




*Capacity is aggregate seasonal water use as a percent of capacity (including existing storage and conveyance).*
*Source: Author estimates.*

“Now there were, in the aggregate, 12,755 quinariae set down in the records, but 14,018 quinariae actually delivered; that is, 1,263 more quinariae were reported as delivered than were reckoned as received. Since I considered it the most important function of my office to determine the facts concerning the water-supply, my astonishment at this state of affairs stirred me profoundly and led me to investigate how it happened that more was being delivered than belonged to the property, so to speak.” - Sextus Julius Frontinus (97 AD), The Aqueducts of Rome

# 1 INTRODUCTION

7. As the passage above suggests, effective water policy has long relied on detailed, accurate, and timely data on water’s many sources, needs, and uses. In developing countries, data constraints on resources generally, and water in particular, can undermine the best intentions of those who want to meet the essential social and economic needs of their populations. To support more effective water planning, we propose a three stage approach to empirical analysis of water allocation, accompanied by an inventory of what kind of data are needed to implement this kind of decision support. To a significant extent, the scope of available data will delineate the scope of water policy analysis, and the accuracy and timeliness of data will determine its effectiveness and relevance. For a rapidly emerging economy like Viet Nam, it is essential to anticipate changing patterns of water need, availability, and options for reconciling the two.

8. In terms of decision support, we recommend a three tier system, including economywide water accounts, a water allocation model, and finally an integrated assessment tool that couples the first two with an economic model that can forecast emerging resource requirements and values. These notes summarize needs for the first two components. Where timely and detailed data are already available from official sources, they can be incorporated directly. When data of the right kind exist but are too old, we can attempt to update them by comparison to proxy variables. Where important data to not appear to exist at all, we shall propose ways to impute values from secondary sources.

9. Decision tools and data requirements are summarized below, grouped in generic categories according to sources and uses. We are also developing more detailed spreadsheets to structure and maintain this data as it becomes available, but these designs will depend on what we can expect to receive from water management agencies and other sources.

## 2 FORECASTING WATER DEMAND

10. Although many of the water challenges facing Viet Nam are already acknowledged, empirical evidence to support effective adaptation policies remains relatively weak. Because of the importance of agriculture generally and the long lead times required for structural adjustment in this sector generally and water resource management in particular, policy makers need better foresight about emerging risks in this sector. To provide this kind of empirical policy support, we use a dynamic forecasting model calibrated to detailed information on Viet Nam's economic structure, including regional crop and water use information.

11. Models like to one used here are intended to capture the extended linkages and indirect effects that follow from specific external shocks policies. The complexities of today's global economy make it very unlikely that policy makers relying on intuition or rules-of-thumb will achieve optimality. Market interactions are so pervasive in determining economic outcomes that more sophisticated empirical research tools are needed to improve visibility for both public and private sector decision makers. The preferred tool for detailed empirical analysis of economic policy is now the Calibrated General Equilibrium (CGE) model. It is well suited to trade analysis because it can detail structural adjustments within national economies and elucidate their interactions in international markets. Technical details of the Viet Nam CGE are presented in an annex to this report, and a large research and policy literature documents this general approach, but a few general comments will facilitate discussion and interpretation of the scenario results that follow.

### A. Scenarios for Growth and Sustainable Water Use

12. One of the challenges of very dynamic growth, as Vietnam and other Asian "miracle" economies have experienced it is emergent imbalance in patterns of domestic resource allocation and use. Vietnam has relatively abundant aggregate water resources, but their availability is spatially heterogeneous around the country. Over longer historical periods, population settlement, economic activity, and its attendant resource have adapted to this, generally ensuring as locally sustainable balance between water needs and availability. In modern times, however, much more dynamic economic growth can accelerate local resource use, leading to scarcity and bottlenecks. Policy responses include a combination of demand and supply side measures, such as efficiency measures and investments in water storage and conveyance. A number of Asian economies have passed through this phase, and in this section, we use the economic forecasting model to assess Vietnam's prospects for balancing growth-driven water demand and supply.

13. Table 2.1 summarizes the four scenarios we evaluate. Generally speaking, these are chosen to establish a reference growth trajectory over the two decade period 2010-30 and test it against the main archetypes for demand-side management and supporting policies that can improve water use sustainability without sacrificing growth objectives.

**Table 2.1: Long Term Policy Scenarios**

| | Scenario | Description |
|---|---|---|
| 1 | **Baseline** | Business-as-usual reference trends. No policy changes. |
| 2 | **MacEff** | Macro water use efficiency gains of 2 percent per annum |
| 3 | **AgEff** | Water use efficiency in agriculture improves 50 percent over 2010-2030 |
| 4 | **AgEfPr** | Water use efficiency combined with agricultural productivity growth of 2 percent per annum |

### 2.1.1 Baseline

14. No matter how advanced or competently implemented, an economic forecasting model will never be a crystal ball. Having said this, models like the one used here can trace out patterns of growth, resource use, and other economic variables to help policy makers assess aggregate consistency and identify emergent constraints. The Baseline scenario is intended for use as a dynamic reference for so-called Business-as-Usual, or continuation of existing policies. This one is calibrated to consensus forecasts for real GDP obtained from independent sources (e.g. World Bank, International Monetary Fund, Data Resources International, and Cambridge Econometrics). The model is then run forward to meet these targets, making average capital productivity growth for each country and/or region endogenous. This calibration yields productivity growth that would be needed to attain the macro trajectories, and these are then held fixed in the model under other policy scenarios. Other exogenous macro forecasts could have been used and compared, but this is the standard way to calibrate these models.

15. In the results assessment below, we first examine Baseline trends alone, identifying challenges and opportunities in the water sector as these are implied by status quo growth expectations. Because water's linkages across the economy are so pervasive, it is very difficult to rely on intuition alone when anticipating emergent imbalances. After discussing the Baseline, we then compare them to three scenarios representing more determined approaches to national water use efficiency.

### 2.1.2 Macroeconomic Water Use Efficiency

16. As official sponsored and independent assessments have consistently emphasized, Vietnam's successes with economic growth and livelihood improvements have presented some unintended challenges from a water resource perspective, particularly the risk of local scarcity that could undermine both the level and quality of the country's growth experience. In these circumstances, appropriate policy responses exist on both the supply and demand sides. The former include investments in water production, storage, and conveyance, while the latter a generally targeted to promote more efficient water use, including technology adoption and recycling.

17. The purpose of a macroeconomic forecasting exercise like the present one is not to field test individual investment projects or water use technologies, but to examine the overall significance of changing water supply and use conditions for the economy. Because many of Vietnam's water balance challenges have already been identified by others and are further elucidated in the Baseline, our counterfactual scenarios examine the effects of significant improvements in water use efficiency. The first of these, Scenario 2, asks the following question: If economywide average water use efficiency could be improved by 2 percent per annum over the period 2012-2030, what would be the overall impact on the economy?

### 2.1.3 Water Use Efficiency in Agriculture

18. Agriculture represents nearly three-quarters of total fresh water consumption globally, and in Vietnam it exceeds 85%. For this reason, national water conservation strategies in this country, as elsewhere, must target agriculture to have any significant aggregate impact. Vietnam is fortunate in the sense that agricultural technology adoption is in its early phase, meaning that the potential to improve water use efficiency is very substantial. Through more determined investments in infrastructure, as well as diffusion of better irrigation technologies, other countries have achieved water use improvements of 25-75%. As a reference case for macroeconomic assessment, we assume that Vietnam can improve agricultural water use efficiency by an intermediate value, averaging 3.3% improvements per year over the next two decades and achieving 50% lower net water use by 2030.[1]

### 2.1.4 Agricultural Water Use Efficiency and Productivity Growth

19. Improving water use efficiency improves national water security, but the larger agendas of food security and rural poverty alleviation are little affected because water remains a very low cost input. Because of Asia's geographic diversity and substantial differences in stages of development, agricultural yields and productivity in livestock production vary tremendously across the region. In many ADB Developing Member economies especially, agrofood production is far below its ultimate potential. Because of relatively small-scale land tenure patterns, it is unlikely that rural households in these countries can achieve significant livelihood improvements unless output per hectare improves substantially, and migration trends suggest that higher output per household member will also be essential.

[1] This is an ambitious target and should be considered as indicative, but if net water use efficiency includes improvements in conjunctive use and recycling, this target could probably be met against today's low efficiency levels.

**Table 2.2: Average Annual Growth of Agricultural Output**

| | 1970–1979 | 1980–1989 | 1990–1999 | 2000–2006 |
|---|---|---|---|---|
| Sub-Saharan Africa | 1.31 | 2.6 | 3.1 | 2.2 |
| LatinAmerica and Caribbean | 3.07 | 2.37 | 2.87 | 3.13 |
| Brazil | 3.83 | 3.73 | 3.29 | 4.41 |
| Middle East and North Africa | 2.94 | 3.37 | 2.73 | 2.34 |
| NE Asia, High | 2.15 | 1.03 | -0.01 | -0.01 |
| NE Asia, Low | 3.11 | 4.55 | 5.06 | 3.85 |
| PRC | 3.09 | 4.6 | 5.17 | 3.87 |
| SE Asia | 3.68 | 3.59 | 3.13 | 3.54 |
| South Asia | 2.56 | 3.39 | 3 | 2.19 |
| India | 2.69 | 3.52 | 2.94 | 2 |
| North America | 2.17 | 0.73 | 2.03 | 1.1 |
| Oceania | 1.79 | 1.25 | 2.93 | -0.04 |
| Western Europe | 1.54 | 0.94 | 0.46 | -0.35 |
| Eastern Europe | 1.8 | 0.25 | -2.18 | -0.19 |
| Russian Federation | 1.32 | 0.98 | -4.62 | 2.7 |
| Developing countries | 2.82 | 3.46 | 3.64 | 3.09 |
| Developed countries | 1.88 | 0.86 | 1.21 | 0.39 |
| Russian Fed. & Eastern Europe | 1.47 | 0.77 | -3.88 | 1.81 |
| World | 2.23 | 2.13 | 2.04 | 2.22 |

*NE = northeast, SE = southeast*
*Sources: United States Department of Agriculture, World Bank*

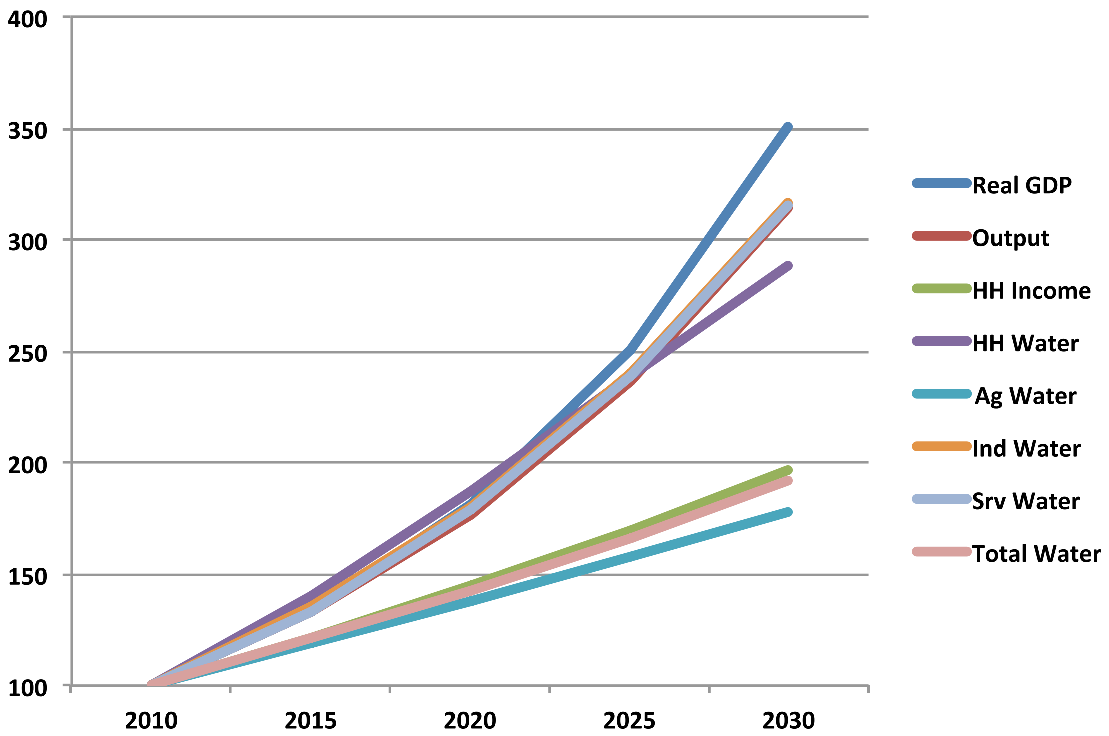
## B. BASELINE FORECASTS TO 2030

20. To better anticipate emerging patterns of water demand in Viet Nam, we applied the forecasting model to project economic growth over the next two decades. Because the model is calibrated to detailed data on the structure of supply, demand, trade, employment, and income, we can map out the resource requirements implied by different expected scenarios for the country's economic growth. Here we use a baseline growth trajectories obtained as from consensus estimates of international agencies (World Bank and IMF), which call for the economy to sustain aggregate real growth in the range of 4-6% over the period 2012-2030. Based on these expectations, we obtained the more detailed demand patterns discussed in this section.

21. The macroeconomic results of these forecasts are summarized in Figure 2.1, suggesting that Viet Nam can nearly triple real GDP by 2030, with slower but very significant progress for real household incomes (the main difference being do to population growth). Meanwhile, our results suggest that aggregate water demand will also rise substantially, albeit less rapidly than aggregate economic growth. Having said this, important divergences in water demand become apparent when we distinguish between agriculture, industry, and household demand. As other authors have noted, agriculture exerts a moderating influence on demand growth, although the magnitude of this sector's needs still pose a challenge. Industrial water use rises at the same rate as real output (314% vs 316%), suggesting that changing economic structure will not improve aggregate industrial water use efficiency, and technical innovation will be needed to accomplish this. By contrast, household water demand will rise much faster than income (288%

vs 197%), suggesting that income growth and demographic transition will accelerate per capita personal water use.

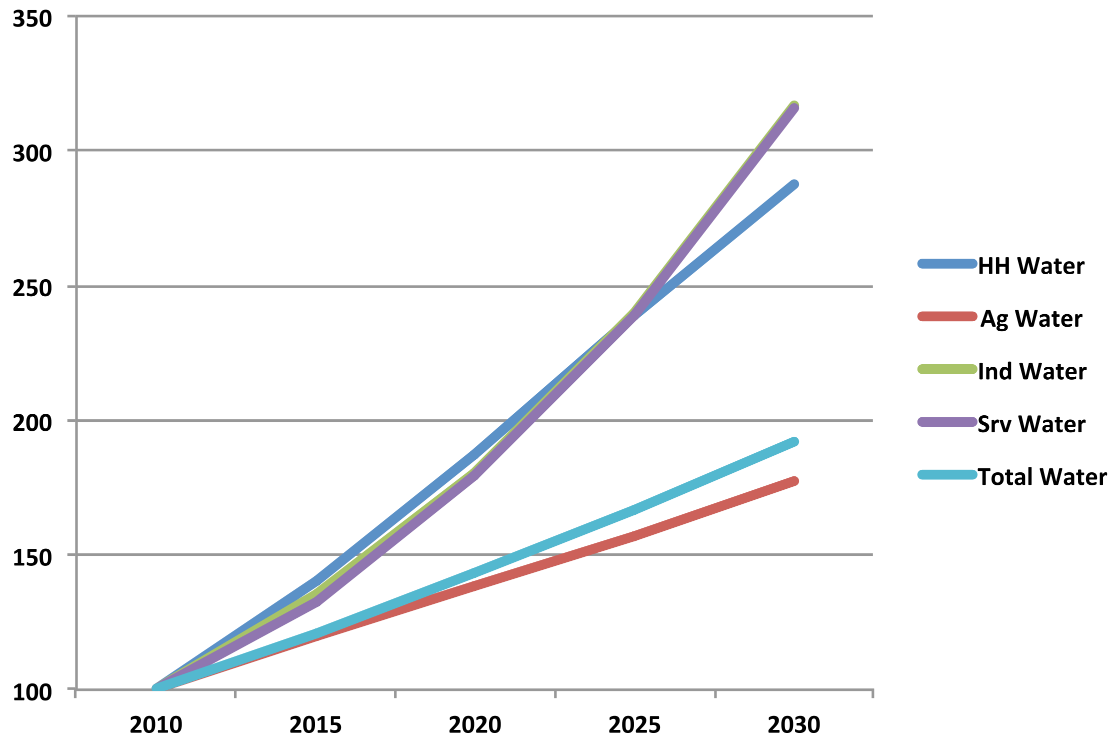
**Figure 2.1: Macroeconomic Growth (indexed to 2010=100)**




*Source: Author estimates.*

22. It should be noted that changes in water demand arise from three decomposable sources: aggregate growth, changes in demand composition, and changes in individual use technology. The baseline scenario assumes that individual water use technology remains unchanged. For this reason, our results reflect the combined impacts of aggregate economic growth (higher output for industry, real incomes for households) and demand composition. This means that the higher aggregate industry use efficiency we observe is the result of changing industrial structure. More efficiency may arise from new technology adoption, but we do not capture this effect within the model. Likewise, changes in household use efficiency are the result of changing demand patterns, including migration, income effects, and population growth. Households could also adopt different water use technologies, but again this is not captured in the model. Technology effects of both kinds, however, can be elucidated by scenario analysis as we shall see below.

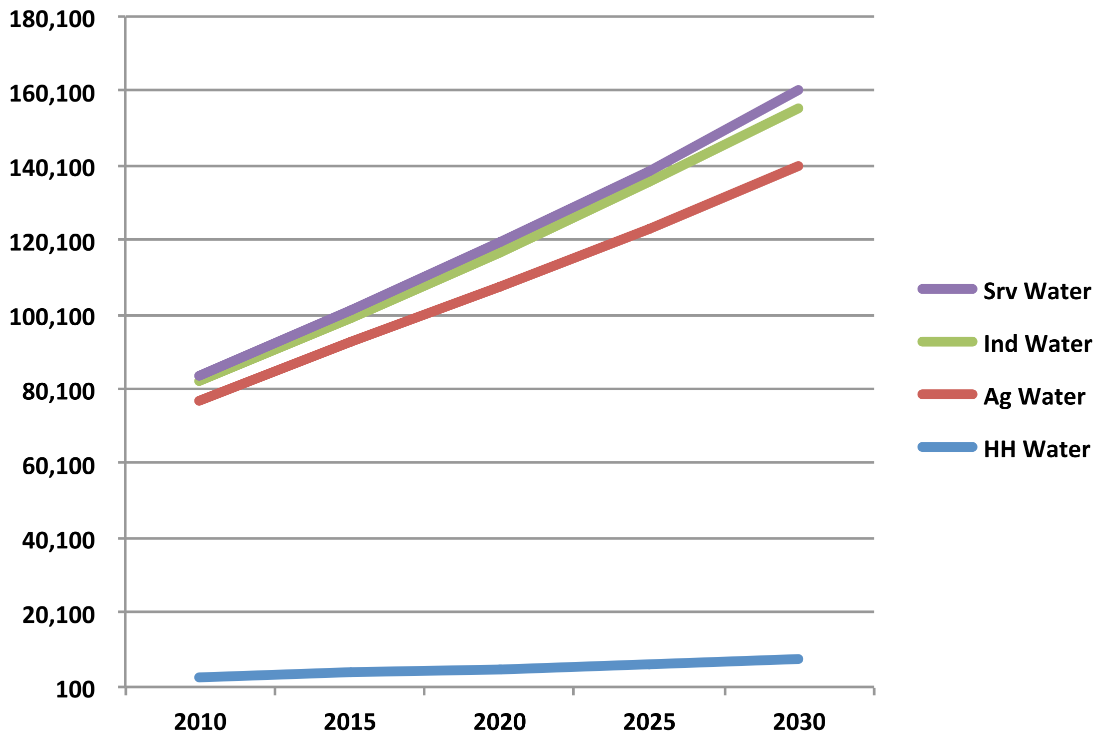
**Figure 2.2: Aggregate Water Demand Growth (indexed to 2010=100)**




*Source: Author estimates.*

23. To summarize the macro findings for water, consider Figure 2.2, which shows the four primary sectoral components of use: Households, Agriculture, Industry, and Services. It should be noted also in passing that the indicator Total Water could be a bit misleading from a resource perspective because it does not take account of conjunctive water use. In other words, the total water resource requirement to support Viet Nam's growth over the next two decades is less than the sum of these four demand sources because water can be applied sequentially across multiple uses. Having said this, it is still essential to anticipate these components of demand, and their growth varies significantly. Assuming no water use technology change in this Baseline, both industry and household water demand will expand robustly, nearly doubling over the next two decades. We discuss all four components in greater detail below.

**Figure 2.3: Aggregate Water Use by Source of Demand (millions of cubic metres, Mm3)**




*Source: Author estimates. Demands are graphed cumulatively.*

**Table 2.3: Aggregate Water Use by Source of Demand (Mm3)**

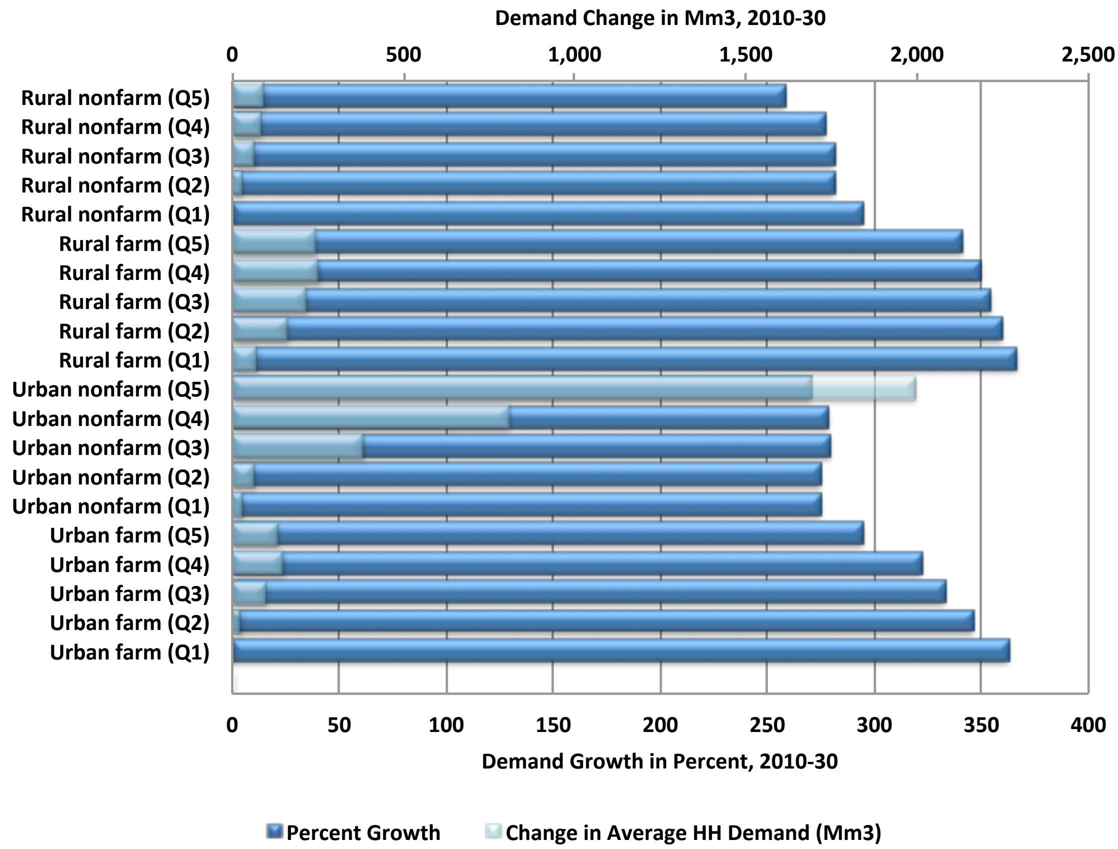
| | 2010 | 2015 | 2020 | 2025 | 2030 |
|---|---|---|---|---|---|
| HH Water | 2,668 | 3,742 | 5,006 | 6,369 | 7,681 |
| Ag Water | 74,262 | 88,742 | 102,606 | 116,925 | 132,042 |
| Ind Water | 5,055 | 6,829 | 9,123 | 12,118 | 16,011 |
| Srv Water | 1,437 | 1,908 | 2,572 | 3,435 | 4,532 |
| Total Water | 83,423 | 101,222 | 119,307 | 138,847 | 160,266 |

*Source: Author estimates.*

### C. Household Water

24. In the aggregate, household water use efficiency (water demand per dollar of household income) worsens over the period considered. Closer examination of household water forecasts suggests that demand patterns vary substantially with income and location and so will their growth rates (Figure 2.4). The latter will vary less than initial allocations by household type but, generally speaking, households with lower initial incomes and use levels will see demand growth significantly faster over time.

## Figure 2.4: Household Water Demand Growth, by Locality and Quintile Income Level




*Source: Author estimates.*

25. This is typical of observed linkages between water demand, rising incomes, and demographic transition. Water begins as a necessity, with very low-income elasticity. As incomes begin to rise above subsistence, however, water becomes a luxury good, with higher per capita demand among high-income urbanites and water use rising faster than income. Combining economic growth and rural-urban migration, as Vietnam has done for the last two decades and will for the next, portends momentous growth in residential water demand. Farm household (non-agricultural) water use will growth most rapidly, nonfarm less rapidly, and lower income groups more rapidly than higher income groups. All this growth and convergence is to be expected, but it is worth noting that the groups with highest baseline demand are also those most eligible (urban and high income) for new use technology adoption and diffusion. Although the aggregate level of household demand appears to be significantly less than industry or agricultural use, this category appears headed for rapid growth and policies for national water management would to well to consider targeting it with efficiency measures, particularly in urban areas where baseline per capita demand is highest.

### D. Agricultural Water

26. At the present time, the overwhelming share of Vietnamese water demand is attributable to agriculture and food processing. Taken together, crops, livestock (including aquaculture), and agrifood processing account for more than 85 percent of water demand nationally and exceed 80% in all the nation's river basins but four (Figure 2.5).

**Figure 2.5: Water Demand by Economic Activity and River Basin**

| | | Irrigation/ Agriculture | Industry | Cities and villages | Aquaculture | Total |
|---|---|---|---|---|---|---|
| 1 | Bang Giang – Ky Cung | 0.274 | 0.000 | 0.011 | 0.025 | 0.311 |
| 2 | Hong (Red) Thai binh | 17.245 | 1.849 | 0.854 | 0.729 | 20.677 |
| 3 | Ma | 4.280 | 0.077 | 0.081 | 0.404 | 4.842 |
| 4 | Ca | 1.701 | 0.022 | 0.099 | 0.289 | 2.111 |
| 5 | Gianh | 0.061 | 0.001 | 0.008 | 0.001 | 0.071 |
| 6 | Thach Han | 0.095 | 0.000 | 0.007 | 0.019 | 0.120 |
| 7 | Huong | 1.292 | 0.105 | 0.060 | 0.101 | 1.559 |
| 8 | Thu Bon & vu gia | 1.278 | 0.141 | 0.052 | 0.122 | 1.593 |
| 9 | Tra Khuc | 0.743 | 0.070 | 0.010 | 0.003 | 0.826 |
| 10 | Kone & Ha thanh & La tinh | 0.907 | 0.009 | 0.024 | 0.021 | 0.961 |
| 11 | Ba | 1.636 | 0.006 | 0.033 | 0.027 | 1.702 |
| 12 | Dong Nai | 2.496 | 0.924 | 0.302 | 0.948 | 4.670 |
| 13 | SERC | 1.420 | 0.300 | 0.116 | 0.634 | 2.469 |
| 14 | Se San | 0.183 | 0.016 | 0.009 | 0.012 | 0.220 |
| 15 | Sre pok + Ya… | 0.764 | 0.015 | 0.040 | 0.062 | 0.881 |
| 16 | Cuu Long (Mekong) | 29.121 | 0.008 | 0.413 | 5.869 | 35.411 |
| | Total | 63.496 | 3.544 | 2.118 | 9.265 | 78.423 |

*Source: ADB (2012)*

27. Following the structural transition of other dynamic Asian export economies at this stage of development, Viet Nam is in transition from a predominantly agrarian economy, through a significant degree of industrialization, and ultimately on to a service dominated economy. This rotation of economic structure will see agrifood activities continue to expand in response to population and income induced demand growth, but agriculture's share of growth will be smaller than that of industry or services over the next two decades. This means water demand growth in agriculture can be expected to be more moderate, as long as use efficiency does not deteriorate and crop selection and aquaculture development do not shift strongly toward water-intensive activities. At the moment, crops dominate water use, and both this an aquaculture are expected to grow at less than half the rate of industry. Even so, 60-78% real output growth will require significant water resources, meaning that enterprise use efficiency and conjunctive use should remain high priorities for water policy involving agriculture.

**Table 2.6: Sectoral Real Output Growth**

**(percent change from 2010 in 2030)**

| | Sector | Demand | Output | Imports | Exports |
|---|---|---|---|---|---|
| 9 | Crops | 86 | 60 | 162 | 1 |
| 10 | Livestock | 89 | 83 | 202 | 9 |
| 11 | Forestry | 224 | 317 | 65 | 225 |
| 12 | Fishery | 80 | 78 | 17 | 66 |
| 16 | Processed Food | 77 | 79 | 12 | 72 |

*Source: Author estimates.*

## E. Industrial and Service Sector Water

28. The trends in Figure 2.1 show that industrial output is growing at about the same rate as its water requirements, which under our assumption of technology neutrality means that the composition of economywide industry output is not changing aggregate industrial water use efficiency. As has already been emphasized, this implies that efficiency improvements in non-agricultural activities must come through technological change and individual user efficiency measures. While the Viet Nam economy will see some structural rotation over this period, toward lower GDP shares for agriculture and higher shares for manufacturing and services, water requirements by the latter groups could more than triple without policies to promote this kind of technological change.

29. Service sector water use closely follows aggregate direct consumer demand in percentage growth terms. This is typical of most economies, as service water use patterns most closely mirror household uses (food preparation, hospitality, etc.). Taken together, household and service sector water represent the fastest growing demand sources (Figure 2.2), but are still the smallest aggregate categories (Figure 2.3). As incomes and urban populations continue to rise, however, together they will soon overtake industry as the second most prominent use category.

## F. Water Efficiency Scenarios

30. Across the large and growing literature on Vietnam water policy, there is near-consensus that significant opportunities exist for improvements in average water use efficiency. Regardless of the sector considered, combinations of technological improvement and different economic incentives have been and are being recommended that can avert critical shortages and improve water productivity. Without addressing specific technology choice or targeted investments, we review three scenarios of efficiency improvement for their potential to support more sustainable growth and livelihoods improvements.

31. The scenarios have already been summarized above, and their macroeconomic impacts are set forth in Table 2.7 below. The first thing to note about the first two counterfactuals is the relatively weak link between efficiency and growth impacts. The reason for this is simple, and generally relevant to sustainability policies. Resource conservation in itself does little to stimulate economic growth, but mainly serves to secure the growth potential of other growth drivers. Thus we see that greater efficiency has confers a modest aggregate growth dividend, about 1% higher real GDP and household real income than the Baseline by 2030. Real

consumption does somewhat better because water savings translate into slightly lower prices for food and other necessities, but generally the growth impacts are positive yet modest.

**Table 2.7: Macroeconomic Impacts of Efficiency Improvements (percent change from Baseline in 2030)**

| | MacEff | AgEff | AgEfPr |
|---|---|---|---|
| Real GDP | 0.9% | 0.8% | 11.5% |
| HH Real Income | 0.8% | 0.7% | 16.0% |
| Real Consumption | 2.2% | 2.0% | 16.5% |
| Real Wage | 0.7% | 0.7% | 4.8% |
| Revenue | 0.4% | 0.4% | 8.1% |
| HH Water | -0.5% | 7.7% | 21.2% |
| Ag Water | -33.6% | -48.6% | -34.1% |
| Ind Water | -33.8% | -1.0% | 5.5% |
| Serv Water | -0.6% | -0.6% | 8.0% |
| All Water | -32% | -44% | -30% |

*Source: Author estimates.*

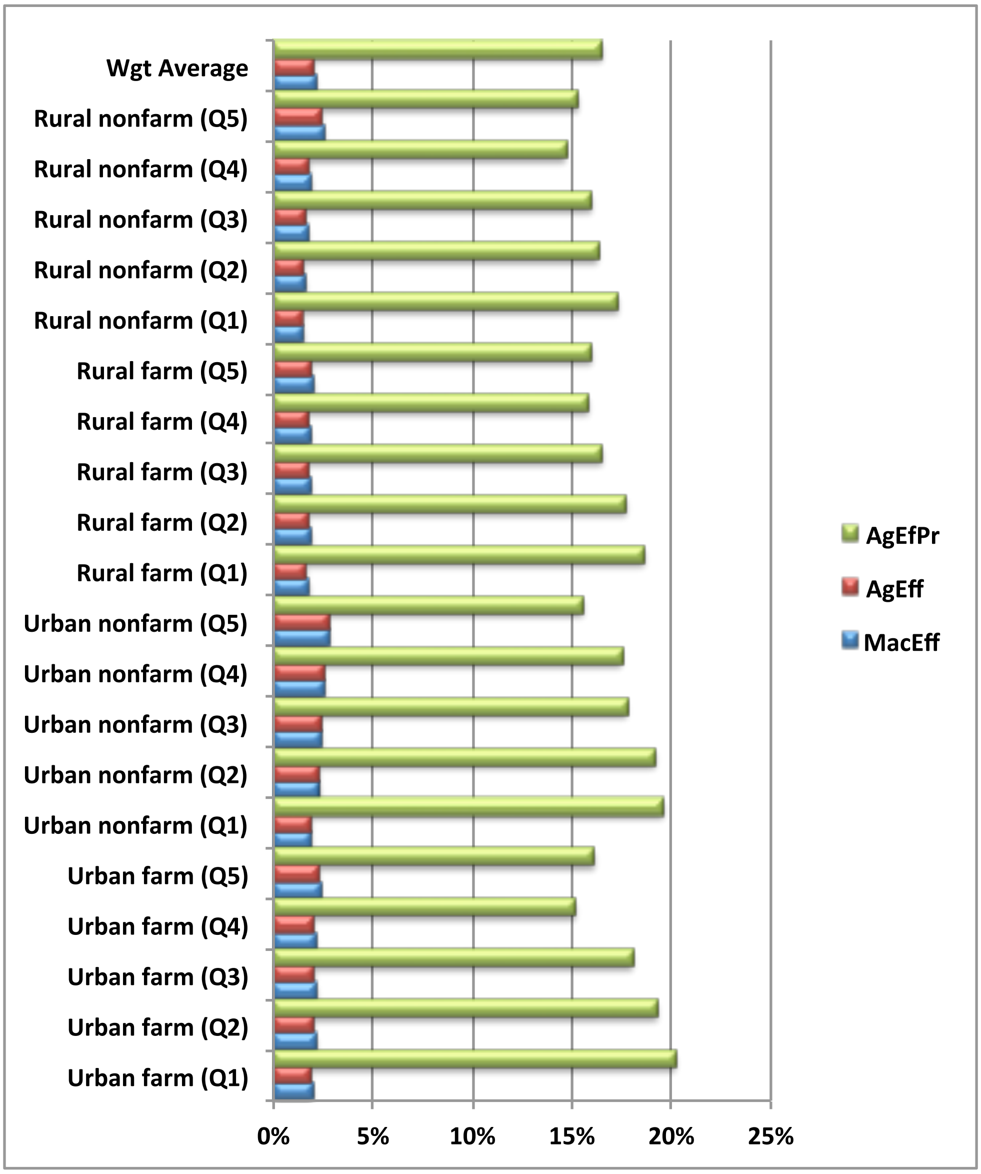
32. The model used here is designed for demand-side forecasting, and in terms of economic impacts only captures the net benefits of water saving. For an economy like Vietnam, these tend to be small because water is a very inexpensive (if essential) resource. A combined economy-hydrology model might be able to identify critical water shortages in the Baseline, making it easier to measure the benefits of efficiency in terms of loss-aversion, but that is outside the scope of the present approach.

33. The final counterfactual makes a related point, that water use efficiency is generally part of a larger process of agricultural modernization that enhances productivity of all resources (land, labor, and water). When this progress is measureable in terms of total factor productivity growth (TFP), the economic dividends of improving use efficiency become more apparent and quite significant. For the current example (AgEfPr), where we assume only about the median level of TFP for Vietnam, substantial growth and livelihoods dividends become apparent. Thus we see that, while water remains somewhat below the economic radar because of its negligible cost, in productivity terms this and other resources are the bedrock of food security and national livelihoods improvements. This reflects the so-called Diamond-Water Paradox of Value in economics.[2] Water has a low direct cost because it is abundant, but a very high opportunity cost because it is essential. In the next section, we look at patterns of Thus policy makers may have difficulty measuring the economic benefit of an additional unit of water, but large investments to avert losses from scarcity are easier to justify. In the next section, we use the model to help identify emergent constraints that might threaten such losses.

34. In terms of households, the impacts vary in interesting ways with locality and income. As Figure 2.6 indicates, aggregate water efficiency is slightly more beneficial to higher income groups because they spend more on this resource. When agricultural water use efficiency is combined with TFP growth, however, we see strong pro-poor effects.

[2] See e.g. http://en.wikipedia.org/wiki/Paradox_of_value

**Figure 2.6: Effects on Real Household Incomes by Locality and Quintile**




35.

## 3 SPATIAL AND TEMPORAL COMPOSITION OF WATER IMPACTS

36. While overall water resources are relatively abundant in Vietnam, their distribution is spatially quite heterogeneous in terms of local capacity (Table 3.1, see also KBR: 2008, WB: 2007, and Soussan et al: 2005). Just as heterogeneous are use patterns (Figure 3.1) and the combination of these with high growth rates presents challenges for balanced resource allocation and sustainability.

37. Because aggregate growth statistics can mast these more detailed issues of local resource constraints, we now make an effort to disaggregate the scenario results of the last section. Our general findings regarding the growth dividends of efficiency and (especially) productivity growth remain in place, but spatial detail offers additional insights about the need for policies that might be needed to avert resource constraints and their attendant adverse effects on the level and quality of Vietnam's economic growth.

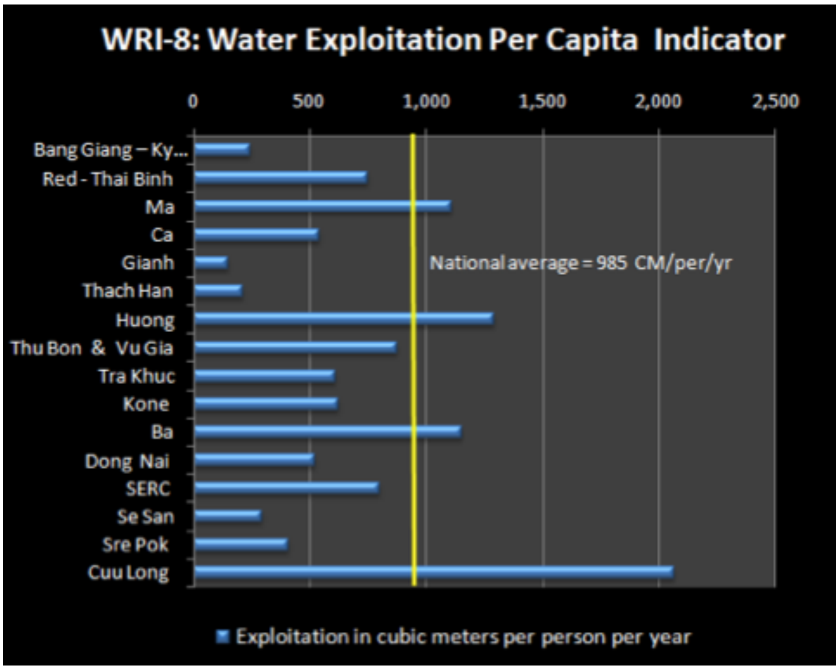
38. Using a variety of more detailed national data on economic activities, particularly high-resolution surveys of agriculture, enterprises, and households, we have estimated water use changes across both river basins and by province. This information suggests that commitments to improved supply and flatter trajectories of demand growth will have higher priorities in some parts of the country than others, providing a roadmap for water sector reform that facilitates growth and poverty reduction. We also see indications that market forces could shift agricultural water use toward localities with lesser supply-use constraints, helping Vietnam accommodate industrial and urban growth more efficiently.

### Table 3.1: Characteristics of Major River Basins in Vietnam

| | | Catchment | | | Average Annual | | | Dry | With |
|---|---|---|---|---|---|---|---|---|---|
| | River Basin | External | Domestic | Total | External | Domestic | Total | Season | Transfer |
| 1 | Bang Giang – | 2,658 | 10,722 | 13,380 | 1.70 | 7.30 | 9.00 | 2.25 | 2.31 |
| 2 | Red Thai binh | 82,340 | 86,680 | 169,02 | 51.82 | 81.86 | 133.68 | 35.85 | 51.38 |
| 3 | Ma | 10,680 | 17,720 | 28,400 | 3.90 | 14.10 | 18.00 | 4.76 | 6.22 |
| 4 | Ca | 9,470 | 20,460 | 29,930 | 3.00 | 20.50 | 23.50 | 6.84 | 10.45 |
| 5 | Gianh | | 4,680 | 4,680 | | 7.49 | 7.49 | 2.03 | 2.17 |
| 6 | Thach Han | | 2,550 | 2,550 | | 4.40 | 4.40 | 1.10 | 1.47 |
| 7 | Huong | | 3,300 | 3,300 | | 6.73 | 6.73 | 1.83 | 3.14 |
| 8 | Thu Bon & Vu | | 10,350 | 10,350 | | 20.40 | 20.40 | 6.23 | 7.34 |
| 9 | Tra Khuc | | 5,200 | 5,200 | | 9.48 | 9.48 | 2.95 | 3.28 |
| 10 | Kone | | 3,640 | 3,640 | | 7.23 | 7.23 | 1.99 | 2.72 |
| 11 | Ba | | 13,900 | 13,900 | | 10.34 | 10.34 | 2.48 | 3.53 |
| 12 | Dong Nai | 6,700 | 33,594 | 40,294 | 3.80 | 31.90 | 35.70 | 7.64 | 13.95 |
| 13 | SERC | | 15,760 | 15,760 | | 9.78 | 9.78 | 2.00 | 2.71 |
| 14 | Se San | | 11,450 | 11,450 | | 12.90 | 12.90 | 3.70 | 7.18 |
| 15 | Sre Pok | | 18,200 | 18,200 | | 15.04 | 15.04 | 3.95 | 4.72 |
| 16 | Cuu Long | 723,574 | 37,165 | 760,73 | 457.00 | 22.90 | 479.90 | 108.9 | 108.9 |
| 17 | Other V1 & V4 | | 2,606 | 2,606 | | 29.1 | 29.1 | | |
| | Totals | 835,422 | 297,977 | 1,133,3 | 521.2 | 311.5 | 832.67 | 194.5 | 231.5 |

*Source: MONRE (2012)*

**Figure 3.1: Water Exploitation Indicator by River Basin**




*Source: KBR: 2008.*

39. Estimating water supply and use patterns is a challenge in any country, but particularly so in emerging economies, where monitoring capacity significantly lags changes in water system capacity and needs. Extensive systems of informal conveyance and storage render large quantities of rural water unobservable or only observable with significant measurement error. Urban and peri-urban water systems are only partially covered by consistent monitoring and regulatory capacity, again making data gathering difficult and unreliable. In Vietnam, utility coverage has been growing steadily, yet official water distribution still represents less than half the nations allocation and use. Other official and independent data on water are often inconsistent and partially conflicting.

40. For these reasons, any effort to assess detailed patterns of water use will be uncertain, but it remains important to develop indicative evidence that can improve visibility for policy makers, identifying potential risks to water security, including potential growth and public health related constraints on availability. In the present exercise, we have attempted to disaggregate our aggregate projections by imputing use patterns from detailed survey data. Fortunately, Vietnam is well endowed with the latter, and we have consulted three of these representing the major constituents of national water demand.

41. The first survey was used to impute residential demand. This is the nationally representative Vietnam Household Living Standards Survey (VHLSS0 now available for 2010 and comprising over 60,000 observations across the country. These data provide detailed information on local water services, which we combined with data on income, household size, and consensus demand parameters (e.g Bhatti et al: 2010 and Minot: 2000) to impute water use by province. Provincial estimates were then mapped to river basins using regional aggregation data.

42. For agricultural water use, we relied on the 2011 Vietnam Agricultural Census. This survey of over 10 million rural households provides detailed information on individual patterns of

cropping, livestock production, and aquaculture. This land use data was then combined with use-level data on water requirements from FAOSTAT using techniques applied from climate risk assessment (e.g. Nahn et al: 2007 and Heft-Neal and Roland-Holst: 2012), allowing imputation of water requirements by province and river basin.

43. Finally, water use by industry and services was imputed by combining the 2010 Vietnam Enterprise Census (VEC) with national data on water use intensity by economic activity. The VEC data have been collected by the GSO since 2005, and by 2010 their sample comprised over 300,000 firms of all sizes and (ISIC) sectors. These data also support the GSO's quintennial input-output tables, which detail patterns of intermediate and resource use (including water as an individual category) for 122 ISIC aggregated sectors. Using the latter average use sectoral use intensities, we imputed water demand by enterprise and location across the VEC sample. This in turn was aggregate to the provincial and river basin levels for industry and service enterprises.

### A. Annual Water Requirements

44. As a starting point for the present discussion, Table 3.2 presents our initial year (2010) estimates for water use by activity and river basin, with comparison numbers for the supply side (annual water capacity) obtained from independent estimates (MONRE: 2006).

**Table 3.2: Annual Water Use by Activity and River Basin (2010, Mm3)**

| | Residential | Agriculture | Industry | Services | Total | Capacity* | Use Ratio |
|---|---|---|---|---|---|---|---|
| Bang Giang – Ky Cung | 7 | 300 | 0 | 4 | 311 | 9,000 | 3% |
| Hong (Red) Thai binh | 555 | 17,974 | 1,849 | 299 | 20,677 | 133,680 | 15% |
| Ma | 53 | 4,684 | 77 | 28 | 4,842 | 18,000 | 27% |
| Ca | 64 | 1,990 | 22 | 35 | 2,111 | 23,500 | 9% |
| Gianh | 5 | 62 | 1 | 3 | 71 | 7,490 | 1% |
| Thach Han | 4 | 114 | 0 | 2 | 120 | 4,400 | 3% |
| Huong | 39 | 1,393 | 105 | 21 | 1,559 | 6,730 | 23% |
| Thu Bon & vu gia | 34 | 1,400 | 141 | 18 | 1,593 | 20,400 | 8% |
| Tra Khuc | 6 | 746 | 70 | 3 | 826 | 9,480 | 9% |
| Kone & Ha thanh & La tinh | 16 | 928 | 9 | 8 | 961 | 7,230 | 13% |
| Ba | 21 | 1,663 | 6 | 12 | 1,702 | 10,340 | 16% |
| Dong Nai | 196 | 3,444 | 924 | 106 | 4,670 | 35,700 | 13% |
| SERC | 75 | 2,053 | 300 | 40 | 2,469 | 9,780 | 25% |
| Se San | 6 | 195 | 16 | 3 | 220 | 12,900 | 2% |
| Sre pok + Ya... | 26 | 826 | 15 | 14 | 881 | 15,040 | 6% |
| Cuu Long (Mekong) | 268 | 34,990 | 8 | 145 | 35,411 | 479,900 | 7% |
| Total | 1,377 | 72,761 | 3,544 | 741 | 78,423 | 803,570 | 10% |

*Notes: Capacity from MONRE: 2008. Use Ration = Total/Capacity. Source: Author estimates.*

45. Accepting the caveats above regarding estimation uncertainties, one can still discern significant spatial heterogeneity in these estimates. Noting that national averages for water use are about 3% residential, 90% for agriculture/aquaculture, 5% for industry, and 2% services, we see significantly different use intensities across basins, particularly in those with high urban and industry populations. At the same time, taking account of supply side conditions, we see even greater diversity in Use Ratios (use as a percent of capacity), a rough measure of the tightness of local water constraints. Having said this, however, the maximum use ratio is only about a third of capacity (Dong Nai) and national water use remains about one quarter of existing

capacity.[3] For reference, initial year water use patterns by province are presented in Table 3.4 below.

46. Using the forecasting model to take the demand side of these water results forward, we obtain the results in Table 3.3, where emergent constraints have become more apparent. The Ma, Huong, and SERC basins all approach half of total annual capacity, which could pose risks in the context of annual fluctuations in rainfall cycles, as well as limiting opportunities for local intensification and improvements in average water quality.

### Table 3.3: Annual Water Use by Activity and River Basin (Baseline scenario 2030, Mm3)

| | Residential | Agriculture | Industry | Services | Total | Capacity* | Use Ratio |
|---|---|---|---|---|---|---|---|
| Bang Giang – Ky Cung | 20 | 533 | 2 | 12 | 566 | 9,000 | 6% |
| Hong (Red) Thai binh | 1,598 | 31,959 | 5,856 | 943 | 40,355 | 133,680 | 30% |
| Ma | 152 | 8,328 | 244 | 89 | 8,813 | 18,000 | 49% |
| Ca | 185 | 3,538 | 70 | 109 | 3,903 | 23,500 | 17% |
| Gianh | 15 | 110 | 2 | 9 | 137 | 7,490 | 2% |
| Thach Han | 13 | 202 | 0 | 8 | 223 | 4,400 | 5% |
| Huong | 113 | 2,477 | 333 | 67 | 2,989 | 6,730 | 44% |
| Thu Bon & vu gia | 97 | 2,489 | 447 | 57 | 3,091 | 20,400 | 15% |
| Tra Khuc | 18 | 1,326 | 222 | 11 | 1,577 | 9,480 | 17% |
| Kone & Ha thanh & La tinh | 45 | 1,651 | 29 | 26 | 1,751 | 7,230 | 24% |
| Ba | 62 | 2,957 | 19 | 36 | 3,074 | 10,340 | 30% |
| Dong Nai | 565 | 6,124 | 2,927 | 333 | 9,949 | 35,700 | 28% |
| SERC | 216 | 3,650 | 950 | 128 | 4,945 | 9,780 | 51% |
| Se San | 17 | 347 | 51 | 10 | 424 | 12,900 | 3% |
| Sre pok + Ya… | 75 | 1,469 | 48 | 44 | 1,635 | 15,040 | 11% |
| Cuu Long (Mekong) | 773 | 62,214 | 25 | 456 | 63,468 | 479,900 | 13% |
| Total | 3,963 | 129,373 | 11,223 | 2,339 | 146,898 | 803,570 | 18% |

*Notes: Capacity from MONRE: 2008. Use Ration = Total/Capacity. Source: Author estimates.*

47. Even doubling of water use requirements, which we are forecasting by 2030, would only lead to average capacity use of 18% across the year and the overall Vietnamese economy. Unfortunately, water requirements vary substantially over both space and time. The first is apparent in capacity use differences across basins (Tables 3.2 and 3.3). Without an extensive system of national water conveyance, national average capacity use is of little relevance to basins that have more fully utilized their local water resources. More water intensive growth could apparently be easily accommodated in basins like Gianh, Thach Han, and Se San, but this will be little comfort to the SERC, Ma, or Huong basins, who face the prospect of significant investments to increase local water capacity.

48. Our results suggest that business-as-usual economic growth in Vietnam will escalate risks of water insecurity, nearly doubling national average capacity use (from 10% to 18%) and presenting greater sustainability risks in several strategically important basins. Among these, Ma, Huong, and SERC represent sentinel challenges for water policy. On an annual average basis, we estimate that current growth trends will lead to over 40% capacity use in this baseline by 2030, almost certainly implying critical scarcity on a seasonal basis.

[3] It must be emphasized, however, that these annual averages understate the potential for water shortage because they do not capture seasonality in either demand or supply. Ideally, this analysis would be extended, at a minimum, to wet and dry season comparisons.

**Figure 3.1**
**Growth Rates of Water Use**
**2010-2030 (percent)**

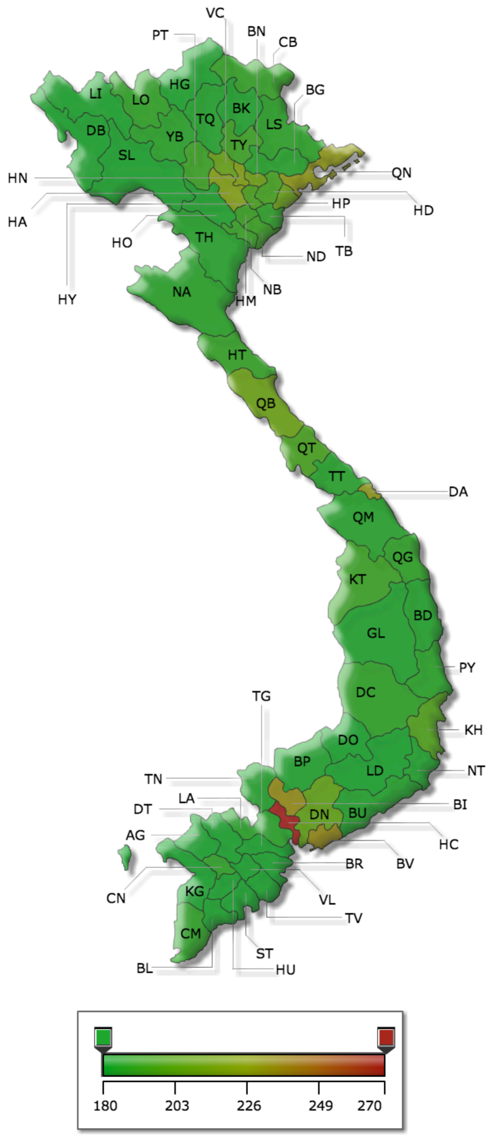
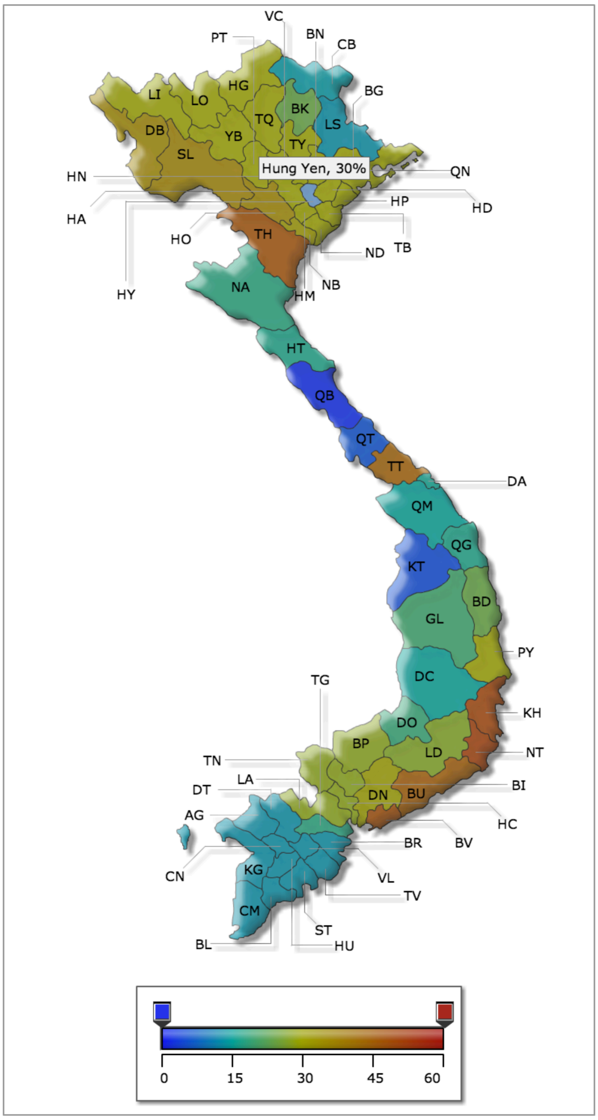



**Figure 3.2**
**Water Capacity Use by Province**
**(percent)**




*Capacity is aggregate seasonal water use as a percent of capacity (including existing storage and conveyance).*
*Source: Author estimates.*

49. Figure 3.2 presents these demand growth results in an explicitly spatial context, showing the impacts of differential growth rates at the provincial level. As the left-hand figure suggests, overall rates of water demand growth are not too differentiated. This is a result of agriculture's pervasive (geographic) and relatively moderating influence of water demand over 2010-30 by province. Only in provinces with high concentrations of industry to we see water demand growing significantly above the national average of 192% over 2010-30.

50. When we look at demand growth with river basin capacity in mind, however, a very different picture emerges in the right-hand map. This depicts provinces, with average basin capacity use, weighted by the percent of each basin within a given province. Here the potential water constraints in rapidly growing regions of the country become immediately apparent.

51. Policy implications are equally straightforward - significant needs for some combination of demand management, spatial activity adjustments, and greater capacity for storage and conveyance. While detailed strategic planning on for both demand and supply side interventions is outside the scope of the present study, our efficiency scenarios can shed useful light on the potential of demand side solutions, especially with respect to agriculture.

52. The results depicted in the next four maps (Figures 3.3 and 3.4) clearly reveal that demand side measures, if successfully deployed, offer Vietnam the opportunity to fulfill its growth objectives within the envelope of existing national water resources. Under the macro or economywide efficiency scenario (MacEff) average and individual basin capacity use levels stay well within relatively safe thresholds (again on an annual average basis). This implies that targeting water use behavior could save the country billions in defensive water infrastructure investments. Such investments will remain essential to secure water quality, and probably to avert the shocks of seasonal fluctuations, but improving underlying use efficiency can make cost effective contributions to national water security.

53. The second two maps reveal another essential property of the Vietnam water situation, however. Because of its sustained prominence in national water use, efficiency measures in one sector alone, agriculture, hold enormous potential for more sustainable water policy. Vietnam's modernization process will continue to shift human, land, and other resources toward non-agricultural activities, value added, and employment creation. If agricultural policy can support this with more active intervention to improve farm water use efficiency, Vietnam could complete this transition without severe water bottlenecks and the disruptions they cause.

54. Indeed, the results of the last scenario suggest that agricultural water use efficiency could even accommodate higher growth rates, particularly if these are part of an integrated approach to agrifood modernization and productivity growth. Thus we see that the growth potential of Vietnam's economy may be led by industrialization, but its sustainability can be secured by improved practices in the rural sector.

## B. Annual Average Capacity Use (percent) – 2030

**Figure 3.3**
**Baseline**

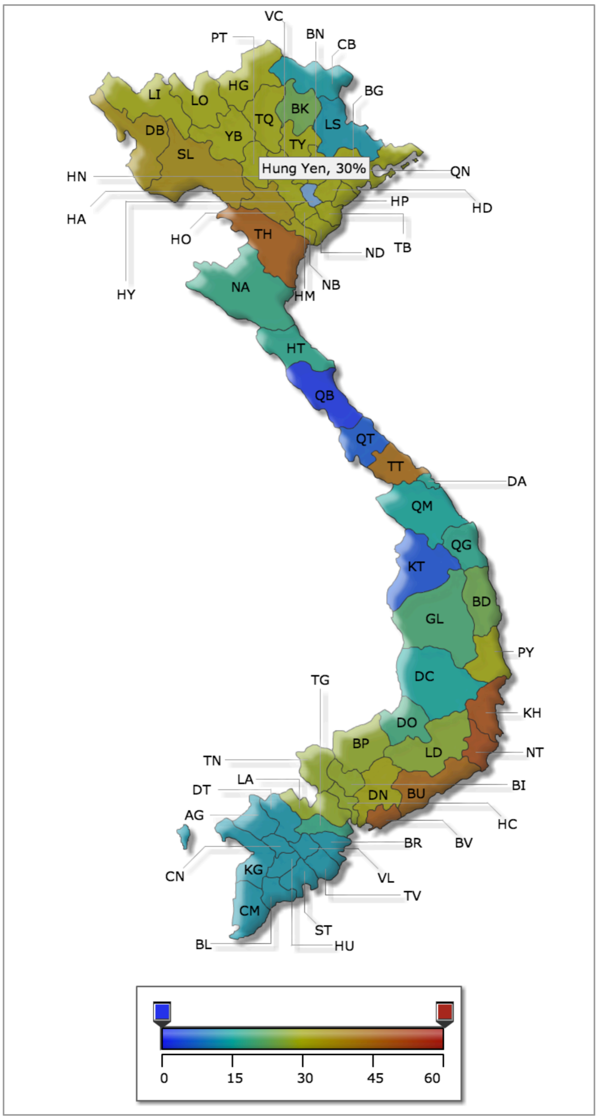
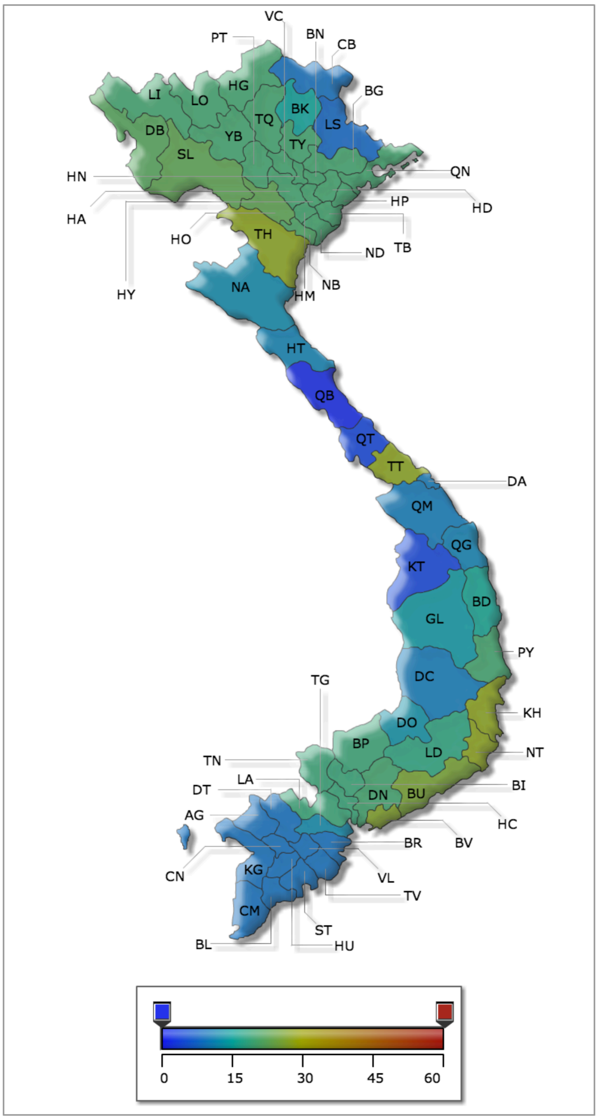



**Figure 3.4**
**Macro Water Efficiency**




*Capacity is aggregate seasonal water use as a percent of capacity (including existing storage and conveyance).*
*Source: Author estimates.*

**Figure 3.5**
**Ag Water Use Efficiency**

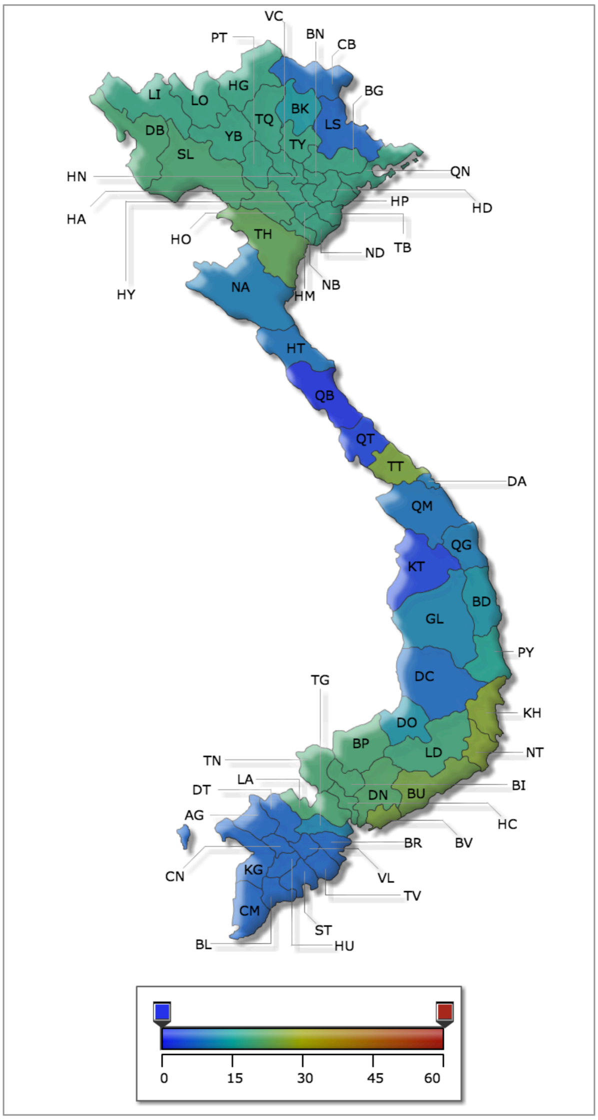
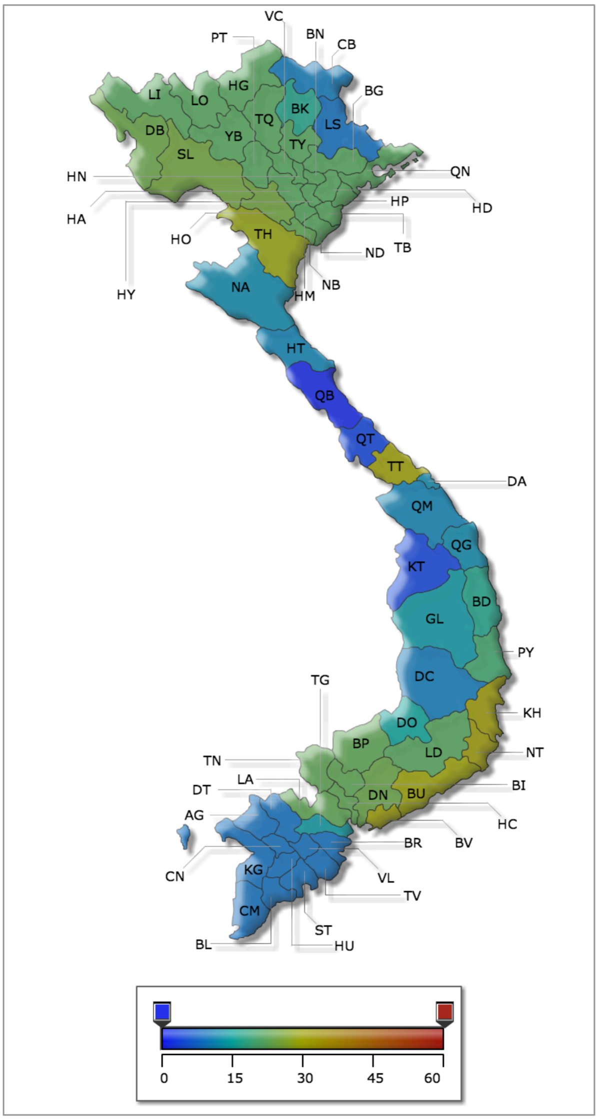



**Figure 3.6**
**With Factor Productivity Growth**




*Capacity is aggregate seasonal water use as a percent of capacity (including existing storage and conveyance).*
*Source: Author estimates.*

## C. Dry Season Water Requirements

55. The same heterogeneity arguments apply over time. That is to say, annual water resources might seem ample on an average basis, but water availability and needs are not uniform across the year. In the absence of storage capacity that can smooth availability, some basins could experience temporary or even prolonged water capacity constraints that are much higher than annual averages would suggest. To assess the importance of this issue for Vietnam water resources, we estimated both water availability and use requirements for the dry season months prevailing in each major basin area.

56. Table 3.4 below illustrates this problem. Across the year, both water supply and demand are variable and covariate. The dry season in Vietnam lasts an average of 8 months (67% of the year), during which time the national water supply (largely through surface and groundwater movement), increases only about 31% across all basins (Table 3.5). At the same time, water use across the year is relatively constant for residential and industry use, while agriculture generally increases irrigation use in response to lower average precipitation. As Table 3.4 also indicates, in most basins the capacity use rate increases for dry season water ("Difference" column), increasing an average of 10.07% across the economy. We obtained these estimates with a national irrigation model based on agronomic requirements of Vietnam's main staple crops.

### Table 3.4: Dry Season Water Use and Capacity (2010, Bm3)

| | Irrigation/ Agriculture | Industry | Cities and villages | Aquaculture | Total Use | Dry season water volume | Use/ Capacity (percent) | Simple Average Use | Difference (percent) |
|---|---|---|---|---|---|---|---|---|---|
| Bang Giang – Ky Cung | 0.148 | 0.000 | 0.006 | 0.015 | 0.170 | 2.308 | 7.35 | 0.181 | -6.85 |
| Hong (Red) Thai binh | 10.175 | 1.079 | 0.498 | 0.425 | 12.177 | 51.381 | 23.70 | 12.062 | 0.94 |
| Ma | 2.525 | 0.045 | 0.047 | 0.236 | 2.853 | 6.215 | 45.91 | 2.825 | 1.00 |
| Ca | 1.266 | 0.013 | 0.058 | 0.169 | 1.505 | 10.450 | 14.40 | 1.231 | 18.16 |
| Gianh | 0.050 | 0.000 | 0.005 | 0.000 | 0.056 | 2.169 | 2.60 | 0.047 | 16.06 |
| Thach Han | 0.077 | 0.000 | 0.005 | 0.013 | 0.094 | 1.467 | 6.43 | 0.080 | 14.79 |
| Huong | 1.052 | 0.070 | 0.040 | 0.067 | 1.229 | 3.140 | 39.16 | 1.039 | 15.48 |
| Thu Bon & vu gia | 1.098 | 0.106 | 0.039 | 0.092 | 1.334 | 7.337 | 18.18 | 1.195 | 10.44 |
| Tra Khuc | 0.638 | 0.053 | 0.007 | 0.002 | 0.700 | 3.284 | 21.32 | 0.619 | 11.56 |
| Kone & Ha thanh & La tinh | 0.779 | 0.007 | 0.018 | 0.016 | 0.820 | 2.720 | 30.14 | 0.721 | 12.06 |
| Ba | 1.332 | 0.004 | 0.022 | 0.018 | 1.376 | 3.530 | 38.98 | 1.135 | 17.52 |
| Dong Nai | 1.857 | 0.539 | 0.176 | 0.553 | 3.125 | 13.946 | 22.41 | 2.724 | 12.83 |
| SERC | 1.056 | 0.175 | 0.067 | 0.370 | 1.668 | 2.710 | 61.56 | 1.440 | 13.67 |
| Se San | 0.110 | 0.008 | 0.005 | 0.006 | 0.129 | 7.184 | 1.79 | 0.110 | 14.51 |
| Sre pok + Ya… | 0.460 | 0.008 | 0.020 | 0.031 | 0.518 | 4.718 | 10.99 | 0.441 | 15.03 |
| Cuu Long (Mekong) | 17.531 | 0.004 | 0.207 | 2.935 | 20.676 | 108.937 | 18.98 | 17.706 | 14.37 |
| Total | 40.153 | 2.110 | 1.220 | 4.946 | 48.430 | 231.490 | 20.92 | 43.555 | 10.07 |

*Notes: The Difference column shows the percent difference in basin capacity use, between annual and dry season averages.*

57. The obvious implication of these heterogeneity issues is that scarcity, from both the supply and demand sides of domestic water markets, becomes more acute during the dry season. This scarcity can be mitigated by conveyance (spatial heterogeneity) and storage (temporal heterogeneity), but the first priority is to identify and assess its significance. After decomposing our analysis into two parts, annual and dry season water availability and use, it is clear that Vietnam faces more serious constraints to growth with food security, potential disruption of

economic and environmental services from water, and will need to seriously consider more determined infrastructure investments to offset these.

58. Table 3.5 below shows what the dry season looks like in the base year of 2010. As is apparent from the last column, capacity use in this season is 2.14 times higher on average, and spikes in some basins to over 2.5 times annual capacity use. Across the economy, even dry season capacity use averages only 21%, but it can be twice to nearly three times as high in individual basins.

### Table 3.5: Dry Season Baseline Water Use by Activity and Basin (2010, Mm3)

| | Residential | Agriculture | Industry | Services | Total | Capacity* | Use Ratio | Dry/Annual |
|---|---|---|---|---|---|---|---|---|
| Bang Giang – Ky Cung | 4 | 163 | 0 | 2 | 170 | 2,308 | 7% | 2.13 |
| Hong (Red) Thai binh | 324 | 10,600 | 1,079 | 174 | 12,177 | 51,381 | 24% | 1.53 |
| Ma | 31 | 2,761 | 45 | 17 | 2,853 | 6,215 | 46% | 1.71 |
| Ca | 38 | 1,434 | 13 | 20 | 1,505 | 10,450 | 14% | 1.60 |
| Gianh | 4 | 50 | 0 | 2 | 56 | 2,169 | 3% | 2.74 |
| Thach Han | 3 | 90 | 0 | 2 | 94 | 1,467 | 6% | 2.35 |
| Huong | 26 | 1,119 | 70 | 14 | 1,229 | 3,140 | 39% | 1.69 |
| Thu Bon & vu gia | 25 | 1,189 | 106 | 14 | 1,334 | 7,337 | 18% | 2.33 |
| Tra Khuc | 5 | 640 | 53 | 3 | 700 | 3,284 | 21% | 2.45 |
| Kone & Ha thanh & La tinh | 12 | 795 | 7 | 6 | 820 | 2,720 | 30% | 2.27 |
| Ba | 14 | 1,350 | 4 | 8 | 1,376 | 3,530 | 39% | 2.37 |
| Dong  Nai | 115 | 2,410 | 539 | 62 | 3,125 | 13,946 | 22% | 1.71 |
| SERC | 44 | 1,426 | 175 | 24 | 1,668 | 2,710 | 62% | 2.44 |
| Se San | 3 | 116 | 8 | 2 | 129 | 7,184 | 2% | 1.05 |
| Sre pok + Ya... | 13 | 491 | 8 | 7 | 518 | 4,718 | 11% | 1.88 |
| Cuu Long (Mekong) | 134 | 20,465 | 4 | 72 | 20,676 | 108,937 | 19% | 2.57 |
| Total | 793 | 45,100 | 2,110 | 427 | 48,430 | 231,496 | 21% | 2.14 |

59. By the time we get to 2030 on Baseline growth trends, acute bottlenecks will appear during the dry season (Table 3.6). The SERC is actually estimated to need more water than is locally available during this time, suggesting that storage and conveyance infrastructure would be a very high priority for this basin, as well as Ma and Huong.

### Table 3.6: Dry Season Baseline Water Use by Activity and Basin (2030, Mm3)

| | Residential | Agriculture | Industry | Services | Total | Capacity* | Use Ratio | Dry/Annual |
|---|---|---|---|---|---|---|---|---|
| Bang Giang – Ky Cung | 12 | 290 | 1 | 7 | 309 | 2,308 | 13% | 2.13 |
| Hong (Red) Thai binh | 932 | 18,847 | 3,416 | 550 | 23,745 | 51,381 | 46% | 1.53 |
| Ma | 88 | 4,909 | 142 | 52 | 5,192 | 6,215 | 84% | 1.71 |
| Ca | 108 | 2,550 | 41 | 64 | 2,762 | 10,450 | 26% | 1.59 |
| Gianh | 10 | 90 | 1 | 6 | 107 | 2,169 | 5% | 2.71 |
| Thach Han | 9 | 159 | 0 | 5 | 173 | 1,467 | 12% | 2.33 |
| Huong | 75 | 1,990 | 222 | 44 | 2,331 | 3,140 | 74% | 1.67 |
| Thu Bon & vu gia | 73 | 2,115 | 335 | 43 | 2,566 | 7,337 | 35% | 2.31 |
| Tra Khuc | 14 | 1,138 | 166 | 8 | 1,326 | 3,284 | 40% | 2.43 |
| Kone & Ha thanh & La tinh | 33 | 1,414 | 22 | 20 | 1,489 | 2,720 | 55% | 2.26 |
| Ba | 41 | 2,400 | 13 | 24 | 2,478 | 3,530 | 70% | 2.36 |
| Dong  Nai | 330 | 4,285 | 1,707 | 194 | 6,516 | 13,946 | 47% | 1.68 |
| SERC | 126 | 2,535 | 554 | 74 | 3,290 | 2,710 | 121% | 2.40 |
| Se San | 8 | 207 | 25 | 5 | 245 | 7,184 | 3% | 1.04 |
| Sre pok + Ya... | 37 | 873 | 24 | 22 | 956 | 4,718 | 20% | 1.86 |
| Cuu Long (Mekong) | 386 | 36,388 | 13 | 228 | 37,015 | 108,937 | 34% | 2.57 |
| Total | 2,283 | 80,189 | 6,683 | 1,347 | 90,502 | 231,496 | 39% | 2.14 |

### D. Dry Season Average Water Capacity Use (percent) – 2030

60. Looking at water supply and demand during the dry season, we see much more serious risks to growth and water security generally. Figure 3.7 suggests that at least five basins will be exceeding 50% of their water capacity by 2030 in the Baseline scenario, while many other's will have much higher capacity use. Figure 3.8, however, illustrates the potential of demand side management policies to mitigate these bottlenecks, reducing the number of critical provinces (red) and shifting some distressed ones (brown) toward more sustainable use trends (green).

**Figure 3.7**
**Baseline**

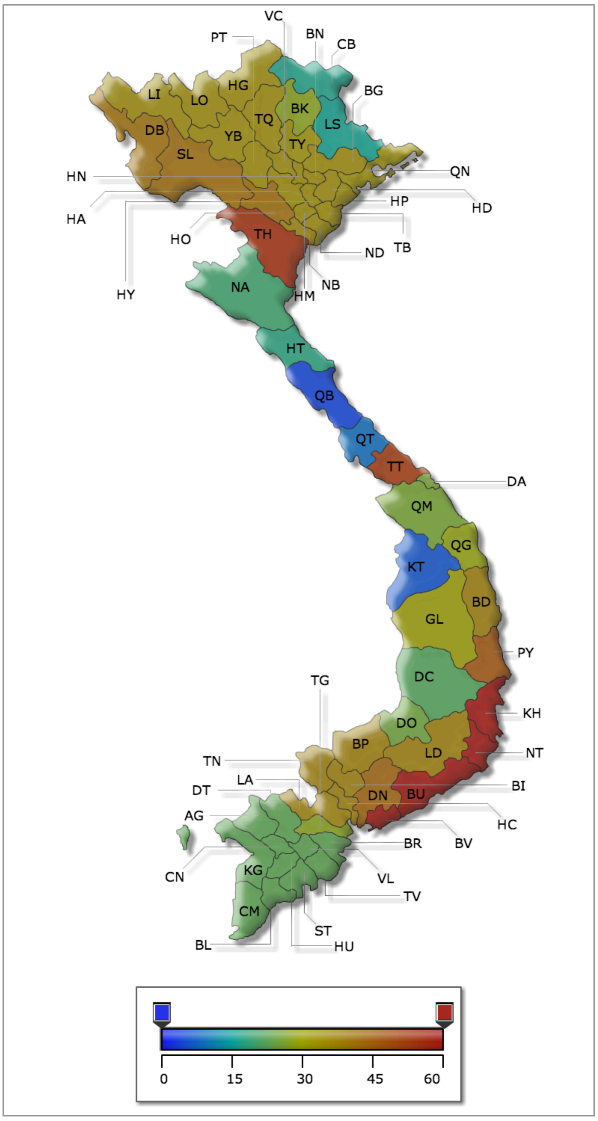
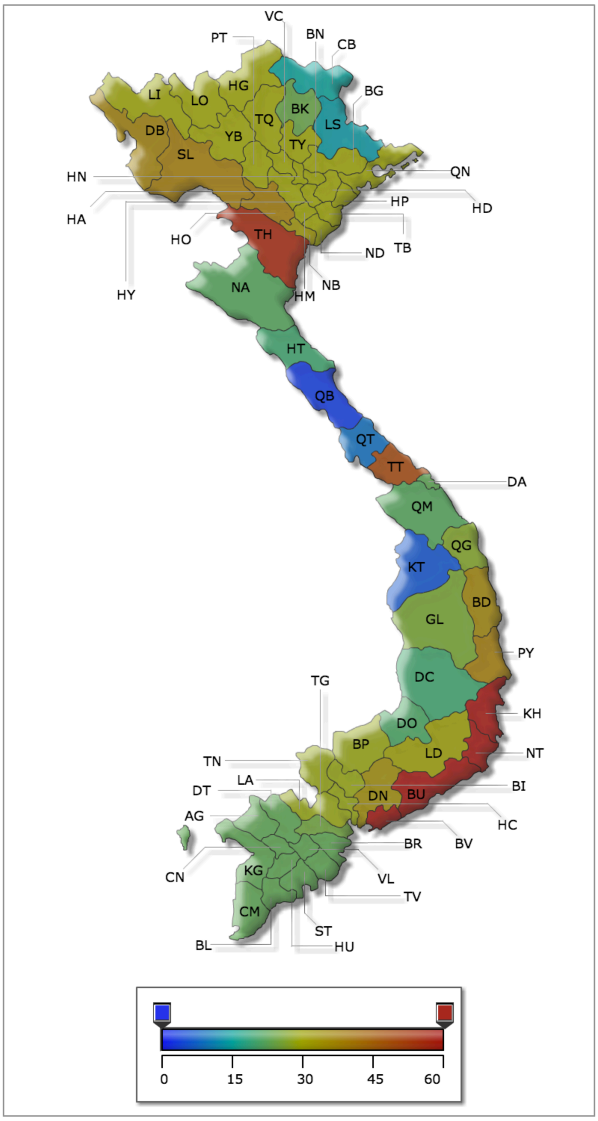



**Figure 3.8**
**Macro Water Efficiency**




*Capacity is aggregate seasonal water use as a percent of capacity (including existing storage and conveyance).*
*Source: Author estimates.*

**Figure 3.9**
**Ag Water Use Efficiency**

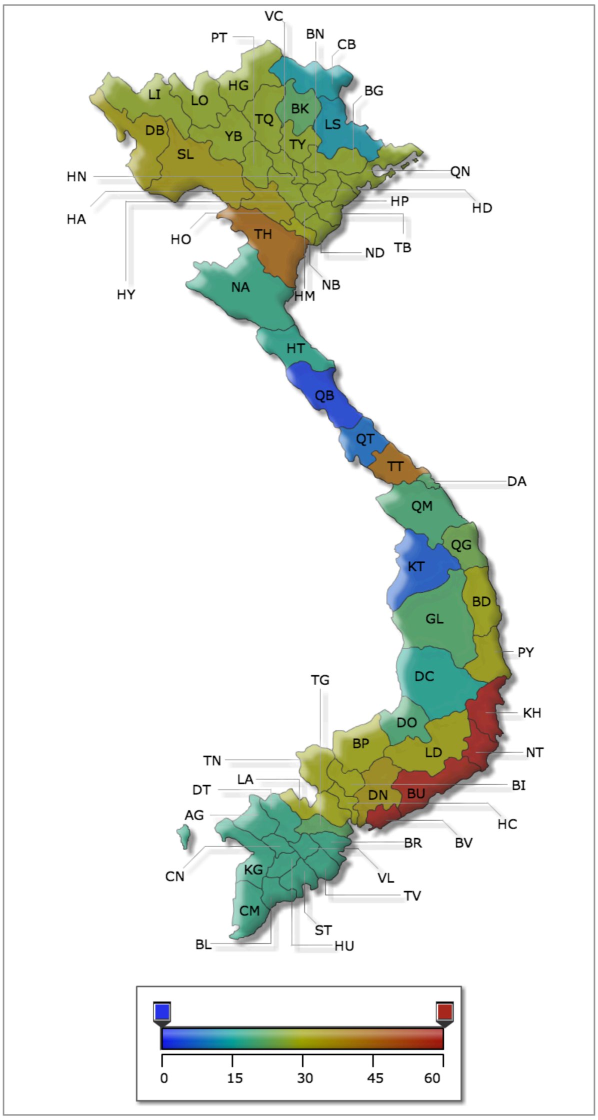
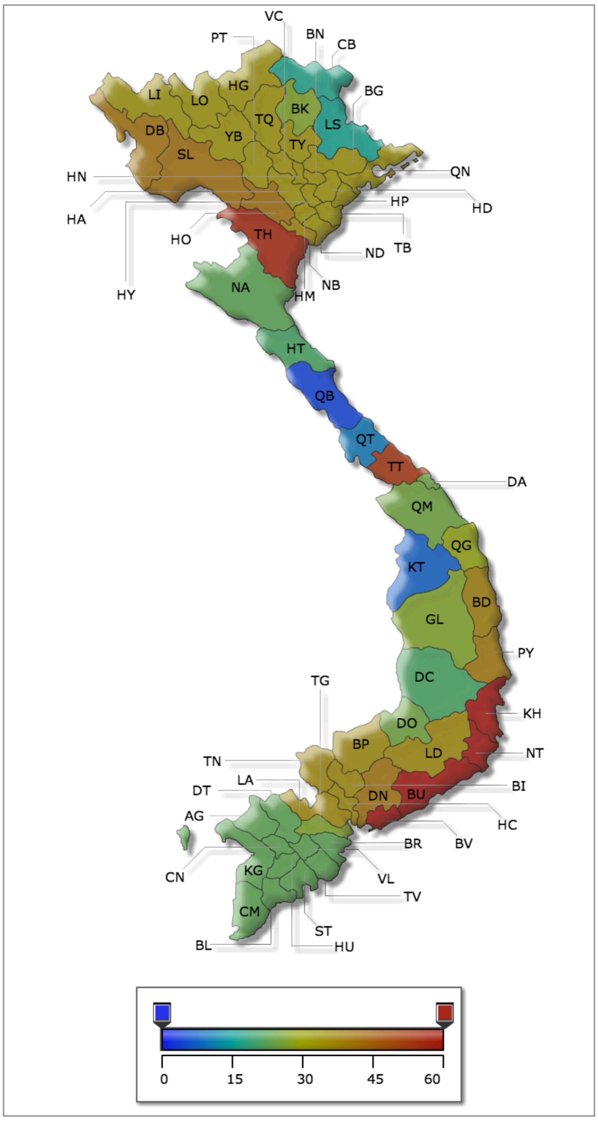



**Figure 3.10**
**With Factor Productivity Growth**




*Capacity is aggregate seasonal water use as a percent of capacity (including existing storage and conveyance).*
*Source: Author estimates.*

61. Despite the importance of efficiency gains on an annual basis, however, it is clear that both spatial and temporal water allocation mismatches will be important challenges for Vietnam. Dry season results reveal critical scarcity under all scenarios (esp. SERC), meaning that demand side management must be complemented by investments in water infrastructure and management institutions. Expanded conveyance systems can help overcome spatial mismatches, while greater storage capacity can mitigate temporal mismatches.

## 4 OVERVIEW OF THE FORECASTING MODEL

62. Although many of the water challenges facing Viet Nam are already acknowledged, empirical evidence to support effective adaptation policies remains relatively weak. Because of the importance of agriculture generally and the long lead times required for structural adjustment in this sector generally and water resource management in particular, policy makers need better foresight about emerging risks in this sector. To provide this kind of empirical policy support, we developed a dynamic forecasting model calibrated to detailed information on Viet Nam's economic structure, including regional crop and water use information.

63. Models like to one used here are intended to capture the extended linkages and indirect effects that follow from specific external shocks policies. The complexities of today's global economy make it very unlikely that policy makers relying on intuition or rules-of-thumb will achieve optimality. Market interactions are so pervasive in determining economic outcomes that more sophisticated empirical research tools are needed to improve visibility for both public and private sector decision makers. The preferred tool for detailed empirical analysis of economic policy is now the Calibrated General Equilibrium (CGE) model. It is well suited to trade analysis because it can detail structural adjustments within national economies and elucidate their interactions in international markets. Technical details of the Viet Nam CGE are presented in an annex to this report, and a large research and policy literature documents this general approach, but a few general comments will facilitate discussion and interpretation of the scenario results that follow.

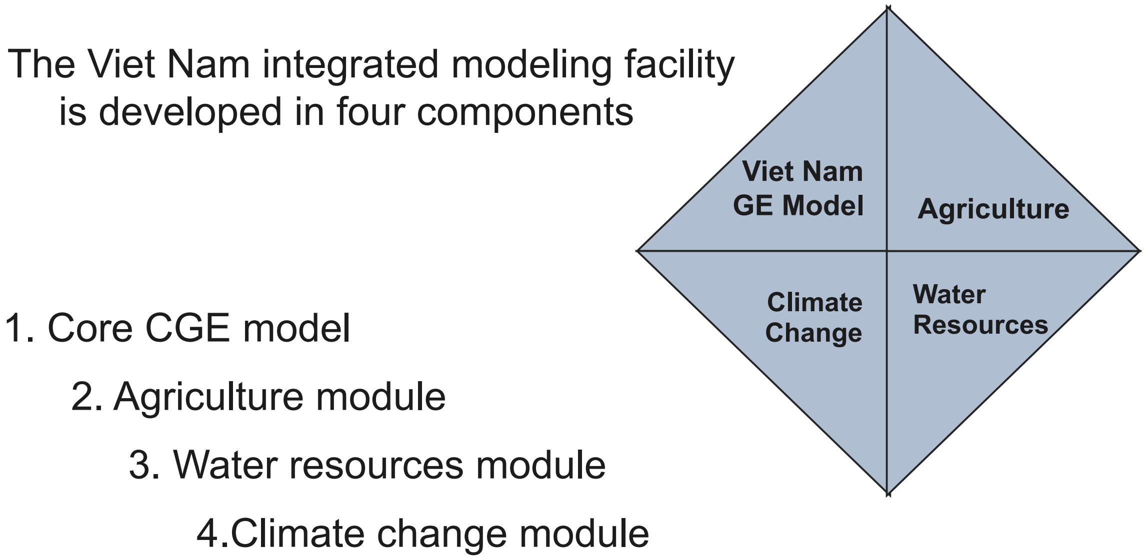
64. Technically, a CGE model is a system of simultaneous equations that simulate price directed interactions between firms and households in commodity and factor markets. The role of government, capital markets, and other trading partners are also specified, with varying degrees of detail and passivity, to close the model and account for economywide resource allocation, production, and income determination.

65. The role of markets is to mediate exchange, usually with a flexible system of prices, the most important endogenous variables in a typical CGE model. As in a real market economy, commodity and factor price changes induce changes in the level and composition of supply and demand, production and income, and the remaining endogenous variables in the system. In CGE models, an equation system is solved for prices that correspond to equilibrium in markets and satisfy the accounting identities governing economic behavior. If such a system is precisely specified, equilibrium always exists and such a consistent model can be calibrated to a base period data set. The resulting calibrated general equilibrium model is then used to simulate the economywide (and regional) effects of alternative policies or external events.

66. The distinguishing feature of a general equilibrium model, applied or theoretical, is its closed form specification of all activities in the economic system under study. This can be contrasted with more traditional partial equilibrium analysis, where linkages to other domestic markets and agents are deliberately excluded from consideration. A large and growing body of evidence suggests that indirect effects (e.g., upstream and downstream production linkages) arising from policy changes are not only substantial, but may in some cases even outweigh direct effects. Only a model that consistently specifies economywide interactions can fully assess the implications of economic policies or business strategies. In a multi country model like the one used in this study, indirect effects include the trade linkages between countries and regions which themselves can have policy implications.

67. The general equilibrium aspect is particularly useful in assessment of resource issues like those related to climate change. In this context, many activities compete explicitly or implicitly for resources (e.g. water), and direct effects on one (e.g. agriculture) induce many effects on others. While the present analysis will not include assessment of direct climate impacts on non-agricultural activities (e.g. mortality/morbidity, fire risk, coastal inundation and storm damage), the CGE model faithfully captures indirect effects across all actors as these arise from agro-food and water scarcity impacts.

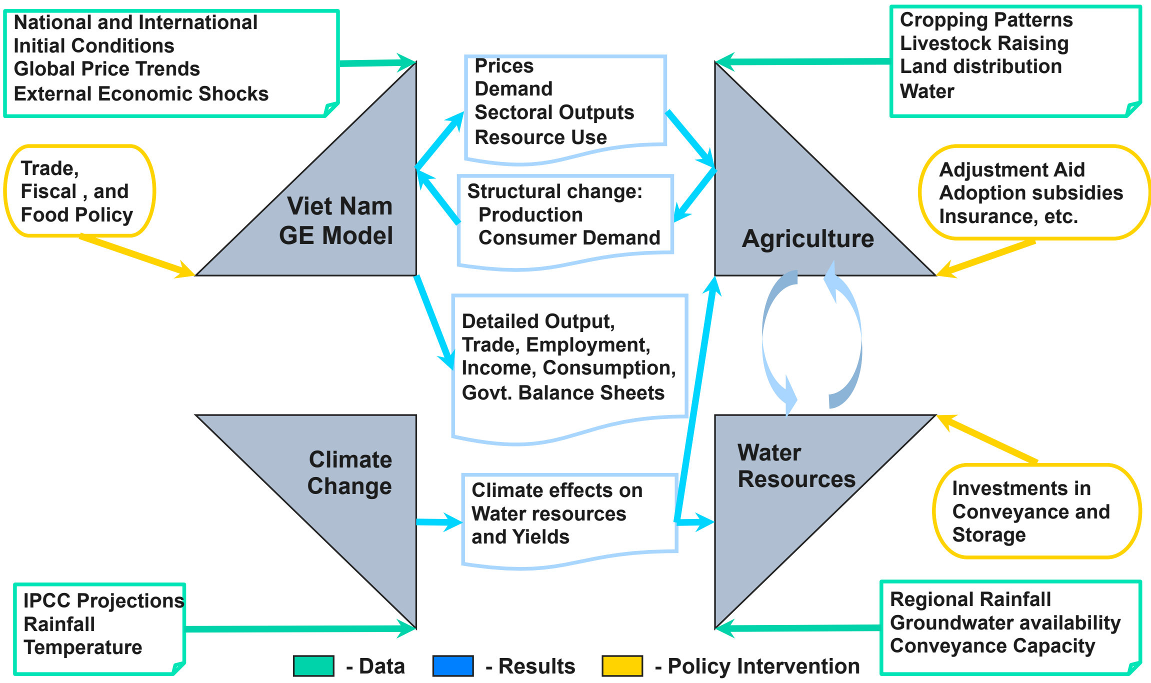
**Figure 4.1: Model Components**




68. The model we use for this work has been constructed according to generally accepted specification standards, implemented in the GAMS programming language, and calibrated to a detailed base year (2010) Social Accounting Matrix (SAM) for Viet Nam. As the above figure indicates, the modeling facility has four generic components, each capturing a different aspect of the problem at hand, the overall economy, the agricultural sector, water resources, and climate change. We do not model climate change, but assume the exogenous climate trends are specified in this component according to internationally established independent estimates.

69. Schematically, each component relies on different data resources and is relevant to different policies, yet all are connected through systemic linkages of economic activity, agronomic relationships, resource allocation, and environmental interaction. These linkages are illustrated schematically in following, although the functional relationships and structural detail are greatly simplified.

## Figure 4.2: Schematic Decomposition of the Viet Nam CGE Model




### 4.1.1

### 4.1.2 SAM Data Framework

70. The genesis of the SAM, the basic economic data resource, goes back to the Nobel Laureate Richard Stone's pioneering work on social accounting, and during the past 25 years a variety of formalizations have appeared in the academic literature. In essence, the SAM is an economywide accounting device that captures the many interdependencies among sectors and institutions in the economy. As such, the SAM becomes the basis for detailed multiplier analyses that go well beyond more traditional input-output multiplier analysis, and also forms the informational basis for the building and calibration of a variety of applied general equilibrium models. Such models are important analytical tools for policy support. They take explicit account of the importance of price-mediated resource allocation, the hallmark of a market economy, and are therefore well suited to analyze issues such as the impact of liberalization with respect to domestic and international markets.

71. Thus the SAM provides a closed form, economywide accounting of linkages between activities (and/or commodities), factors, households, domestic institutions (e.g., investment, government), and foreign institutions. The SAM used in the present study includes 97 activities and commodities, of which 25 are agro-food, and 12 are agricultural (Annex 1). Also detailed are four factors of production (labor, capital, land, and water), and quintile households in both rural and urban areas.

72. By including these characteristics for each agricultural activity and region, the complete regional model thus captures both structural and spatial heterogeneity in the Viet Nam economy at an unprecedented level of detail.

73. From the base year calibration, we carry forward the model and data forward under a variety of scenario assumptions to 2030, discussed in the next section. Apart from its traditional neoclassical roots, an important feature of this model is product differentiation, where we specify that imports is differentiated by country of origin and exports are differentiated by country of destination (e.g., de Melo and Tarr, 1992). This feature allows the model to capture the pervasive phenomenon of intra industry trade, where a country is both an importer and exporter of similar commodities, and avoids tendencies toward extreme specialization.

### 4.1.3 Model Characteristics Relevant to Agriculture

74. While the overall structure of the model is schematically laid out in Figure 8 and specified analytically in the annex below, it is useful in the present context to summarize how the CGE captures linkages between water and agriculture. In particular, we discuss four important relationships in nontechnical terms to clarify the drivers of subsequent assessment results.

#### *4.1.3.1 Water availability*

75. Estimates of aggregate water stocks, the sum of underground, impounded, and snowpack water, will obtained from other project activities and independent sources on a n annual basis in the initial year (2010) and obtained from the water accounting system discussed above. These figures are disaggregated regionally, and then carried forward a constant in the base case and exogenously variable in climate change scenarios. For the latter, we rely on IPCC/FAO estimates of changing rainfall and snow retention. For a given source of water, availability is assumed to be uniform across all agricultural activities in the same region. For the present we assume there is no inter-regional water transfer.

#### *4.1.3.2 Water requirement / unit output*

76. Water is assumed to be a factor of production for each commodity, differentiated by source: large-scale hydro, ground water, rain-fed and other. In this framework, water requirements and costs are calibrated directly from the regional and sectoral production structure of the base year SAM. These accounts detail water value added for each commodity, by source of the water, and thus reflect both unit input/output shares and costs.

77. As output changes in response to other economic forces over the baseline and in scenarios, water prices can respond to combinations of demand induced by corresponding water requirements and changing water supply conditions. The latter, as indicated above, will be specified exogenously for total water availability, but where water prices are endogenous markets will ration it across alternative uses. Thus output drives water requirements, but water prices will also drive output.

78. All the baseline water/output relationships depend on existing technologies, and improved conveyance and use efficiency can reduce the vulnerability of yields to water scarcity. For this reason, it would be desirable to assess the potential benefits of investments in agricultural water efficiency, including drip irrigation and low evaporation storage and conveyance.

#### *4.1.3.3 Rainfed yield effects*

79. Agricultural yields with respect to water inputs, both rainfed and irrigated, are calibrated in the base year with SAM shares of water value added for each crop. From this point, yields are assumed constant in the baseline scenario and then modified using FAO yield estimates in the

climate change scenarios. In particular, FAO estimates that two components, a positive CO2 fertilization and a negative heat/desiccation effect, will interact to reduce average crop yields (for constant inputs) as climate change progresses. These yield effects are captured in the CGE with a total factor productivity parameter that will fitted to FAO trend estimates. As a consequence, maintaining output will require higher total expenditure on agricultural inputs and, given variable scarcity of these, input substitution. For water in particular, it is reasonable to expect increased absolute and relative scarcity to drive agriculture toward less water-intensive technologies and/or crops. For irrigated agriculture, yields may also be affected, but we need examine the FAO estimates in more detail to ascertain the importance of this.

#### *4.1.3.4 Livestock*

80. In the CGE model, livestock is a commodity produced with inputs including pasturage, feed, and water. Water is a factor whose availability and use have already been described, but both pasturage and feed are commodity inputs. For pasturage, yield effects of climate change can be expected to be negative (see the last paragraph), so this input will be more scarce relative to the baseline scenario. Likewise, feed is crop dependent and can likewise be expected to be more scarce or expensive in the climate change scenarios. Because external supplies of feed may be more elastic than domestic ones, we can expect to see import substitution that will moderate but not completely offset higher costs of livestock production. Demand for domestic feed and grains will be lower, but the net income effect on Viet Nam farmers will depend on prices and costs as well as quantities. In its current configuration, the CGE model allows for substitution between pasturage and other land use, but not between pasturage and feed.

**Table 4.1: Institutions in the 2010 Vietnam SAM**

| | Activities and commodities | | |
|---|---|---|---|
| **1** | apadd | cpadd | Paddy rice |
| **2** | asugr | csugr | Sugarcane |
| **3** | aacrp | cacrp | Other annual crops |
| **4** | arubb | crubb | Rubber |
| **5** | acoff | ccoff | Coffee |
| **6** | altea | cltea | Tea leaf |
| **7** | apcrp | cpcrp | Other perennial crops |
| **8** | abovp | cbovp | Cows and pigs |
| **9** | apoul | cpoul | Poultry |
| **10** | aoliv | coliv | Other livestock |
| **11** | acfore | ccfore | Forestry |
| **12** | afish | cfish | Fishery |
| **13** | aaqua | caqua | Aquaculture |
| **14** | acoal | ccoal | Coal mining |
| **15** | acoil | ccoil | Crude oil |
| **16** | angas | cngas | Natural gas |
| **17** | aomin | comin | Other mining |
| **18** | ameat | cmeat | Meat processing |
| **19** | apfsh | cpfsh | Fish processing |
| **20** | apveg | cpveg | Vegetable and fruit processing |
| **21** | apoil | cpoil | Oils and fats processing |
| **22** | adair | cdair | Dairy |
| **23** | arice | crice | Rice husking |
| **24** | aflou | cflou | Other flours |
| **25** | afood | cfood | Other food processing |
| **26** | abevn | cbevn | Non-alcoholic beverages |
| **27** | abeva | cbeva | Alcoholic beverages |
| **28** | atoba | ctoba | Tobacco processing |
| **29** | afibr | cfibr | Yarn and other fibres |
| **30** | atext | ctext | Textiles |
| **31** | aclth | cclth | Clothing |
| **32** | aleat | cleat | Leather products |
| **33** | afoot | cfoot | Footwear |
| **34** | awood | cwood | Wood products |
| **35** | apapr | cpapr | Paper products |
| **36** | aprnt | cprnt | Printing products |
| **37** | afuel | cfuel | Petroleum products |
| **38** | achem | cchem | Other chemicals |
| **39** | anmet | cnmet | Non-metallic minerals |
| **40** | aceme | cceme | Cement |
| **41** | ametl | cmetl | Basic metals |
| **42** | ametp | cmetp | Metal products |
| **43** | amach | cmach | Machinery and equipment |
| **44** | aemch | cemch | Eletrical machinery |

| | | | |
|---|---|---|---|
| **45** | avehe | cvehe | Vehicles and transport equipment |
| **46** | afurn | cfurn | Furniture |
| **47** | aoman | coman | Other manufacturing |
| **48** | aelec | celec | Electricity and gas distribution |
| **49** | awatr | cwatr | Water distribution and utilities |
| **50** | acons | ccons | Construction |
| **51** | atrad | ctrad | Retail and wholesale trade |
| **52** | ahotl | chotl | Hotels and catering |
| **53** | atrnr | ctrnr | Road transport |
| **54** | atrna | ctrna | Air transport |
| **55** | atrno | ctrno | Other transport |
| **56** | acomm | ccomm | Communications |
| **57** | abusi | cbusi | Business services |
| **58** | afsrv | cfsrv | Financial services |
| **59** | areal | creal | Real estate |
| **60** | aadmn | cadmn | Public administration |
| **61** | aeduc | ceduc | Education |
| **62** | aheal | cheal | Health |
| **63** | aosrv | cosrv | Other services |

| **Factors** | | |
|---|---|---|
| **flab-rp** | Rural | Primary school |
| **flab-rs** | | Secondary school |
| **flab-rt** | | Tertiary school |
| **flab-up** | Urban | Primary school |
| **flab-us** | | Secondary school |
| **flab-ut** | | Tertiary school |
| **fcap-ag** | Capital | |
| **fcap-na** | | |
| **flnd** | Agricultural land | |
| **fliv** | Livestock | |
| **ffsh** | Fisheries capital | |
| | | |
| | | |
| **Households** | | |
| **hhd-uf1** | Urban farm (Q1) | |
| **hhd-uf2** | Urban farm (Q2) | |
| **hhd-uf3** | Urban farm (Q3) | |
| **hhd-uf4** | Urban farm (Q4) | |
| **hhd-uf5** | Urban farm (Q5) | |
| **hhd-un1** | Urban nonfarm (Q1) | |
| **hhd-un2** | Urban nonfarm (Q2) | |
| **hhd-un3** | Urban nonfarm (Q3) | |
| **hhd-un4** | Urban nonfarm (Q4) | |
| **hhd-un5** | Urban nonfarm (Q5) | |
| **hhd-rf1** | Rural farm (Q1) | |
| **hhd-rf2** | Rural farm (Q2) | |

| | |
|---|---|
| **hhd-rf3** | Rural farm (Q3) |
| **hhd-rf4** | Rural farm (Q4) |
| **hhd-rf5** | Rural farm (Q5) |
| **hhd-rn1** | Rural nonfarm (Q1) |
| **hhd-rn2** | Rural nonfarm (Q2) |
| **hhd-rn3** | Rural nonfarm (Q3) |
| **hhd-rn4** | Rural nonfarm (Q4) |
| **hhd-rn5** | Rural nonfarm (Q5) |

| **Other accounts** | |
|---|---|
| **trc** | Trade margins |
| **gov** | Government |
| **atax** | Activity taxes |
| **ftax** | Factor taxes |
| **dtax** | Direct taxes |
| **mtax** | Import tariffs |
| **stax** | Sales taxes |
| **s-i** | Savings-investment |
| **dstk** | Changes in stocks or inventories |
| **row** | Rest of world |
| **total** | Total |

## 5 CONCLUSIONS AND POLICY IMPLICATIONS

81. This report presents long-term estimates of water requirements to support economic growth in Viet Nam. As a dynamic Asian exporter, Viet Nam is undergoing continued agrifood expansion combined with a reform and modernization transition, intensifying of industrial activity and expanding service sector growth. All this has been accompanied by sustained income growth and demographic transition from rural to urban majority populations. These dynamics portend significant increases in water demand and changing patterns of primary and conjunctive use across a complex, rapidly changing economy.

82. Our forecasts for growth over the next two decades indicate that aggregate water demand will grow more slowly than real output, primarily because agriculture, the dominant user of water, will grow more slowly than manufacturing or services. Despite this fact, total water use is estimated to nearly double by 2030. Given current and future water supply conditions, this trend will make essential more determined policies to promote water use efficiency, particularly in farming and rapidly expanding, water-intensive industrial activities.

83. Of special importance in this analysis is the need to recognize spatial and temporal heterogeneity in both water supply and demand. By decomposing these resource characteristics, the risks of water scarcity become much more serious. Simply put, our results show that water resources may be available for the whole country and all year around, but this will require storage and conveyance investments that are designed in recognition of dry season realities. For the same reasons, policies that promote more extensive conjunctive water use, water recycling, and market-oriented approaches to spatial and seasonal water scarcity also deserve careful consideration.

84. Viet Nam households will achieve substantially higher real incomes if expected growth rates can be sustained, but this prosperity could be accompanied by rapidly accelerating per capita water use. While this is a common feature of so-called middle class emergence, it also suggests that residential water use efficiency should be a high priority for policy attention. Of particular concern in this context, although it is not directly addressed in this study, will be water quality considerations. The scope of water treatment investments will require significant expansion in the coming years, and expanded conjunctive use will necessitate this.

85. In summary, Viet Nam’s expectations for economic growth are ambitious, and their resource management policies should be correspondingly so, particularly in the context of sustainability. This economy can continue to confer significant livelihood improvements on its population, but to do so it must avert scarcity in a resource critical to every economic activity, indeed to life itself.

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## 7 Annex 1 – Province Map Codes

| Code | Province | Code | Province |
|---|---|---|---|
| **AG** | An Giang | KH | Khanh Hoa |
| **BG** | Bac Giang | KG | Kien Giang |
| **BK** | Bac Can | KT | Kon Tum |
| **BL** | Bac Lieu | LI | Lai Chau |
| **BN** | Bac Ninh | LD | Lam Dong |
| **BV** | BaRia-VungTau | LS | Lang Son |
| **BR** | Ben Tre | LO | Lao Cai |
| **BD** | Binh Dinh | LA | Long An |
| **BI** | Binh Duong | ND | Nam Dinh |
| **BP** | Binh Phuoc | NA | Nghe An |
| **BU** | Binh Thuan | NB | Ninh Binh |
| **CM** | Ca Mau | NT | Ninh Thuan |
| **CN** | Can Tho | PT | Phu Tho |
| **CB** | Cao Bang | PY | Phu Yen |
| **DA** | Da Nang | QB | Quang Binh |
| **DC** | Dac Lac | QM | Quang Nam |
| **DO** | Dac Nong | QG | Quang Ngai |
| **DB** | Dien Bien | QN | Quang Ninh |
| **DN** | Dong Nai | QT | Quang Tri |
| **DT** | Dong Thap | ST | Soc Trang |
| **GL** | Gia Lai | SL | Son La |
| **HG** | Ha Giang | TN | Tay Ninh |
| **HM** | Ha Nam | TB | Thai Binh |
| **HN** | Hanoi | TY | Thai Nguyen |
| **HA** | Ha Tay | TH | Thanh Hoa |
| **HT** | Ha Tinh | TT | Thua Thien Hue |
| **HD** | Hai Duong | TG | Tien Giang |
| **HP** | HaiPhong | TV | Tra Vinh |
| **HU** | Hau Giang | TQ | Tuyen Quang |
| **HC** | Ho Chi Minh | VL | Vinh Long |
| **HO** | Hoa Binh | VC | Vinh Phuc |
| **HY** | Hung Yen | YB | Yen Bai |